Comprehensive Redundancy Management and Verification Strategy For Task-based Air Management System

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Abstract

Environmental control system of a large transport aircraft adopts comprehensive control technology, and takes two air management computers of the same structure as the core to realize the comprehensive control and monitoring of engine bleed air ,refrigeration and heating the engine air ,cabin area air distribution ,cabin pressure regulation, electronic equipment ventilation and heat dissipation and anti-icing. In this paper, the task-based air management structure was studied, the comprehensive management strategy and experimental verification strategy of task redundancy based on air management are proposed.

Keywords: air management computer ;environmental control system; simulation verification platform; Redundancy management

1. The introduction

The Aircraft Environment Control System is a system to ensure the safety and comfort of the flight crew and passengers, and to provide normal working environment for the on-board electronic equipment.It mainly includes engine bleed air, air-conditioning, air distribution, electronic equipment ventilation and heat dissipation, pressure regulation, environmental protection and so on.

At present, in-service aircraft environmental control system in China is mostly independent control, its control accuracy is low, the control effect is poor, the stability is poor. The integrated control technology is adopted in a large aircraft's environmental control system, and the energy distribution is used to optimize the control system and minimize the compensation damage. Taking the integrated air management computer as the core, the system uses redundancy technology to manage its subsystems to improve the mission reliability of the subsystem.

2. Composition of Task-based Air Management System

The task-based environmental control system takes the air management computer as the core component, which is used to control and monitor the whole environment of the aircraft. The system is mainly controlled by temperature and pressure, and uses flow regulation auxiliary. It involves the co-control and monitoring of several sub-systems, such as engine bleed air sub-system, air conditioning sub-system, air distribution sub-system, ventilation and heat dissipation sub-system of electronic equipment, pressure regulation sub-system, environmental protection sub-system and so on.

As shown in figure 1, the task-based air management system is designed with a similar four-redundancy structure. In the same sampling period, the redundancy task of air management computer is in the working stage for part of the time, and in the hot backup state for another part of the time. Firstly, The cabin pressure control sub-system is designed with three redundancy. Secondly, the engine bleed air sub-system is controlled left and right separately, and a two-redundancy design is carried out to ensure that the system can be reduced even if the redundancy is lost. Thirdly, the air conditioning sub-system, air distribution sub-system and electronic equipment ventilation sub-system are designed with 2 redundancy design. Finally, the anti-ice sub-system adopts single redundancy design.

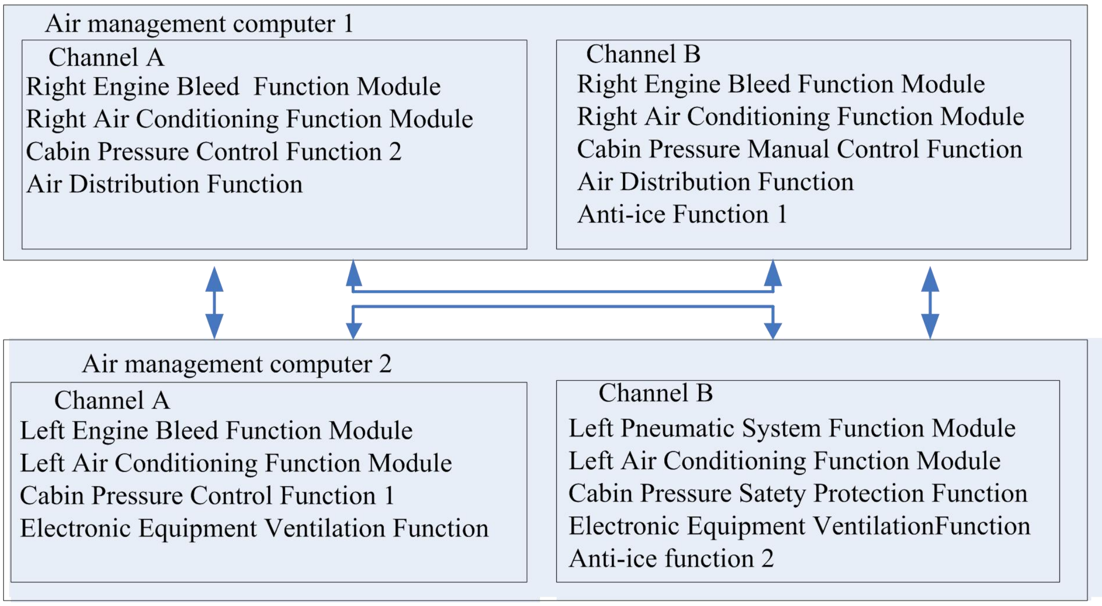

Figure 1 Function task assignment of Environmental Control System

3. Comprehensive redundancy management technique

3.1 Air management computer design technology

As shown in figure 2, the core control unit of task-based air management system is composed of two air management computers with the same structure, and each air management computer has two control channels with the same structure (channel A and channel B).

