Design and Implementation of a High Available Distributed Measurement and Control System for Spacecraft Vacuum Thermal Test

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Abstract - Based on the requirements analysis of the high reliability of long-period spacecraft vacuum thermal test, with server cluster technology, a high available distributed measurement and control system for spacecraft vacuum thermal test is designed. This paper expounds the system structure, the detailed method of system build and implement. The scheme can optimize hardware resource allocation, achieve failover and fault recovery, guarantee the continuous and stable running of measurement and control system during the long test period. Finally, test proves that the system shutdown time is less than 15 minutes and the high available system can relieve the loads of operators, decrease the test hazard due to system defects and man-made errors, and improve the precision, efficiency, automation of spacecraft vacuum thermal test.

Index Terms - Vacuum Thermal Test; Distributed Measurement and Control System; High Availability; Cluster

1. Introduction

70% of the spacecraft fault is due to the influence of orbital space environment, especially by spatial thermal vacuum environment. Therefore, the spacecraft vacuum thermal test is the most time-consuming, expensive and essential part in spacecraft development project [1]. The measurement and control system of the vacuum thermal test consists of two parts, the process control system and the test control system. The process control system establishes and maintains a vacuum and low temperature condition by PLC. The test control system, which uses PC as control center controls programmable power supply and data acquisition instrument, simulates the external heat flux and controls the test temperature [2]. The measurement and control system mentioned in this paper refers to the test control system. It is the core operating system in spacecraft vacuum thermal test. Its reliability directly affects the result of the test.

In order to ensure the success of spacecraft vacuum thermal test, the measurement and control system must be stable during the test cycle (usually about a month) [3].However, the current software and hardware framework of the system was designed to meet the demand of former spacecraft thermal test, which has problems in server security. A high available distributed measurement and control system is urgent to be established to meet the reliability requirement of the long-period spacecraft vacuum thermal test. When the system shuts down, it must be recovered automatically in an acceptable time to guarantee the safety of the spacecraft.

In this paper, we propose a high available solution to meet the demand of uninterrupted operation for the distributed measurement and control system. By establishing a reasonable hardware framework and a high available cluster management strategy, the system can operate continuously for 7*24 hours.

2. Present Status and Demand Analysis

At present, the company which the author worked for possess a variety of advanced data acquisition instruments, more than 1000 different types of programmable power supply and a variety of environment simulators making up distributed measurement and control system by LAN.

The hardware framework of system in each environment simulators is the same. Take the 3# environment simulator's test control system for example. As is shown in Fig.1, the database server, measurement PC, control PC and data monitoring PC are located in the central control room. The data acquisition instrument and programmable power supply are located in the equipment room. The computers and instrument are interconnected by network cables, making up an internal local area network. The software, which deals with data acquisition, external heat flux control and data monitoring and analysis, is run on different computers to complete specific test respectively and achieves the remote data acquisition, storage and real-time monitoring of the test parameters.

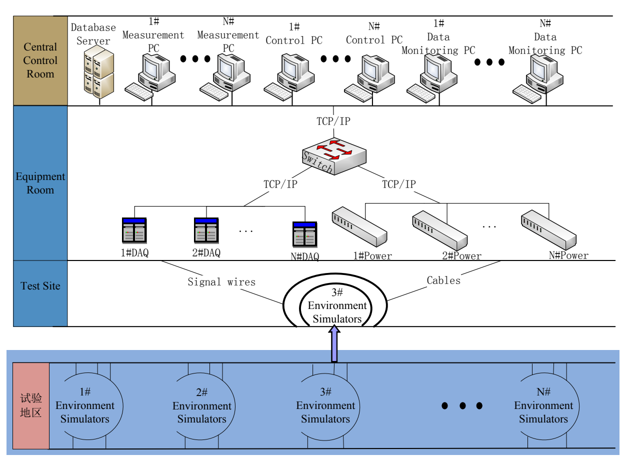

Fig. 1 The hardware architecture of existing system

The existing system began in the mid 90's. It has formed three software parts, the data acquisition part, heat flow control part and data monitoring part. It has got the ability to complete the test for most model types [4]. However, the existing software is designed for different data acquisition instruments and programmable powers. It is a plurality of independent function program based on different language platform, which run in different computers in order to meet the demand of temperature control and measurement using different sensor and mode. The computers work in special use and single function mode.

