Application of spectrum analysis technology in health management of vehicle control system

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Abstract. With the increasing complexity of vehicle control system, the failure rate has also been enhanced accordingly. Through traditional maintenance techniques, only the intact state of the qualitative vehicle control system can be achieved, and functions such as analyzing and predicting the hidden failure and technical state of vehicle control system, health management, etc., cannot be realized, which seriously restricts the formation of maintenance efficiency. According to the signal characteristics of the vehicle control system, the electric signal spectrum analysis method is used to realize intelligent detection, evaluation, management, fault prediction and diagnosis of vehicle control system performance indicators, so as to ensure vehicle control system is always in good condition, has a very important significance to improve the maintenance support ability of vehicle control system.

1. Frame system

The acquisition circuit transmits the various states of each component to the controller during operation. Due to the different characteristics of each aviation plug pin measurement signal, all signals are roughly divided into digital signal, DC analog signal and AC analog signal. The collected signals are then processed and transmitted to the CAN bus or to the upper computer via the spectrum analyzer. The upper computer is responsible for processing, summarizing and concluding the collected data by using various complex algorithms and intelligent models, extracting the feature information and monitoring the system status in real time [1].

The fault diagnosis and health management software embedded in upper computer is an expert system diagnosis model based on spectrum analysis and fault tree rules. The essence of an expert system is an intelligent program, which USES expert knowledge and experience in a specific field to imitate the thinking of experts when solving problems, and conducts reasoning and analysis on problems. AC signal spectrum analysis is the use of a period of time, multistage frequency domain characteristic of signal analysis, to establish library vehicle control system fault spectrum characteristics, extraction of feature points and feature points fault library than matching spectrum characteristics, trend reasoning judgment for recessive fault happened at the same time, through the system of the state of health's failure to predict the future of the system [2].

The software framework of fault diagnosis and health management is shown in Figure 1. The software is centered on the diagnosis and prediction engine, and consists of configuration module,
signal processing module, model library, frequency domain analysis, fault location display module and health management module [3].

![Figure 1. Software framework for troubleshooting and health management.](image)

2. Health status module

The health status module mainly includes component status indication and component fault diagnosis. The function of data acquisition and processing module is to predict, evaluate and monitor the state of vehicle control system and its key components. Data based on various health history data, fault diagnosis and fault forecast data and historical data, and so on maintenance, by comparing the systems of these data, to evaluate the health status of system, and to determine the possibility of failure prediction system to detect defects, the early malfunction or failure [4, 5].

In order to realize the health management of the system, it is necessary to collect, analyze, diagnose and evaluate the signals of the tested components. DC signal and AC signal analysis are common health management cases [6].

2.1. DC signal diagnosis

The 26V power supply signal is analyzed, and the data is extracted through the equipment acquisition interface. Spectrum analysis and state evaluation of the signal are realized by software.

When the power supply is normal, the signal waveform of 26V power supply is shown in Figure 2.

![Figure 2. Signal waveform of 26V power supply.](image)

It can be seen from the waveform that in addition to the acquisition error in time domain, the DC signal should be a constant straight line without fluctuation. The waveform display shows that the surface performance of the power supply is good and the state is normal.

There is time domain error in the waveform of DC signal. The waveform of DC signal is flat and the power supply works normally. The spectrum of DC signal is shown in Figure 3.
In normal DC signal, there is no harmonic component in frequency domain, and the amplitude of characteristic point is 26V, which is at frequency 0. Through detection and analysis, it is concluded that "26V power supply works normally".

As the vehicle control system works for a long time, the performance of the internal equipment, modules and components of the components is reduced. By means of signal detection and spectrum analysis, the performance changes of components can be detected. Figure 4 shows the performance change waveform of 26V power supply.

It is observed that the waveform of 26V power supply fluctuates slightly, the voltage error varies between 0.4 V and 0.6V, and the voltage increases. Through software analysis, the signal spectrum diagram is shown in Figure 5.

The spectrum analysis shows that the characteristic point of 26.5V appears at 0Hz and the harmonic component of 0.5V appears at 400Hz, which affects the performance of DC power supply.

