Combined Control Design and Energy Saving Benefit Analysis of Air Compression Station

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Combined Control Design and Energy Saving Benefit Analysis of Air Compression Station

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Abstract. The combined control of air compression station in an electronic production enterprise is carried out to effectively control the start and stop of air compressors and dryers, and reduce the leakage loss of compressed air at the end of the air pipeline during non-working hours. The combined control system can automatically match the required number of equipments according to the actual compressed air consumption, thereby reducing unnecessary power consumption and having obvious energy saving effects. According to the actual energy saving test results, the power consumption per unit of compressed air has a significant decrease under the combined control of the air compression station. The power saving rate of 10.9% can be achieved, which can bring considerable energy saving and economic benefits to the enterprise.

1. Introduction

Air compressor is widely used in various industries by converting mechanical energy into compressed air energy. It is an important part of the general equipment of the factory. In most existing industrial enterprises, special air compression station (ACS) is built. Air compressor system energy consumption occupies a large proportion of the total energy consumption of the plant [1, 2]. If the air compressor is not efficient, it will cause high energy consumption and increase energy utilization costs. Production processes in different industries are different. The requirements for compressed air parameters of various types of equipment are also inconsistent. To ensure the demand of production processes and equipment and reduce the energy consumption of ACS, industrial enterprises will generally deploy multiple air compressors to combine operate, and automatically control the pressure of the pipeline network to realize the optimal operation of ACS.

However, the efficient operation of ACSs is not only affected by the demand for compressed air parameters, but also by factors such as production rhythm, environmental conditions and technical level of management personnel. Therefore, most of the existing ACSs have low operating efficiency, resulting in the power consumption per unit of compressed air (PCCA) far exceeds the standard requirements. To improve the operation efficiency of the ACS, the energy-saving measures for the compressed air supply system mainly include: motor frequency conversion speed regulation, combined control, reduction of compressed air leakage and waste heat utilization, etc. Among them, the air compressor combined control has obvious effects on energy saving of the ACS with multiple air compressors running simultaneously [3]. However, there are few reports on the energy conservation and economic benefits generated by the air compressor combined control transformation. Therefore, this paper will introduce the combined control transformation case of the ACS, and quantify its energy saving benefits generated by the transformation. It can provide a theoretical and practical basis for further improving the operation efficiency of the ACS.

2. Design principle of ACS combined control system

The ACS combined control system can realize the simultaneous control of multiple air compressors, so that each air compressor can meet the operation requirements. The system is equipped with a lower machine to ensure the minimum air supply pressure. It also has a pressure change prediction function to realize the advance control and a self-learning function to adapt to the gas demand of the enterprise at different time periods. The control system can reach high-level control to minimize the ACS energy consumption. At the same time, the connection of each compressor is realized through the communication interface, and the PID control channel is provided to meet the requirements of installing the inverter.

The combined control system can automatically control the start and stop functions of multiple air compressors under the condition of satisfying the supply air flow and pressure demand of the equipment through the operation parameter of the air compressor and the pressure feedback of the air supply pipe network. According to the working time of each production workshop, the control system can control the start and stop of the electric valve of the air supply pipeline by setting the time, and prevent the leakage air leakage loss at the end of the air pipe network during non-working period. It will keep the pressure of the air compressor fixed at or close to the user's set value, while ensuring the stability of the terminal gas pressure and dew point. Through the control of the combined control system, the no-load loss of the air compressor and the dryer can be reduced by about 8-10%, and the leakage loss at the end of the air supply pipe network is reduced by 3-5%. Overall, the ACS power loss can be reduced by about 10-15%.

This paper takes an electronics factory as an example to carry out energy-saving transformation of its ACS. The plant's ACS has a total of seven air compressors, each with a power of 37kW. When the ACS of the plant has not implemented the combined control transformation, it can only rely on manual and simple control. It is very difficult to control the start and stop of the air compressor and the dryer in time according to the on-site load and the supply pressure demand. At the same time, it is hard for the ACS to distinguish the working period of the production workshop before the transformation. It is impossible to close the start and stop of the air supply network valve in the non-working time accurately and timely. As a result, the compressed air leakage at the end of the air pipe network during non-working time is large, and its power consumption is additionally increased. Therefore, the operational efficiency of the ACS before the transformation is poor.

3. ACS combined control transformation technical solution

The ACS is controlled by a combined control system, which can control the starting and stopping, loading and unloading of multiple air compressors; the starting and stopping of the refrigerating dryer and the adsorption dryer; and the starting and stopping of the electric valve. The control system keeps the pressure of the air compressor at or close to the user set value, while ensuring the stability of the compressed air pressure and dew point.

