A REDUNDANT EPICS CONTROL SYSTEM BASED ON PROFINET*

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Abstract

This paper will demonstrate a redundant EPICS control system based on PROFIENT. The control system consists of 4 levels: the EPICS IOC, the PROFINET IO controller, the PROFINET media and the PROFINET IO device. Redundancy at each level is independent of redundancy at each other level in order to achieve highest flexibility. The implementation and performance of each level will be described in this paper.

INTRODUCTION

Availability is a key parameter for big scientific facilities, especially for user facilities. High availability drives the reliability demands for the control system. Redundancy is a common approach to improve the reliability and availability of a system. Some efforts are made to implement the system redundancy under EPICS environment, e.g. the redundant IOC is developed based on the redundancy monitor task (RMT) at DESY for the cryogenic system of the European XFEL project [1]; redundancy technology of the IOC is realized via Xen or Linux-HA base on ATCT at Institute of High Energy Physics(IHEP), Chinese Academy of Sciences [2]; the redundant control system is designed at Shanghai Institute of Applied Physics(SINAP), Chinese Academy of Sciences for the Thorium Molten Reactor System(TMSR) project [3].

PROFINET is a standard for Industrial Ethernet, it is defined by PROFIBUS and PROFINET International (PI) and, since 2004, is part of the IEC 61158 and IEC 61784 standards. PI released the Specification "PROFINET IO System Redundancy" on July 19, 2011, which describes the mechanism to build up a redundant PROFINET IO system [4]. There is no product which is consistent with this specification at present. However there are some existing commercial redundancy solutions with PROFINET, e.g. the redundancy system based on Phoenix Redundancy Layer from Phoenix contact [5].

By integrating the commercial solution into EPICS environment, we set up a prototype system. The prototype system consists of 4 levels: the EPICS IOC, the PROFINET IO controller, the PROFINET media and the PROFINET IO device. Redundancy at each level is independent of redundancy at each other level to achieve highest flexibility.

SYSTEM ARCHITECTURE

The system architecture of the redundant control system is shown in Figure 1. The system includes 4 levels: the EPICS IOC, the PROFINET IO controller, the PROFINET media and the PROFINET IO device.

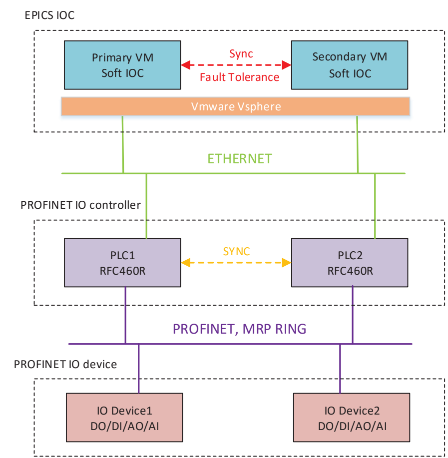

Figure 1: System architecture of the redundant control system.

EPICS IOC

VMware vSphere is the industry's leading and most reliable virtualization platform. It achieves always-available IT with live migration for virtual machines and high availability for applications in virtual machine (VM) clusters. VMware provides 4 features to improve availability: VMware vMotion, VMware Storage vMotion, VMware High Availability (HA), VMware Fault Tolerance (FT) [6]. In this redundant system, VMware FT is chosen to achieve hot standby for the EPICS IOC.

VMware FT provides continuous availability for VMs by creating and maintaining a Secondary VM that is identical to, and continuously available to replace, the Primary VM in the event of a failover situation. The Primary and Secondary VMs continuously exchange heartbeats. This allows the virtual machine pair to monitor the status of one another to ensure that Fault Tolerance is continually maintained [7].

The EPICS softIOC running on the VM communicates with the redundant pair of two RFC 460R PLCs via TCP/IP. An EPICS driver has been developed for the communication between the EPICS softIOC and the RFC 460R PLCs [8].

PROFINET IO Controller

The RFC 460R PLC from Phoenix Contact is a high performance controller that has been extended to offer redundancy functionality. The redundant pair consists of two synchronized RFC 460R PLCs connected via fiber optics. The built-in fiber optic interface is used for synchronization and adjustment between the connected devices [9].

