

Design of energy saving monitoring system on isothermal oilless lubricated air compressor

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Abstract. This design introduces a kind of STM32F051C8T6 circuit monitoring system which is based on the ARM core. According to the operating principle of air compressor, the reduction of temperature and current is converted to save electricity and directly displayed, save electricity information stored at the same time, to achieve real-time monitoring air compressor energy saving effect in the process of operation.

1.Introduction

The isothermal oilless lubricated air compressor is internationally accepted contract energy management mode was adopted to realize user zero investment, zero risk, high yield of the implementation of the method, need through the energy display monitor system to implement, development and design a set of isothermal oilless lubricated air compressor according to monitoring and control system for energy conservation.

By technical improvement on each air compressor of the station, the energy saving monitoring system takes the decreasing temperature and electricity during running time transform to saving electric energy and displays immediately.

For instance, the 1# air compressor's exhaust temperature decreases from 150 degree to 125 degree and its current decrease from 23A to 20.7A through the improvement, but the air flow and pressure are not change. It requires the energy saving monitoring system is able to display the temperature and the current differences, and figure out the energy-saving effect according to the volumetric expansion coefficient of compressed air(every degree increase in temperature, the compressed air expanded $1/273.15M^3$, or vice versa).

2.System requirements

Based on the description of the energy saving monitor, this system should be able to achieve the following requirements:



- (1) Collecting the operating current and outlet temperature of the air compressor, displaying in real time and updating per second. The accuracy of current and temperature should reach 0.1A and 0.1 degree respectively.
- (2) Calculating and displaying the saving electric energy according to the temperature and the current differences per minute.
- (3) Displaying the cumulative running time.
- (4) Achieving storage function when the system losing power.
- (5) Before the improvement, the operating current and temperature of the air compressor should input by administrators, and they should be observed during the system runtime.
- (6) The system must be equipped with good fault warning.

Considering the high voltage motor with 6000V will cause great electromagnetic interference, the operating current and outlet temperature monitor of the air compressor must adopt industrial level transmitter which has strong anti-disturbance capability, and the data communication method have to uses the 485 buses and 4~20MA data communication with strong anti-disturbance either. This system apply the industrial grade perforated guide rail mounting type current transmitter to its current acquisition module, which has transmission distance and immunity to interference. And the temperature acquisition module makes by the industrial grade thread mounting type light small integrated temperature transmitter, this kind of transmitter is able to use in the difficult conditions and proof of wet, explosion, water, earthquakes, harmful gas and so on.

3.System solutions

Figure 1 is the topology structure graph of this system:

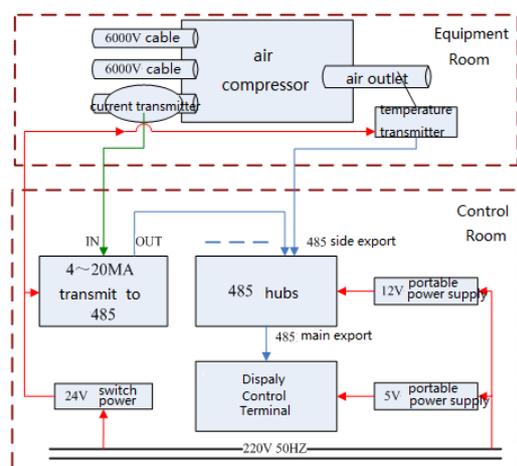


Fig. 1 Topology Structure Graph

(1) Design of monitoring system

Display control terminal is mainly to complete data acquisition of each node from 485 bus, and calculate the saving energy of per minute, as well as display the result with a display panel. Users are

able to check each air compressor by shifting the terminal control panel and by the LED display board, and also allowed to set the reference value of operating current and outlet temperature before improvement. The control terminal circuit also need to achieve storage function when the system losing power, such as the cumulative saving energy, cumulative running time, operating current, outlet temperature and the reference value before improvement.

The display control terminal is equipped in the control room and avoided from strong interference, therefore it is based on the ARM Cortex-M0 processor. This kind of processor is available the most minimum volume, minimum energy consumption and the most energy-saving on the market. With the very low energy consumption, developers could obtained the performance of the 32 bit processor at the price of 8 bit processors.

Due to the power down save function, the EEPROM memory is adopted the AT24CXX series of ATMEL, which could save data up to one hundred years and one million times repeatedly erased. Accordingly, this memory can realize a complete, accurate and long-term storage. At the same time, the memory is built with IIC data communication and simplified PCB routing, in order to reduce the design cost of the circuit under the premise of function completely realized.

