RUNNING MAINTENANCE OF THE BEPCII CONTROL SYSTEM

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Abstract

BEPCII control system has been successfully built using EPICS tools by the development of 5 years and on-site installation of half year. It has been put into the beam commissioning for approximate 3 years. This paper introduces the system overview and hardware installation on-site. It also discusses the performance, improvement and upgrade of the control system. In particular, some problems such as energy ramping and control network are also discussed.

INTRODUCTION

BEPCII [1] is the Upgrade Project of the Beijing Electron Positron Collider, which will provide two rings in the existing tunnel serving high energy physics (HEP) (1.89GeV) and synchrotron radiation (SR) (2.5GeV) research. It was officially approved by the government in 2001. In fact, the BEPCII has three logical rings that are called synchrotron ring (BSR), electron ring (BER), positron ring (BPR).

It reached the goal with luminosity of $3.0\times10^{32}cm^{-2}s^{-1}$ and energy of 1.89GEV in May of 2009 after the beam commissioning of approximate 3 years.

The development of the BEPCII control system started from the year 2001. It took about 5 years for the system development and construction. In order to make sure the early beam commissioning, the control hardware installation started with together a part of the devices installed on-site from January of 2006. Since the tight installation schedule, the magnets were installed in the tunnel region by region, the remote control and calibration of the magnet power supplies had to be done region by region. It took 10 months to complete all hardware on-site installation and testing with the controlled devices on-site.

SYSTEM OVERVIEW

The BEPCII controls system employed Ethernet-based distributed architecture as shown as the figure 1 and was developed using EPICS toolkit. There are one SUN V880 cluster as the EPICS boot server and two PC/Linux servers as Oracle database and data archiving as well as some PC/Linux/Windows workstations as human machine interfaces. EPICS 3.13.8 and VxWorks 5.4 were used for EPICS development environment. The scope of the controls system covered the magnet power supply, vacuum, RF,cryogenic, safety and interlock as well as timing system. There are about 30 VME IOCs as the equipment controls and several soft IOCs as physics model parameters control. There are totally 20,000 PVs.

The network consists of the two layer switches with a redundant core switch (Cisco 4506) and several edge switches (Cisco 3550/2950).

For the equipment interfaces, the magnet power supply control used PSC/PSI developed by BNL. Vacuum control and interlock used AB-PLCs ControlLogix5500 and send messages to a VME IOC through the control-net. The monitoring of Vacuum used VIP616 carriers with IP-232 modules. The Cryogenic control and monitor also employed AB-PLCs ControlLogix5500. There are two VME IOCs to connect to the two AB-PLCs through the control-net. There are two VME IOCs for RF control and monitor. Safety and Interlock system are implemented using OMRON-PLCs. Timing system adopted EVG/EVR.

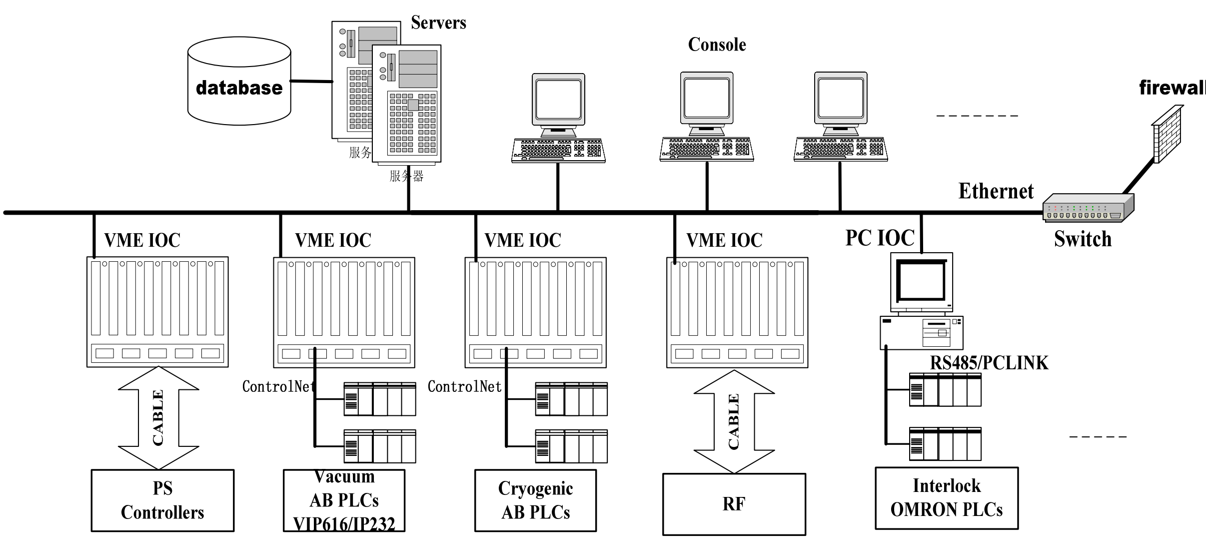

Figure 1: The architecture of the BEPCII control systems.