TABLE I PC resources demands for one test based on existing system

Test	1# Test	2# Test
Environment Simulator Number	1	2
Measurement Channel	1060	1200
Control Channel	500	550
Measurement PC	3	4
Control PC	3	12
Data Monitoring PC	3	8
Database Server	2	2
Total PC Number	11	26

In the Table I, the l# test needs to maintain 11 computers during the test period (about 15*24h=360h). The 2# test is running in two environment simulators at the same time, which needs to maintain 26 computers during the test period (about 5*24h=360h). When the fault of the measurement and control system (application software, computers and network fault) appeared, staff must analyze and deal with the problem quickly. Once much fault appeared at the same time, the staff cannot deal with it in time. The test temperature will be out of control and the spacecraft will be broken even. The measurement and control system of each environment simulator is the same in framework. It leads the hardware capital investment and seriously restricts the researching and developing input of application software.

With the spacecraft's batch production and new spacecraft's fast development, the existing system framework has been unable to adapt to the multi-type, multi-task and parallel test mode. If we just increase the number of computers, it only increases the test risk, reduces the system reliability. Therefore, a high available system is urgent to be developed for guaranteeing tests continuously operate for 7*24 hours and ensuring the safety of spacecraft.

3. System Design and Implementation

The clustering technique is developed recently for high available system. The clustering technique can be classified into 3 types: high available cluster [5], high performance computing cluster [6] and load balance cluster [7]. The clustering technique mentioned in this paper refers to the high available cluster. The high available cluster can avoid system shutdown caused by single fault effectively, guarantee the server's service for outside continues and improve the system availability. It also has the advantage of low cost, easy maintenance and flexible configuration [8-9].

3. 1 *Framework*

This paper design a system that is simple, efficient and reliable to guarantee the high availability of the system based on C/S and clustering technique. The system which can be divided into 4 parts: the client, test portal management subsystem, test application subsystem and database subsystem. Each part is connected by redundant Ethernet. Fig. 2 shows the framework. The function of each part in this system is described as follows:

1) The client part locates in the client computer and offers the entire functional interactive ports to staff;

2) The test portal management subsystem locates in the web server, supporting to the client's request;

3) The test application subsystem locates in the application server. The subsystem assigns different tasks to the power drive unit and the data acquisition drive unit in order to complete the function of data acquisition, data processing, and temperature control.

4) The database subsystem locates in database server. It is the centre of the measurement and control system and is the storage of test process information and result data.

This paper designs a double link structure for data transmission. Each server has two network cards to further guarantee the stability of data transmission.

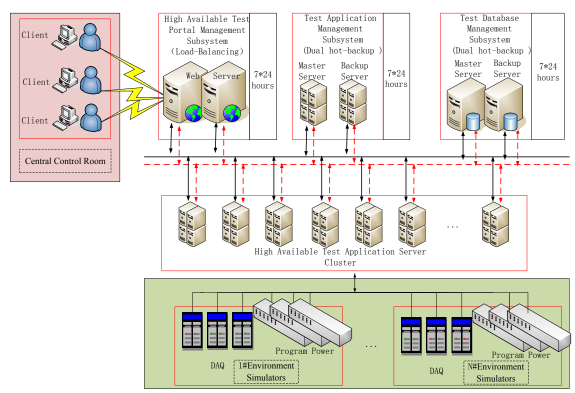

Fig. 2 The architecture of high availability system

TABLE II PC resources demands for one test based on existing system

Environment Simulator Number	1	2	3	4
Measurement PC Number	3	6	9	14
Control PC Number	3	8	13	18
Data Monitoring PC Number	3	6	12	17
Database Server Number	2	4	6	8
Total PC Number	11	24	40	47