Each air management computer consists of eight parts. The two common modules are the chassis and connector module (ULM), the motherboard module (MBM).The difference board card includes an A-channel power module (PSM), an A-channel processor (CPM), an A-channel input/output module (IOM), a B-channel power module (PSM), a B-channel processor (CPM), and a B-channel input output module (IOM).

According to the task management requirements of the environmental control system, the power supply module (PSM) and input/output module (IOM) of the air management computer are designed in different regions, and the input/output of each subsystem and power distribution are independent. Partition fault management is used to switch device outputs between A/B channels when the application software finds fault with partition functions.

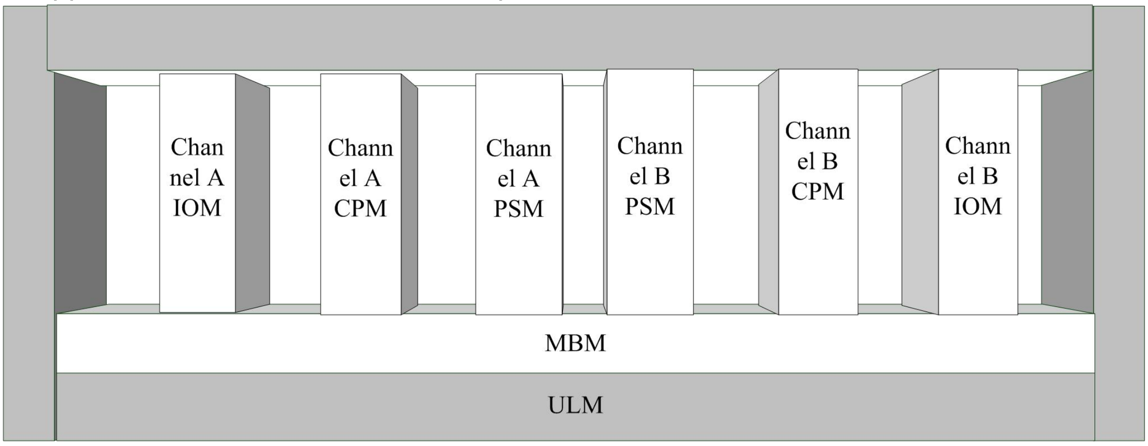

Figure2 Composition of air management computer

3.2 Task-based redundancy management software architecture

The air management computer uses the task-based redundancy management architecture shown in Figure 2.Mainly divided into sub-system function module, sub-system redundancy managing module and sub-system redundancy monitoring module.

Anti-ice Function	Engine bleed function	Air conditioning Function	Air distribution function	Cabin pressure control function	Electronic equipment ventilation function
	Engine bleed system Redundancy Management	Air conditioning system Redundancy Management	Air distribution system Redundancy Management	Cabin pressure control system Redundancy Management	Electronic equipment ventilation system Redundancy Management
	Engine bleed system Redundancy monitoring	Air conditioning system Redundancy monitoring	Air distribution system Redundancy monitoring	Cabin pressure control system Redundancy monitoring	Electronic equipment ventilation system Redundancy monitoring

Figure3 redundancy management software architecture of air management computer

3.3 The function module of the subsystem

The function module of the subsystem is used to realize functions and monitoring of each subsystem, It mainly includes engine bleed air system control, engine bleed air system monitoring, air conditioning system control, air conditioning system monitoring ,air distribution system control ,air distribution system monitoring ,cabin pressure control, cabin pressure monitoring, equipment ventilation control, ice prevention monitoring.

3.4 Subsystem redundancy management

The subsystem redundancy management is used to switch the subsystem according to the functional redundancy requirements in figure 1.It mainly includes cross link communication, Task-level synchronization, Design of Voting level design based on health management and System fault reconstruction.

- Cross Link Communication

  Cross-link transmission uses ARINC429 bus and 1553B dual-bus communication to ensure that the failure probability of data communication is less than 10-9.

- Task-level synchronization

  For the temperature and pressure real-time control system, it is necessary and meaningful to complete the information transmission within the specified time. The air management computer adopts task-level synchronization to ensure the real-time performance of the data transmitted by each redundant module in the system.

- Design of voting surface based on health management

  According to the design requirements of each sub-system redundancy of the environmental control system in Figure 1, the voting surface design is carried out. Voting measures based on self-monitoring and voting data were adopted for a 2-margin vote. The strategy is to use the current master channel data if the dual-channel sub-systems are all in good condition. If there is a fault in the dual-channel subsystem, switch to a healthy state channel for control. If the two-channel sub-system has fault, do not switch the main channel.