SYSTEM RUNNING

The BEPCII beam commissioning has started from September 12, 2006. It had three phase commissioning. The first phase was without SCQ, the second phase was with SCQ, third phase was the accelerator together with the Beijing Spectrometer. Whatever phase it was, the commissioning application of the magnet power supply control is often requested. The control group must provide new application software to meet the beam commissioning.

First Phase

All subsystem implemented testing with the controlled devices on site within the limit time before the beam commissioning.The BEPCII firstly ran for BSR, then for BER and BPR.

During the first phase, the control system worked fine. The first electron beam in the BSR was stored in September 12, 2006. Due to the lack of a full energy injector at BEPCII, most user operations required energy ramping. The energy ramping [2] (from 1.89GeV to 2.5GeV) is performed relatively frequently due to a somewhat short beam lifetime in the BSR.

Traditionally, the ramping synchronization [3] in a storage ring is provided by either a hardware system or the high level control software. While providing a high level of synchronization, the hardware based approach is complex, expensive and less flexible. The software based synchronization is flexible and has been found to be adequate for many storage rings.

The ramp program was developed using SNL and running on a standalone IOC which sent setpoints to the every power supply step by step synchronously. However, the ramping took about 20 minutes. We had to try to find out the solution to increase the ramping rate. Since the control of the power supplies are implemented using 8 VME crates with dozens of PSC modules, the ramping program running in one CPU in a standalone VME crate sent setpoints to every CPU in every VME crate. Though IOC is MVME5100 single board computer with a 450MHz CPU, the ramping rate is limited by VxWorks Clock and CPU load. The response and processing of the CPU in every VME crate couldn't follow the setpoints update so that the jitter of the setpoint PVs update could be observed. We found that default clock of VxWorks is 60Hz (1tick=16.7ms) and EPICS database running on 60Hz VxWorks is slowly processed. So, we changed the clock of VxWorks from 60Hz to 600Hz. After that, the processing of setpoints PVs and the correlative PSC/PSI driver was getting fast. By testing, the energy ramping from 1.89GeV to 2.5Gev took 2.5 minutes with setpoints PVs update 3Hz after every IOC running in 600Hz clock.

Second Phase

The second phase commissioning has been started from October 24, 2007, the two complex super-conducting magnets (SCQ) had been installed in the interaction region. They are also controlled by PSC/PSI. They must interlock with quench protection system. The ramping with SCQ cannot be allowed to cause the quench of the SCQ. And there are special requirements to the control system that are with the slow ramping speed (less than 5A/s) and less setpoints step and setpoint fast update rate. So, we removed several pieces of PSC modules in every VME crates to the new added 4 VME crates. The main goal is to decrease IOC loads and increase IOC processing speed.

There are total 13 VME crates for 420 magnet power supplies control including dipole, quadrupole, sextupole and corrector as well as SCQ. The ramping procedure with SCQ took 3 minutes with setpoints PVs update 10Hz from 1.89GeV to 2.5GeV and didn't cause the quench of the SCQ.

Third Phase

During the third phase commissioning, information exchange was implemented between the accelerator and BESIII using Labview/SharedMemory. Some data such as the luminosity and radiation dose as well as dark current can be displayed in the central control room. It facilitated on shift people to adjust e+/e- colliding with higher luminosity.

Meanwhile, in order to meet the requirement of the BESIII data acquisition, a new ramp program was developed for the double ring energy ramping from 1.825GeV to 2.1GeV with more than 300 magnet power supplies operation.

SYSTEM MAINTENANCE

The controls system has run about three years. The control group performs ongoing support and maintenance. In overall, the controls system worked fine and the hardware failure was lower. VME IOCs and PC IOCs occurred crash by the network trouble. The cause was loosing CA link between OPI and IOCs. IOCs reboot can solve this problem.

In order to make sure the machine stably running for a long term, the control group must prepare spare of the hardware including MVME5100 and VME crates. The possibility of MVME6100 instead of MVME5100 is also under consideration due to the dis-continuance of MVME5100 in a few years.