TABLE III PC resources demands for one test based on existing system

Environment Simulator Number	1	2	3	4
Test Portal Servers Number	2	2	2	2
Test Application Management Servers Number	2	2	2	2
Test Application Servers Number	2	4	6	8
Test Database Servers Number	2	2	2	2
Total PC Number	8	10	12	14

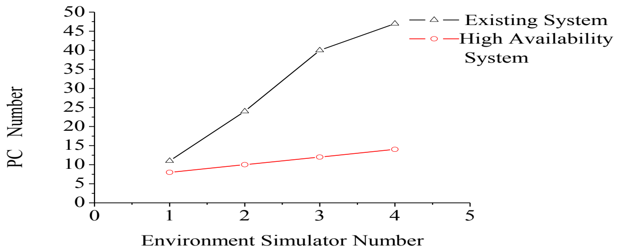

Fig. 3 Comparison of PC resources

From Fig.3 and comparing with Table II and Table III, 26 computers is needed for one environment simulation to do one thermal test, and 47 computers are needed when four environment simulators are working at the same time, according to the existing system framework. In contrast, only 14 servers are needed in the high available cluster system. When four environment simulators are working at the same time, with the decrease of managed computers, the fault rate of hardware decreases and the reliability of measurement and control system improve. It also reduces the computer resource waste dramatically, increases the resource utilization rate and guarantees the high availability of test serve.

3. 2 High Available Test Portal Server

The vacuum thermal test requires the web server to run for 7*24 hours continuously and the network not to be blocked. We apply load balancing technology to locate 2 web servers, realize the high availability of the test portal and achieve the reasonable business assignment between the two servers.

From Fig.4, we can see that the test portal software, load balancing software and high availability software are all located in both of the two servers. One of the servers works as a load node. It receives the entire access request from client, makes load balancing strategy, achieves task assignment, sends a small part of the tasks to itself and leaves most of the tasks to another server.

The load balancing software offers virtual IP for portal visit and automatically assigns the request to 2 servers based on their load status. The server, which received the request, responds to the client after disposing [10].The advantages of the solution are:

1) The two server work at the same, increasing the efficiency of portal responses;

2) The client only needs to deal with one IP ;

3) When one server shutdown, the other one can take over it in a short time, guaranteeing the portal service.

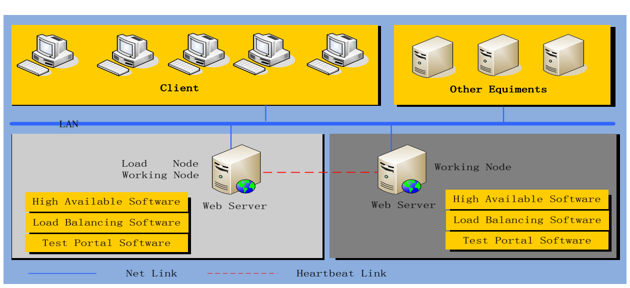

Fig. 4 The architecture of high available test portal

3. 3 High Available Test Application Server

The measurement and control system has a mass of tasks. Each task achieves a special function. The test application servers require:

1) We can create and cancel processes from any server at any time without affecting other servers' work;

2) The test application servers are high available. An application process in one server can be remote monitored and controlled by other servers. In this way, if the application process terminates or run into dead state in the local server, the process can restart in another server in an acceptable time and the test won't stop.

This paper develops a process guard program based on windows system to monitor the entire processes in servers, which is located in a server (process protected server) with the dual-computer hot-standby system. Fig.5 shows the designed framework.