- System fault reconstruction

  When the environmental control system works normally, the software function with redundancy function works in the controller A channel. When the local function is lost, part of the redundancy function is taken over by backup, and the software function is reconstructed in the controller B channel. When the failure can not be restructured, manual intervention is was used for important software prompts, the output is passivated for non-important software.

3.5 Redundancy monitoring based on subsystem health management

The air management computer adopts the fault monitoring system based on subsystem health management, as shown in figure 1,It is mainly used for computer redundancy monitoring ,subsystem interface state monitoring ,subsystem component monitoring.

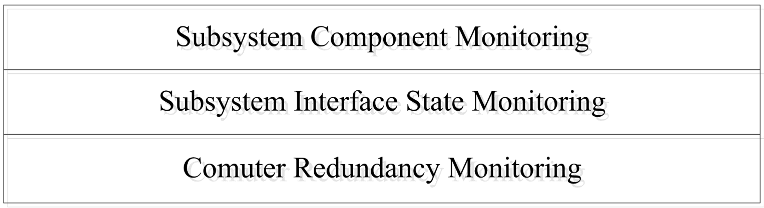

Figure4 subsystem redundancy monitoring system

- Computer redundancy monitoring

  Computer redundancy monitoring mainly monitors the common resources inside the computer. There are two categories according to whether the system's task operation is affected or not. The resource monitoring which has influence on the task running includes CPU processor, SDRAM test, FLASH test, etc. The resource monitoring which has no influence on the task running includes NVRAM test, debug port test, partial input/ output port test and so on.

- Monitoring the interface state of the sub-system related controller

  The computer internal input/output module (IOM) and power supply module (PSM) faults are monitored separately according to the requirements of each sub-system. It is composed of Engine bleed related port monitoring, air-conditioning related port monitoring, air distribution related port monitoring, cabin pressure related port monitoring, equipment ventilation control related port monitoring and anti-icing related port monitoring.

- Sub-system LRU component monitoring

  The LRU components that affect the operation of the sub-system are monitored.The Sub-system LRU component monitoring can be divided into Air system LRU components monitoring, air conditioning system LRU components monitoring, air distribution system LRU components monitoring, cabin pressure system LRU components monitoring, equipment ventilation system LRU components monitoring and anti-icing system LRU components monitoring.

4. System redundancy verification method

The task-based air management system takes the air management computer as the core, manages and backups the environment control system to ensure the safety level of the task. The redundancy management algorithm needs to be fully verified, so that when the fault occurs, the redundancy management module can accurately and quickly carry out the task redundancy management of the fault subsystem, without affecting the operation of other subsystem tasks, and the switching process will not cause any damage to the system or the aircraft.

4.1 Environment control system simulation verification platform

The simulation verification platform as shown in figure 5 is adopted to verify the system redundancy. The platform has more than 70 system models and more than 300 LRU component model libraries. According to the function and performance requirements of two air management computers, the virtual environment control cabin of the aircraft is constructed.

It is mainly composed of upper computer operation platform, real-time execution platform and interface cross-linking platform.

The upper computer test platform consists of five monitors, main server, left/right test upper computer, reflective memory switch and Ethernet switch. The three monitors are used to display the equipment status information of the test bed, and The two monitors are used to display the left/right avionics CAS alarm.

The real-time execution platform uses two interlocked 18-slot PXI chassis, embedded processor and PXI signal simulation card to form the real-time execution platform running real-time operating system (RTOS). Because of many measuring resources, the system uses two PXI-1045 crates and uses PXI expansion to ensure the synchronization and real-time performance of the system.

Interface cross-linking platform interface box is used to connect air management computer, simulation model, real equipment. Firstly, the input/output signal of the air management computer is led to the interface box. Then, it is switched to the simulation channel or the real equipment by the selection switch. The selector switch is actually a RS-485 bus-controlled relay switch board card. In order to realize internal flexible cross-linking, an internal jumper circuit board is installed in the interface box.

The virtual simulation and physical simulation of the large aircraft environmental control system can be completed by this platform.