The control system improvement and upgrade are often requested during the beam commissioning. Some demands often exceed the capacity of available resources. So, the system upgrade must be done. A new Oracle database server and archiver data storage array were added. In addition, some available tools such as Archiver and StripTool cannot meet the requirements of the physics commissioning, the control group must develop some new high level software to support the commissioning. For example, during the third phase beam commissioning with higher current (>500mA), one corrugation pipe at the insertion wiggler was broken so that the vacuum was getting worse. At that moment, the operators didn't know what happen. So, a software was developed to save automatically vacuum data and reminder the operators when the vacuum gauge or pump current are more than the upper limit. This can help the beam commissioning with higher current.

Oracle Server

Oracle server computer was with lower configuration (2 x Intel Xoen 3.0GHz, 2 RAM, 120GB Disk) at the development stage. It could archive 4000 PVs within 1 minute. The disk usage was 300GB/year. The data storage space was too small so that it couldn't meet the data storage for a long term. So, the Oracle computer was replaced by HP DL380G5 with a disk array with 1.2T data storage capacity. Oracle database has also been moved to the new computer and put into the second phase commissioning.

The Oracle database was originally designed to create an independent table for each subsystem and implemented data retrial and query for each subsystem. There is no corelation between any two tables. It hasn't been implemented to retrieve and query data of each subsystem with the definite beam current and lifetime. So, the Oracle database must be upgraded to meet the requirement of high level data query in future.

Archiver

Archiver employed a HP XW4600 PC/Linux workstation with a lower configuration (250GB disk) at the development stage. It could store one year data with the archiving capacity 2GB/day for approximate 8000 PVs. It couldn't meet the requirement for long term data storage. So, the archiver computer was replaced by HP DL380G5 with a disk array including 12 pieces of 750G SATA disks and one hardware RAID controller with 7T data storage capacity. All PVs historical data has also been moved to the new computer and put into the third phase commissioning. This new archiving server can save 3 three years data.

However, the Archiver Viewer is not convenient to query a plenty of PVs with the data limit. For example, the operators want to know which devices were changed when the orbit changed or beam lifetime went down. Since about 8000 PVs have been stored into Archiver according to the time period, all PVs are nothing to do with the beam current and the beam lifetime. So, we are developing a new software to monitor the change of each devices such as magnet power supply and BPMs during the machine running. This software can inform the operator and save the changed PV into a file.

Network

The control network is divided into two virtual subnets. There is a PC/Linux as a firewall between the control network and campus network. At the development stage, there was no CA Gateway employed in the control network. The Oracle Server and its data acquisition system were located inside the control network. This data acquisition system communicated with IOCs and got PVs by UDP. Once it has problem with communication to IOCs, it would continuously send broadcast packages along the whole network so that the network traffic often occurred. So, the control network had to be reconfigured and managed. A CA Gateway was configured on the firewall.

The Oracle server and its data acquisition system were removed from the control network to the campus network. The Oracle server saves PVs from the control system through the CA Gateway. After that, the network traffic related to the Oracle database never happened. Beside the CA Gateway, a commercial network monitoring and diagnosis software is added. It can automatically monitor the status of any node of the whole network including the IP address and protocol. Using this software, any problem related to the network can be solved soon. After that, the network traffic was greatly minimized.

Environment Temperature Monitor

For safety, we used YOKOGAWA PLC with LED meters to implement the monitoring of the environment temperature in the central control room and local stations.. In case the temperature is more than the limit, the system can send warning messages to the cellphone of the maintenance stuff.

SUMMARY

The next goal of the BEPCII is towards high stability, high availability and high performance with luminosity of $1.0\times10^{33}cm^{-2}s^{-1}$.

For this purpose, the high level application software is requested to be improved and upgraded according to the experience of the beam commissioning. It is expected to automatically monitor the state of the machine running. An e-log is requested for tracking the commissioning path of the physicist. So, the control system needs to continuously update application software to meet the new requirement.

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REFERENCES

[1] BEPCII Construction Report.
[2] C.H.Wang, J.Liu, et. al, "Energy Ramping in the BEPCII", ICALEPCS2007, Knoxville, Tennessee, USA, Oct. 15-19, 2007
[3] Y. K. Wu† , S. Hartman, S. F. Mikhailov, "A Physics Based Control System For The Duke Storage Ring", Proceedings of the 2003 Particle Accelerator Conference, p. 2482-2484, California,USA,2003