The control system has two operation modes: sequential or user adjustable, and can be adjusted according to the requirements of the specific compressed air system to suit the needs of the terminal. The control system responds to changes in compressed air pressure collected by sensor, and increases or decreases the number of air compressors or dryers operating according to the actual set requirements of the terminal in accordance with the user-selected operating sequence. The air compressor station can be divided into two parts: remote single unit and remote combined control. The functions realized by each are as follows:

(1) Remote single unit: Each unit's own equipment is started and stopped remotely by the upper computer.

(2) Remote combined control: Select the manual input order mode and the sequential switching time for control, as follows:

1. The control system can control 1# to 7# air compressors and drying units;
2. System pressure control: according to the pressure sampling point on the terminal output manifold, the system automatically adjusts the number of equipment running according to actual demand;
3. System pressure setting can be changed by user programming on the upper computer;
4. The delay interval when adding and reducing the number of equipment can be set separately according to the working characteristics of the compressed air system and the drying system;
5. The control system can be installed independently from the air compressor and the dryer, and remotely operate the air compressor and the drying unit;
6. The control system starts a set of compressor and dryer system at a time to achieve energy saving optimization;
7. The running sequence smoothly switches to avoid fluctuations in the compressed air pressure and fluctuations in the dew point;
8. Control system operating parameters can be changed without stopping the system.

4. ACS combined control transformation energy saving test

4.1. Comparison of operating parameters before and after transformation

4.1.1. Comparison of compressed air flow before and after transformation. The comparison of compressed air flow before and after the transformation is shown in Figure 1. The company uses three shifts, each production period is: 8:00-11:30 (early shift); 2:00-17:00 (middle shift); 19:00-21:30 (night shift). The cycle of change in compressed air flow is also consistent with the production cycle of the company. When the company is in normal production, its compressed air flow fluctuates around 1200 m3/h; when the company is in non production, the compressed air flow will be reduced to a lower level, but will not fall to zero. The change of compressed air flow before the transformation is not big, especially when the normal production of the enterprise is basically the same. When the company stops production, the compressed air flow after the transformation is higher than the compressed air flow before the transformation. Since the product types and output produced by the enterprises before and after production are consistent, it can be seen that the ACS supply flow rate of the enterprise is mainly affected by the production process and production cycle, while the ACS control system has little effect on the supply flow.

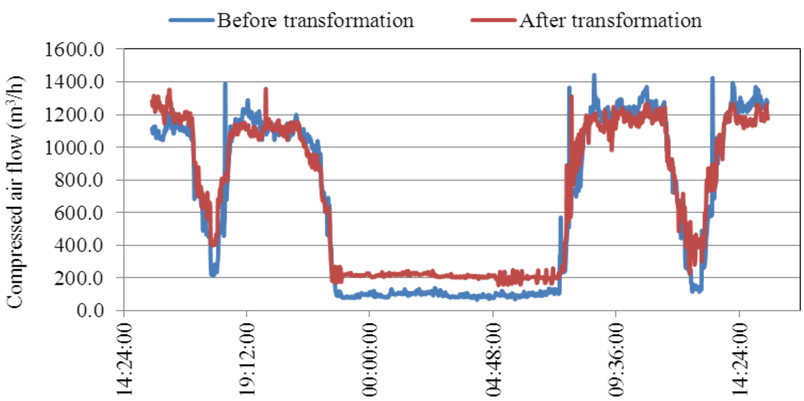

Figure 1. Comparison of compressed air flow before and after transformation

4.1.2. Comparison of ACS electric power before and after transformation. The ACS electric power before and after the transformation is shown in Figure 2. It can be seen that after the combined control transformation. The ACS electric power is not always lower than that before the transformation. In the morning shift, the ACS consumes the nearly same power consumption during normal production. On the contrary, the electric power in the non production is higher than that before the transformation. In the middle class, the law of electric power consumption is basically the same as that of the early shift. However, in the evening shift, the ACS electric power after the transformation was significantly reduced compared with that before the transformation. However, when all equipments were shut down in the middle of the night, the ACS standby power was higher than that before the transformation. In summary, after combined controlled transformation, it can reduce power consumption during normal production. When the enterprise stops production, the electric power is higher than that before the transformation, because the installation of the combined control system needs to add auxiliary electricity consuming equipments.