Figure 2 is the circuit graph of the monitoring system:

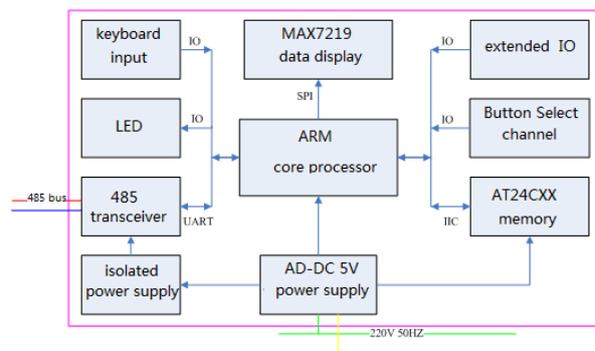


Fig. 2 Monitoring System Circuit Graph

According to the shell box structure of terminal, the monitoring system circuit is required to fall into 2 parts, the ARM core circuit include the STM32F051C8T6 core circuit, the 485 bus transceiver circuit, the AT24CXX data storage circuit and the power isolation circuit. The other part is display circuit consist of MAX7219 drive digital tube, the button selection circuit and the LED indicator circuit of air compressor.

Display circuit as shown in figure 3:

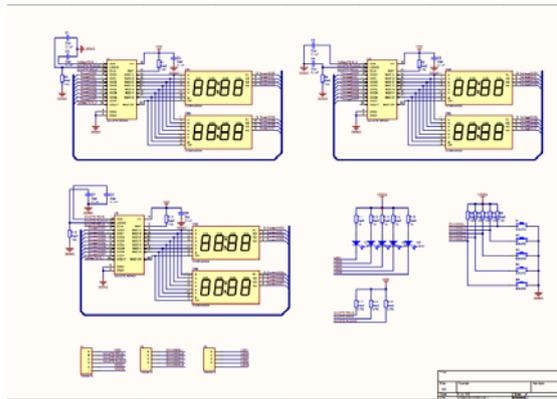


Fig. 3 Display Circuit

(2) Software Design

The software design is mainly to analyze and calculate from data acquisition of each node. The following tree distribution is abstracted from the topology structure graph(as shown in figure 4):

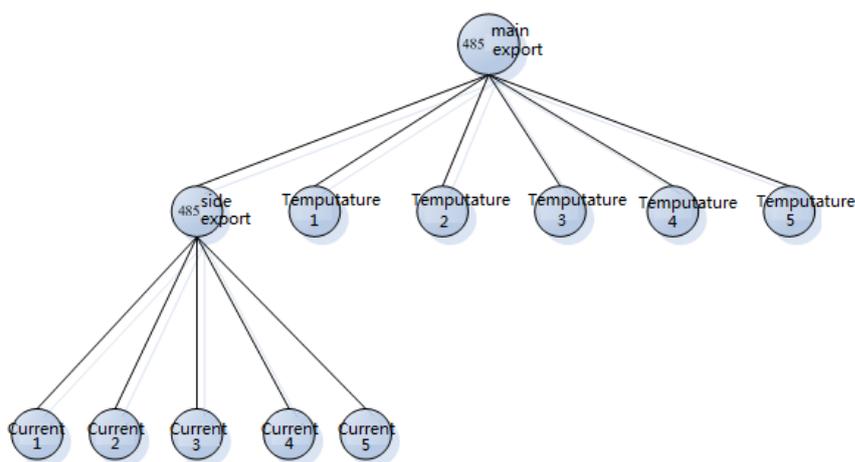


Fig. 4 Tree Distribution

It can be seen that we can complete data acquisition as long as traverse every node of the tree distribution.

The software distribute a data structure which include the cumulative saving energy, cumulative running time, operating current, outlet temperature and the reference value before improvement. The core function of software system is to maintain these data structures. With powered on, the software system analysis if the air compressor had reference values, and make calculations on the basis of reference values. The program traverses every node of the tree distribution per second, and assigns to corresponding data structure, meanwhile displays the present air compressor's current and outlet temperature. When the time accumulates to one minute, the program will figure out the saving energy in this period and display the total result on the panel. Certainly, the program will not work when the air compressor is shutdown equates to the acquired current is 0A. At the end of this one minute, the system will store the cumulative saving energy, cumulative running time, operating current, outlet

temperature into the EEPROM and provide to the next computing cycle.

