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Design of Monitoring and Control System of Train Air Conditions

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Abstract—Energy saving and emission reduction request us to pay more attention to electrical energy metering. By the electrical energy metering and the real-time monitoring to the air conditions of the train, some corresponding active measures were adopted to reduce energy consumption. And the air conditions of the train were controlled to keep the coaches comfortable. A high accuracy 3-phase electrical energy measurement IC was applied in this monitoring system. Frequency converter and PLC was applied in this control system.

Keywords-energy saving; electrical energy metering; frequency converter

1. Introduction

Currently more attentions are paid to the comfort of train air conditions. A monitoring and control of train air conditions is needed. The monitoring electrical parameters are active, reactive, apparent energy, voltage of the air conditions and temperature of the coach. There are three methods for energy metering as electromagnetic induction measure, electronic measure and mechanic-electrical integrity measure. Electromagnetic induction measure is very simple and older. It meters the rotating magnetic field to calculate electrical energy. Electronics measure makes use of energy-metering chip to calculate electrical energy. Mechanic-electrical integrity measure also meters the rotating magnetic field. And pulse is given to the electronics part to count and calculate the electrical energy.

In the monitoring system of train air conditions, the parameters that need to be measured are more, not only active, reactive, apparent energy, electric voltage, electric current air quality and temperature, also need to analyze the quality of electric power. Electronics measure can satisfy this need. The electrical energy metering chip ADE7758 was selected. It is a high accuracy 3-phase electrical energy measurement IC with a serial interface. The ADE7758 is suitable to measure active, reactive, and apparent energy in various 3-phase configurations, such as WYE or DELTA services, both with three or four wires. A CO_2 sensor is used to measure the air quality via SPI interface. The chip DS18B20 is selected to sample the temperature.

In the control system of the train air conditions, the control objects are air blowers and air compressors. Frequency converters are applied to control the electrical motor of the air blowers and air compressors. It can save energy, keep the system safe and been controlled easily.

2. ADE7758 features

The ADE7758 is a multi-function, high accuracy and 3-phase electrical energy measurement IC. It has following features.

a) Highly accurate.

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b) Compatible with 3-phase/3-wire, 3-phase/4-wire, and other 3-phase services.

c) Less than 0.1% active energy error over a dynamic range of 1000 to 1 at 25°C.

d) Supplies active/reactive/apparent energy, voltage rms, current rms, and sampled waveform data.

e) Two pulse outputs, one for active power and the other selectable between reactive and apparent power with programmable frequency.

f) Digital power, phase, and rms offset calibration.

g) On-chip, user-programmable thresholds for line voltage SAG and overvoltage detections.

3. The Design of Monitoring System

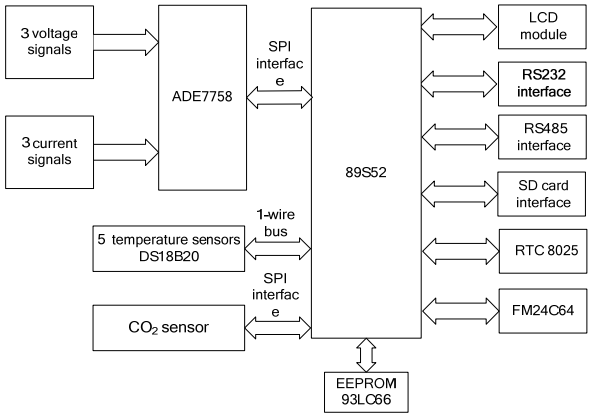

Fig.1. Hardware block diagram of the monitoring system.

The power rating of the coach air condition is 35kW. The inputs of the monitoring system are three voltage signals in range 0-400 V, three current signals in range 0-50A and five temperature signals in range 0-120 degree. Figure 1 shows the hardware block diagram of the monitoring system.

Three electric voltage signals and three electric current signals after processing are connected into ADE7758. The microcontroller 89S52 reads data from the ADE7758 via the SPI serial interface. Data is read in a cycle when the zero-crossing detection generates an interrupt. The temperature sensor is DS18B20. Five positions of temperature are measured. One position is outside of coach; one is the seat side of coach entrance; two positions are the seat side in the meddle of the coach; last one is the aisle of coach.

In the monitoring system, a CO_2 sensor is used to measure the air quality. A LCD module is used by serial communication to show electrical data and temperature. A RS-232 interface is used to facilitate communication with the computer. A RS-485 interface is used to communicate with the PLC. A SD card interface is used to store data to the SD card. A real time clock/calendar chip RTC8025 is applied in this system. The FM24C64 is used to store data. The 93C66 is used to save the coefficient.