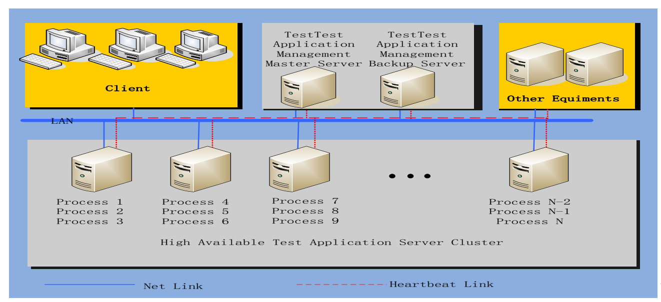

Fig. 5 The architecture of high availability test application

From the Fig.5, we can see that the test application processes are parallel and run in different test application servers. The high available cluster management server use dual-computer hot-standby system (two-node cluster) to guarantee the 7*24 hours continuous operation of the process guard program. This paper tried a fault transfer and recovery test with 3 nodes and 2 processes through cluster software and 3 computers.

Test 1:

1) The cluster software is installed in 3 computers. Process 1 (IE explore) runs in 1#computer, process 2(Clac calculator) runs in 2#computer and 3# computer is a reserved one;

2) Terminate the process 1 and process 2 forcedly. Then the process 1 and process 2 transfer to the node 3 and recover automatically. Fig.6 shows the principle and Fig.7 shows the result.

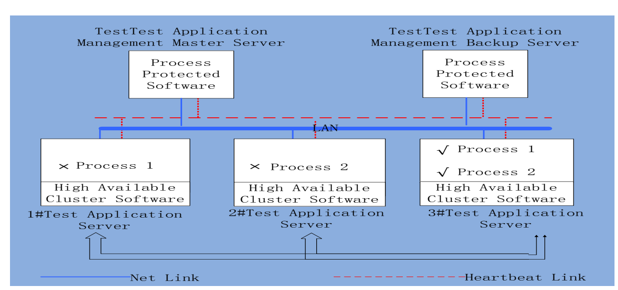

Fig. 6 Schematic diagram of test 1

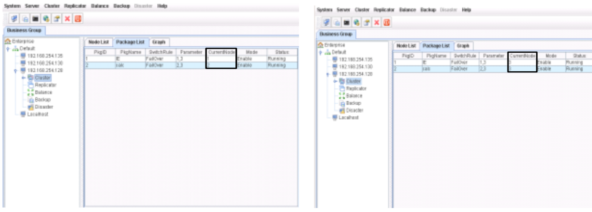

Fig. 7 Results of test 1

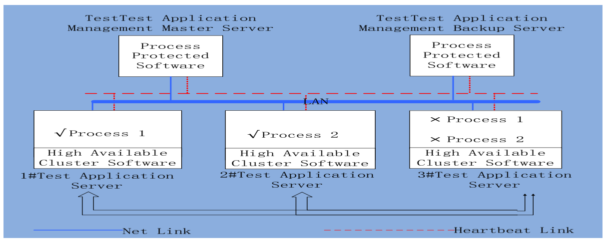

Fig. 8 Schematic diagram of test 2

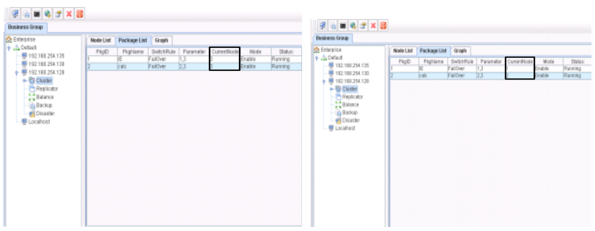

Fig. 9 Results of test 1

Test 2:

1) The cluster software is installed in 3 computers and process 1 (IE explore) and process 2 (calculator) run in 3#computer;

2) Terminate the test process 1 and process 2 forcedly. Then the test process 1 and process 2 transfer to node 1 and node 2 and recover automatically. Fig.8 shows the principle and Fig.9 shows the result.

The fault transfer and recovery was managed in 3s in the 2 tests above.

3. 4 High Available Test Database Server

Database is the key point of the entire platform. Therefore, we choose the dual-computer hot-standby mode. Fig.10 shows the designed framework.