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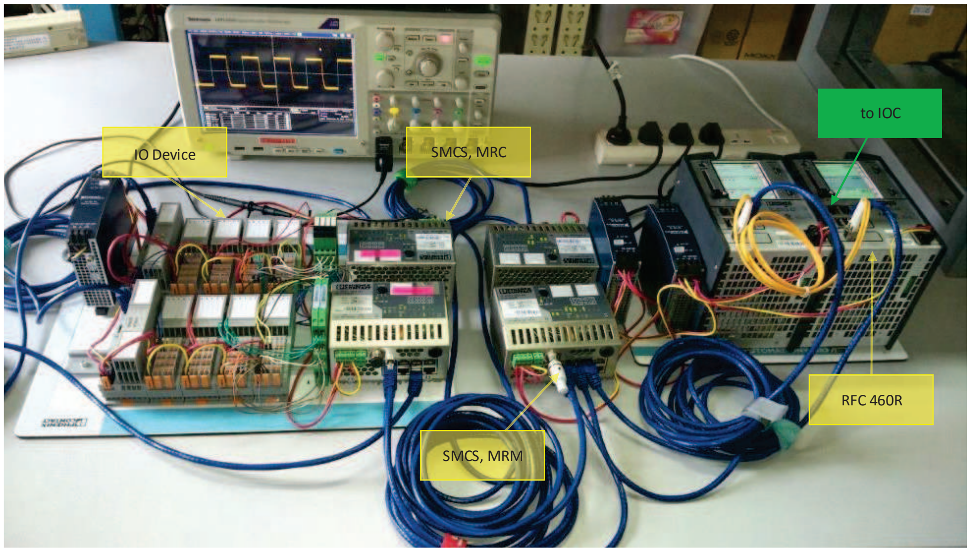

Figure 2: Photo of the prototype system.

During initial startup redundancy type FIRST must be assigned to one of RFC 460R PLCs and redundancy type SECOND to the other. The redundancy type does not change during operation. The SECOND PLC always has the IP address of the FIRST PLC increased by 1. The redundancy role of the RFC 460R PLC (i.e. PRIMARY or BACKUP) may change depending on the status of the redundant control system.

PROFINET Media

The Media Redundancy Protocol (MRP) is used to realize the redundancy of PROFINET. MRP is a self-recovery media redundancy protocols based on physical ring topological network architecture, designed for the fault of single switch or single switch link in ring network. One switch of the ring has the role of ring manager named Media Redundancy Manager (MRM), while the remaining switches have the role of ring clients named Media Redundancy Clients (MRCs). Each switch is connected to the ring through two ring ports. The MRM switch is responsible for handling failure/recovery events, and recovery time is a key parameter of MRP. [10].

PROFINET IO Device

The redundant pair of PROFINET IO devices consists of two PROFINET IO stations, one is primary station and the other is backup station. The wiring for the AO, AI, DO, DI modules installed on the PROFINET IO stations is redundant. Phoenix Redundancy Layer from Phoenix contact is used as the communication protocol between the redundant pair of RFC 460R PLCs and the redundant pair of PROFINET IO devices.

PROTOTYPE SYSTEM AND PERFORMANCE

A prototype system is set up based on the commercial solution, as shown in Figure 2. Two RFC 460R PLCs construct the redundant pair, four FL SMCS switches form the MRP ring, two AXL F BK PN bus coupler and the related IO devices establish the redundant pair. The EPICS softIOCs running on the VMs connect to the redundant PLC pair via Ethernet, however they are not visible in this photo.

EPICS IOC

In order to investigate the availability of the softIOCs running on the VMs with FT, an ao record is created, and it outputs a triangle waveform with 100 ms step. The EPICS extensions Striptool and the EPCIS command camonitor are used to monitor the value of the ao record.

Figure 3 shows the switch-over of the softIOC monitored by Striptool, and the switch-over time is about 800 ms. The switch-over time can be calculated precisely by camonitor, and the result is 809 ms, shown in Figure 4.

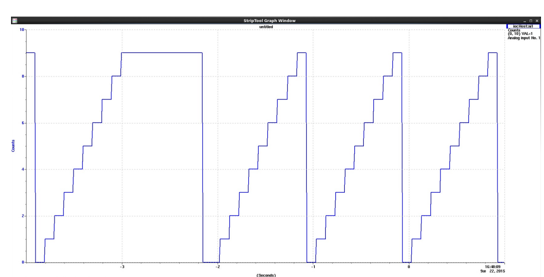

Figure 3: Switch-over of the softIOC monitored by Striptool.