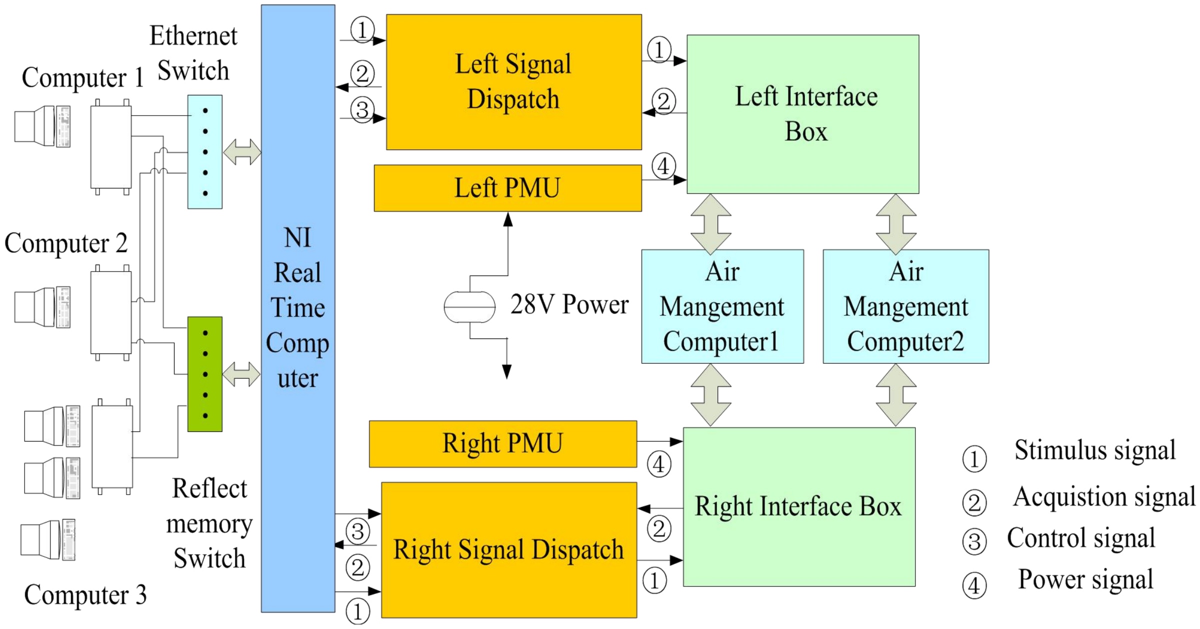

Figure5 the simulation verification platform

4.2 The fault model of environment control system

According to the above task redundancy management framework, the fault models affecting task redundancy switching are established, including communication fault, power drive output fault, power supply fault ,controller fault and subsystem component fault.

Communication faults can be simulated and injected by disconnection, which can be divided into sending and receiving faults.

Function-driven output faults can be simulated and injected via external short circuits.

Power failure can be simulated and injected by external circuit-breaking and power-off.

The fault of the controller can be simulated and injected by power-off and restart.

The failure of each system component needs to be realized by simulation model.

4.3 Fault excitation of environment control system

Simulation verification platform shown in figure 5 is adopted to list the fault setting table of each subsystem .Faults related to the environmental control system are injected into the simulation model to motivate a task to conduct task management ,so as to verify whether the task is switched according to requirements, whether the system works normally after switching ,and whether other systems are affected.

When the LRU equipment failure is injected into the system, the task redundancy management module of the left air-conditioning system finds out the internal or external fault of the controller related channel, and carries out the redundancy management. The related LRU device fault type is shown in Table 1.

Table 1 Air Conditioning Fault Setup Table

Item	Fault	Type	Fault Injection Mode
1	A-channel air conditioning system failure	28V Power supply	Disconnect DC Normal 2
2	B-channel air conditioning system failure	28V Power supply	Disconnect DC Normal 3
3	Temperature control valve output fault	28V/Open Output	Injection short-circuit fault at output pin
4	Compressor outlet temperature sensor failure	760~2120Ω	Model injection sensor temperature over-range

4.4 system redundancy management verification

List the switching and management results under each subsystem fault .Fault injection is conducted through the fault setting table of each subsystem to verify whether the redundancy management logic was managed according to the set logic in the case of failure.

Table 2 is a logic switch table for the output failure of a temperature control valve in an aircraft's left air conditioner.

Table 2 logic switch table

		Item1	Item2	Item3	Item4	Item5
Pre-fault master channel		A	A	A	A	B
Fault state	Channel A	Normal	Normal	Fail	Fail	Normal/Fail
	Channel B	Normal	Fail	Normal	Fail	Normal/Fail
Control result	A	A	B	B	B	B

5. Conclusion

Taking a large transport aircraft environmental control system as an example, this paper expounds the structure of similar four degrees of redundancy of task-based air management system, introduces the hardware and software design technology of core air management computer ,and puts forward the verification method of system redundancy of task-based environmental control system.

The task-based air management system has been successfully applied to a large transport aircraft .Through ground tests and flight tests ,it is verified that its function and safety meet the requirements of the aircraft, and its economy and comprehensive capability are optimized.

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