Together the workflow of software program and the tree diagram, Figure 5 is the design of software process:

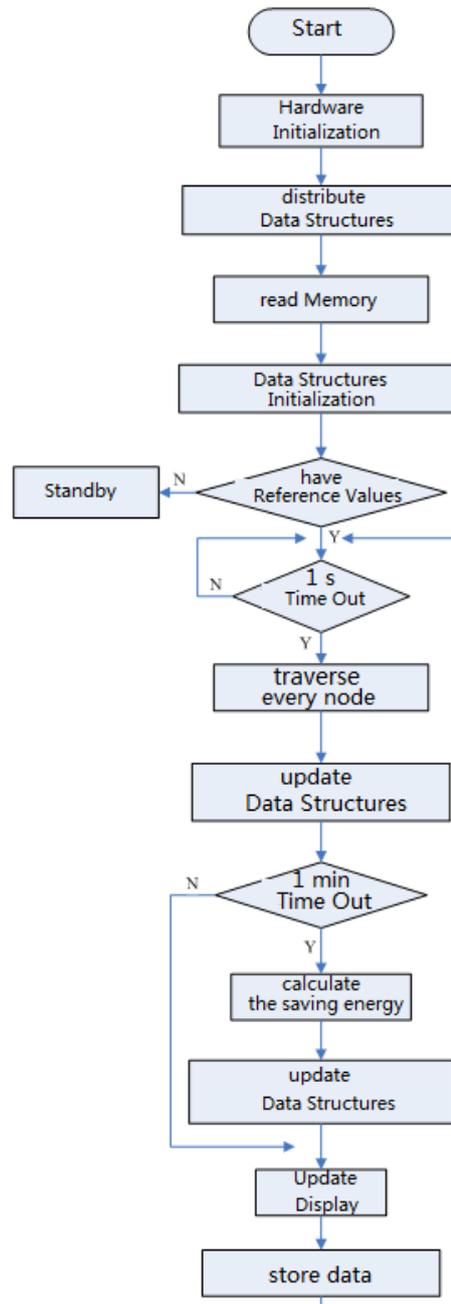


Fig. 5 Design of Software Process

The saving energy of air compressor which display on the panel mainly comes from two aspects, for one thing is the energy consumption caused by current decrease, for another is caused by temperature decrease. The calculation algorithm is as follows equation (1).

$$P = P_T + P_C \quad (1)$$

In the above equation, P_T represent the energy consumption caused by temperature decrease, P_C represent the energy consumption caused by current decrease.

The change of compressed air temperature must lead to the change of volume, therefore the temperature decrease will cause the increase of gas production. In accordance with 40m^3 per minute gas production, the actual added gas production (ΔV) caused by temperature decrease per minute is equation (2).

$$\Delta V = \Delta T \times \frac{1}{273.15} \times 40M^3 \quad (2)$$

In the above equation, ΔT represent the temperature difference of the air outlet between before and after the improvement, $1/273.15$ represent the volumetric expansion coefficient of compressed air, 40m^3 represent the exhaust volume per minute.

Considering of the 250KW motor power, the consumed power (ΔP) per cubic meters is equation (3).

$$\Delta P = \frac{250KW}{60MIN} \times \frac{1}{40M^3} \quad (3)$$

Therefore the saving energy per min is equation (4).

$$P_T = \Delta V \times \Delta P = \left(\Delta T \times \frac{1}{273.15} \times 40M^3 \right) \times \left(\frac{250KW}{60MIN} \times \frac{1}{40M^3} \right) \quad (4)$$

According to the collected single-phase current and the consumed power of air compressor, the saving energy caused by current decrease is equation (5).

$$P_c = \Delta C \times 6000V \times \frac{1}{1000} \times \sqrt{3} \times PF \times \frac{1}{60MIN} \quad (5)$$

In the above equation, ΔC represent the operating current difference between before and after the improvement, PF is power factor (obtain from the power factor table), $\sqrt{3}$ represent the coefficient of three phase electric, then divided by 60 is the saving energy per minute. And then transform to the unit of electrical energy divided by 1000.

4. Conclusion

The innovation points of this system: (1) Considered the high voltage of air compressor station, the collectors of current and temperature both use the acquisition transmitters with strong anti-interference ability; (2) The data communication method adopt the 4~20MA and 485 buses with strong anti-disturbance, which are widely used in industry and adapt to rough conditions. (3) Due to the calculation of consumed power involved floating point operation, the control terminal adopts ARM processor which has excellent capacity of rapid floating-point.

5. Acknowledgements

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