Oracle RAC(real application cluster) is the most outstanding product in the existing commercial high available database system. It supports cluster with two or more equipment and makes the work more flexible [11].

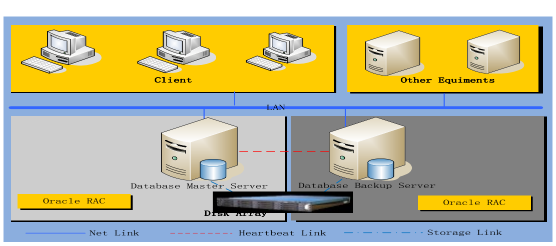

Fig. 10 The architecture of high availability test database

Fig.10 shows the high available database system, which consists of 2 high performance servers with shared storage. Both of the servers are installed with Oracle RAC and provide service concurrently. During the working period, 2 servers provide service with 1 virtual IP. The load can be balanced when the 2 servers work normally. When one of the servers shuts down, the rest one can judge through the heart line and uses the pre-connect function provided by RAC to realize switching and take over the service. It is automatic to clients, is managed in a short time and won't affect the business.

4. Conclusions

Aiming at the uninterrupted operation requirement of spacecraft vacuum thermal test, this paper proposes a high available cluster solution, builds a reasonable hardware framework and redundant network link, realizes the high available portal by using 2 servers with load balancing technology, and realizes the test high available database by using a 2 nodes database cluster with the dual-computer hot-standby mode. This paper develops a process guard program based on Windows to monitor the entire processes in test application servers, achieves the automatic transfer and recovery of process fault and guarantees the high availability of test application servers. The solution optimizes the hardware resources, avoids the fault of nodes, enables the measurement and control system to hot switch faults and recover automatically and quickly, guarantees the 7*24 continuous operation of the system, and enhances the reliability of the measurement and control system. It will meet the batch and parallel thermal test requirements and will be a reference to achieve high available system on other industries.

5. References

[1] Fan Hanlin, Wen Yaopu, "Research on the thermal balance test for spacecraft," *Spacecraft Environment Engineering*, vol. 24, no. 2, pp. 63-68, April 2007.

[2] Wang Zhu, "The Vacuum Thermal Test Of a Small Satellite," *Spacecraft Environment Engineering*, vol. 22, no. 2, pp. 97-99, April 2005.

[3] Shi Zhimin, Wen Jie, Li Diqin, "Improvement for Multi-console Management Technique in Satellite Integration Test System," *Spacecraft Engineering*, vol. 21, no. 2, pp. 119-122, April 2005.

[4] Liu Chang, Wang Yirong, "The software architecture design of measurement and control system in vacuum thermal tests," *Spacecraft Environment Engineering*, vol. 27, no. 3, pp. 324-327, June 2010.

[5] Enrique Vargas, *High Availability Fundamentals*, Sun Blue Prints online, 2000.

[6] D. Dolev, D. Malki, "The transis approach to high availability cluster communication," *Communications of the ACM,* vol. 39, no. 4, pp. 63-70, 1996.

[7] E. Eager, D. Lazowska, J. Zahorjan, "Adaptive load sharing in homogeneous distributed systems," *IEEE Transactions on Software Engineering*, vol. 12, no. 5, pp. 662-675, 1986.

[8] Zhang Xiaofangr, Hu Zhengguor, Zheng Jichuan, "Research and Application of High Availability Cluster," *Computer Engineer*, vol. 29, no. 4, pp. 26-28,March 2003.

[9] Linux Clustering with CSM and GPFS,IBM redbook, 2004.

[10] A. Iyengar, J. Challenger, D. Dias.D, and P. Dantzig, "High-Performance Web Site Design Techniques," *IEEE Internet Computing*, vol. 4, no. 2, pp. 17-26,2000.

[11] M. Vallath, *Oracle Real Application Ousters*, USA:Elsevier Press,Inc,2004.