4. The Design of Control System

The hardware block diagram of control system of the coach air condition is shown in figure 2. The motors of air blower and air compressor are droved by the frequency converters based on temperature and air quality sampled. The air blower and air compressor can keep working until the power off.

Sampling, calculating and PI algorithm is processed by the microcontroller 89s52. The control messages are sent to two PLCs via RS485 interface.

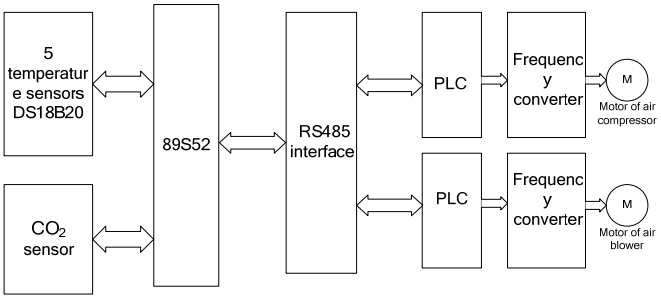

Fig.2. Hardware block diagram of the control system

Figure 3 is the block control diagram of the coach air condition. The air compressor controlled by the frequency converter can keep working without stop. Without frequently stop and start the air compressor can serve longer. And the output of the air compressor can changed with those 4 positions temperatures. But the coefficients K1, K2, K3 and K4 are not equal. K1 is smallest; K4 is smaller; and K2 and K3 are large. The air blower is rated with that temperatures and CO_2 potential of coach. K5 is the air blower's temperature coefficient. K6 is the air quality coefficient. K6 is larger than K5. PI regulators are applied to the control system.

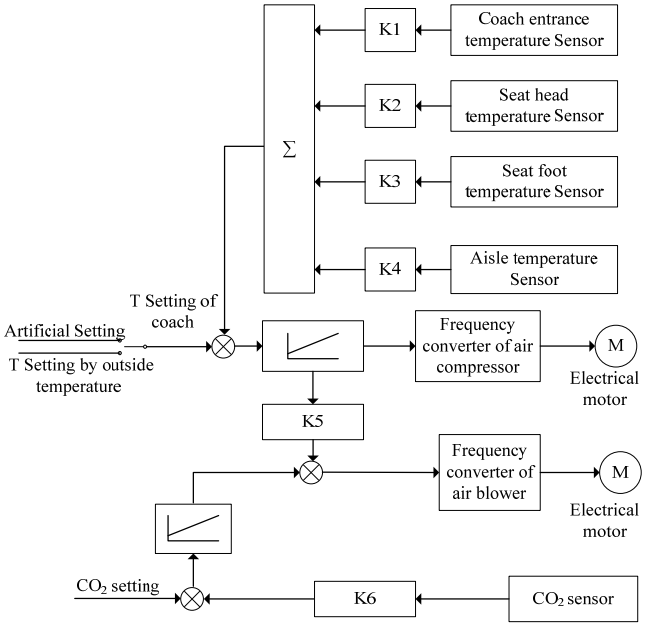

Fig.3. Block control diagram of the coach

5. Data

The data shown in TABLE I and TABLE II came from real test. TABLE I is the electrical data. TABLEII is the temperature data.

TABLE I. ELECTRICAL DATA

Time	**Electrical data**				
	phase	***Active monitor***	***Active meter***	***Voltage monitor***	***Voltage meter***
1	A	9.4026	9.38	233.34	232.8
	B	9.3952	9.37	232.35	232.7
	C	9.3825	9.37	233.13	232.9
2	A	9.1912	9.20	231.31	231.8
	B	9.2193	9.22	232.24	231.2
	C	9.1843	9.22	230.75	231.3
3	A	9.3525	9.32	229.70	230.4

Time	Electrical data				
	phase	***Active monitor***	***Active meter***	***Voltage monitor***	***Voltage meter***
	B	9.3623	9.34	229.83	229.9
	B	9.3546	9.34	231.19	229.8

TABLE II. TEMPERATURE DATA

Time	Temperature				
	out	***head***	***foot***	***aisle***	***entrance***
1	27.500	23.500	22.250	22.250	23.725
2	27.725	22.725	22.375	22.250	23.500
3	28.125	23.125	22.725	22.500	23.500

From the data we can see the error of active data is less than 1%; the error of electric voltage data with actually data is less than 0.5%; and the temperature of coach can been controlled at a comfortable level.

6. Conclusion

This monitoring and control system can carry on effective supervision to the air condition power supply and air quality. And this system can restore data, analyze data and apply PI regulator. The air compressor can serve longer for the air compressor controlled by frequency converter can keep working without stop and start frequently. This system can save more than 10% electric energy and can improving the reliability of the equipments. This monitoring and control system makes air of coaches more comfortable and saves energy more effectively.

7. References

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