Therefore, the AC interference affects the performance of 26V power supply, but has little effect on it. With the continuous work of the system, the 26V power supply is used for signal acquisition, and the signal waveform is shown in Figure 6.
The amplitude of 26V power supply fluctuates greatly, which greatly affects the stability of power supply. The spectrum diagram of 26V power supply is shown in Figure 7.

The spectrum diagram of power supply voltage shows that the reflected amplitude of characteristic points at 0Hz, 400Hz and 650hz is about 27.8v DC component, 1V AC component and 0.3V AC component respectively. Through spectrum analysis, the power supply performance is degraded. At this time, it is judged that the health state of the system is fault. The fault is located in the 26 volt power supply module. It is recommended to repair the power board or replace the components.

2.2. AC signal diagnosis
The 23V/1.2khz AC signal was selected as the analysis object. The device was connected to the detection interface for data acquisition, and the signal spectrum analysis and state assessment were conducted by software.

The output normal 23v / 1.2kHz AC signal waveform of the system is shown in Figure 8.

The collected 23v / 1.2kHz AC signal is a wave free active wave in time domain, and its amplitude is stable at 23v, so the signal is normal. The spectrum diagram of AC signal is shown in Figure 9.
Figure 9. The spectrum diagram of AC signal.

The system works normally, the harmonic component does not appear in the signal spectrum domain, and the position of frequency 1200 and amplitude 23v is the characteristic point.

Through analysis and judgment, the following conclusions can be drawn "the component 23V/1.2khz signal is in normal state", and the analysis results are displayed in the form of health management state interface.

The figure below shows the waveform of 23V/1.2KHz signal after operation for a period of time, as shown in Figure 10.

Figure 10. General abnormal waveform of AC signal.

Through spectrum analysis, the signal spectrum diagram at this moment is shown in Figure 11.

Figure 11. Spectrum of general anomalies of AC signals.

After spectrum analysis, the signal performance is affected by 23.5v characteristic point at 1200Hz and 0.5V harmonic component at 2400hz.

The following conclusions can be drawn from the analysis in the software, as shown in Figure 12.

Figure 12. Spectrum analysis conclusion.

At the same time, the health management interface shows that the component has a fault, and shows the general fault details.
During the operation of the system, the real-time acquisition of 23v / 1.2kHz signal is shown in Figure 13.

![Figure 13. The real-time acquisition of 23v / 1.2kHz signal.](image)

It can be seen from the collected signal waveform that the signal is deformed and the signal performance is degraded. The signal spectrum analysis diagram is shown in Figure 14.

![Figure 14. The signal spectrum analysis diagram.](image)

Through the spectrum diagram, it can be clearly analyzed that the harmonic components in the signal appear on other frequencies, which produce interference to the signal.

The following conclusions are drawn through software analysis, as shown in Figure 15. At the same time, in the health management interface, the component has a serious failure, and the detailed information of the serious failure is displayed.

![Figure 15. Spectrum analysis conclusion.](image)

3. Conclusions
Spectrum analysis technology in health management of vehicle control system, the application of real-time data collection and analysis vehicle control system status, judge vehicle control system health, provide guidance to carry out the performance recovery, ensure that vehicle control system meet the requirement of technique index, and provide effective means of vehicle control system status assessment, fault diagnosis and health management.

References
[1] Park Huijing 2015 Principle and repair of tank fire control system[M]. Beijing: National Defense Industry Press
[2] Ren Jianqiang 2016 Research on intelligent fault prediction and diagnosis of general fire control system[D]. Xi'an: Xi'an University of Technology
[3] Li Zhen 2016 Research on weapon fire control System Fault diagnosis based on information fusion[J]. Automation technology and application
[4] Gao Zehan 2000 Fault diagnosis technology of electronic circuits[M]. Xi'an Dianzi University
[5] Ren Jianqiang 2017 Research on intelligent fault prediction and diagnosis of general fire control system[D]. Xi'an: Xi'an University of Technology
[6] Chen Yibo 2016 Research on improved multiple regression load forecasting method based on rough set theory and D-S evidence theory[J]. Power System Protection and Control