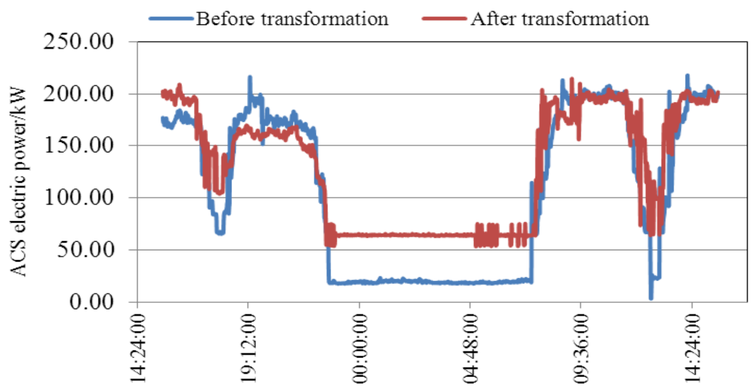

Figure 2. Comparison of ACS electric power before and after transformation

4.1.3. Comparison of compressed air pipe network pressure before and after transformation. The pressure change of the compressed air pipe network before and after the transformation is shown in Figure 3. It can be seen that the pressure of the air compression pipe network is maintained at about 6 to7 bar, and the pressure of the pipe network is not fluctuating. It is close to the pipe network pressure of 6.2 bar, which can meet the compressed air supply requirements of the production process and equipments.

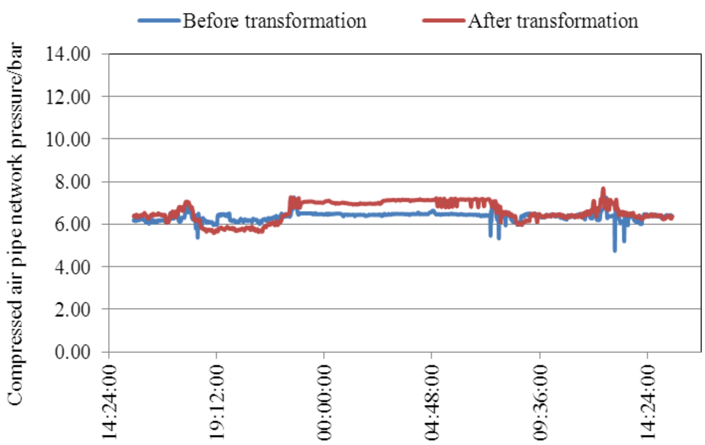

Figure 3. Comparison of compressed air pipe network pressure before and after transformation

4.2. ACS Energy efficiency test

The test uses the self-developed air compressor energy efficiency online detection system to detect ACS energy saving effect. The detection steps are as follows:

(a) Check the ACS site environment and prepare test conditions in advance, including pipeline tapping and pipeline adjustment;

(b) Install test equipment such as flowmeters and power quality analyzer, and start to test the ACS energy efficiency;

(c) After testing for 24 hours in the commissioning state of the combined control system, the test is carried out in the state of closing the combined control system;

(d) End the test and disassemble the test equipment on the third day, while ensuring that the normal operation is not affected.

The test is carried out continuously for 24 hours after the transformation (opening the combined control) and before the transformation (closing the combined control). The analysis results show that:

(1) Before transformation, the total compressed air production is 16839 m3; and the total power consumption is 3084.090 kW·h;

(2) After the transformation, the total compressed air production is 15675m3; and the total power consumption is 2558.779 kW·h;

The energy saving benefits is calculated as follows:

Electric power before transformation

= input average active power (before transformation) ÷total compressed air production (before transformation)

$= (3084.090 \div 24) \div 16839 \times 10^3$

$= 7.63\ W/m^3$

Electric power after the transformation

= input average active power (after the transformation) ÷total compressed air production (after the transformation)

$= (2558.779 \div 24) \div 15675 \times 10^3$

$= 6.80\ W/m^3$

Saving power

= (electric power before transformation - electric power after transformation) ×total compressed air production (before transformation)

$= (7.63 - 6.80) \times 16839$

=13970.8 W

Saving power rate

= [saving power ÷ input average active power (before transformation)] ×100%

$= [13970.8 \div (3084090 \div 24)] \times 100\%$

=10.9%

It can be seen that after the combined control transformation, the power consumption per unit of compressed air supply has dropped significantly. The power saving rate of 10.9% can be achieved, which can bring considerable energy saving benefits and economic benefits to the enterprise.

5. Conclusion

The combined control system of the enterprise ACS can significantly improve its operating efficiency and save power consumption, as follows:

(a) The combined control system can control the start and stop of the air compressor and dryer in time according to the operating conditions of the air compressor unit and the load of the production workshop, while meeting the air flow and pressure requirements of the equipment;

(b) According to the working hours of each production workshop, the combined control system timely control the start and stop of the electric valve of the air supply pipeline, and avoid the leakage of compressed air at the end of the compressed air pipeline during non-working period;

(c) The combined control system can determine the number of air compressor that need to be operated according to the actual compressed air consumption, thereby reducing unnecessary waste and achieving significant energy saving effects;

(d) After the transformation, the ACS power consumption has been significantly reduced. The power saving rate can reach 10.9%, which will bring considerable energy saving benefits and economic benefits to the enterprise.

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