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iocHost:ai1                    2015-09-22 16:48:06.251241 7 HIGH MINOR
iocHost:ai1                    2015-09-22 16:48:06.351407 8 HIHI MAJOR
iocHost:ai1                    2015-09-22 16:48:06.451520 9 HIHI MAJOR
iocHost:ai1                    2015-09-22 16:48:07.260921 0 LOLO MAJOR
iocHost:ai1                    2015-09-22 16:48:07.447481 1 LOLO MAJOR
```

Figure 4: Switch-over of the softIOC monitored by camonitor.

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PROFINET IO Controller

Generally the control process is implemented in the PLC. A triangular wave is produced in order to simulate the control process. There are 9 switch-over ways for the redundant pair of the RFC 460R PLCs, they are switch-over by user, runtime error on Primary PLC, link down at the PROFINET controller interface, parameterization memory of the Primary PLC removed, switch-over by user (firmware service), the PROFINET controller of the Primary PLC has lost the connections to all devices, firmware update has started, firmware has shutdown, a timeout occurred on the SyncLink connection [9]. We test all 9 switch-over ways, and Figure 5 shows the switch-over with the 3rd way "link down at the PROFINET controller interface".

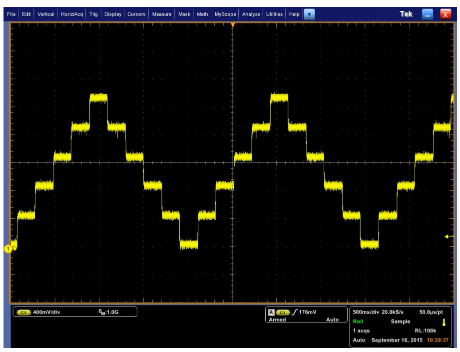

Figure 5: Switch-over of the PLC monitored by the oscilloscope.

The switch-over time is too short to observe from Figure 5. So we use the packet analyzer Wireshark to capture the communication frames between the PLCs and the PROFINET IO Devices. The switch-over time can be analyzed from the captured frames, Table 1 is the results. The average switch-over time is 6.229 ms, and the longest switch-over time is 7.078 ms.

Table 1: PLC Switch-Over Time Test

Number	1	2	3	4	5
Time(ms)	6.964	4.571	6.986	6.953	6.969
Number	6	7	8	9	10
Time(ms)	6.962	6.984	7.078	6.984	2.542

PROFINET Media

The recovery time is a very important parameter for a MRP ring. We also use Wireshark to capture the communication frames between the switches and analyze the recovery time, Table 2 is the results. The average recovery time is 69.338 ms, and the longest recovery time is 87.778 ms.

Table 2: MRP Ring Recovery Time Test

Number	1	2	3	4	5
Time(ms)	67.694	78.618	71.138	73.192	87.778
Number	6	7	8	9	10
Time(ms)	56.787	64.676	59.751	72.223	61.518

CONCLUSION

We set up the prototype system by integrating the commercial solution into EPICS environment. The prototype system consists of 4 levels: the EPICS IOC, the PROFINET IO controller, the PROFINET media and the PROFINET IO device. Redundancy at each level is independent of redundancy at each other level. This means each level can have different redundancy configurations. Beside its flexibility, the prototype system is also easy to implement, and the switch-over performance is good enough to adapt to the most control processes of the big scientific facility.

REFERENCES

[1] M. Clausen, G. Liu, B. Schoenbeurg, Redundancy for EPICS IOC, Proceedings of ICALEPCS2007, Knoxville, Tennessee, USA.

[2] Gang Li, Jijiu Zhao, Ge Lei, et al. Research of redundant EPICS/IOC based on the ATCA platform, Nuclear Electronics & Detection Technology, Vol. 20, No. 7, Jul. 2010.

[3] Zhang Ning, Yin Cong-cong, Han Li-feng, et al. Application Study of EPICS-based Redundant Method for Reactor Control System, Nuclear Electronics & Detection Technology, Vol. 33, No. 11, Nov. 2013.

[4] http://www.profibus.com/nc/downloads/downloads/PROFINET-io-system-redundancy-1

[5] Zhang Long, Du Pin-sheng, PROFINET Redundancy Fieldbus Ethernet PROFINET Technology, China Instrumentation, Vol. 5, 2011.

[6] https://pubs.vmware.com/vsphere-4-esx-vcenter.

[7] vSphere Availability Guide, http://www.vmware.com/products/vsphere/features/fault-tolerance

[8] Liu G, Li C, Li J, et al. EPICS Drive for PHOENIX CONTACT Redundant PLC, Proceedings of IPAC2013, Shanghai, China.

[9] Pheonix Contact, RFC460R User Manual, 2012.

[10] Giorgetti A, Cugini F, et al. Performance analysis of media redundancy protocol (MRP). IEEE Transactions on Industrial Informatics, Vol. 9, No. 1, Feb. 2013.

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