第 31 卷 第 1 期 高 能 物 理 与 核 物 理 Vol. 31, No. 1
2007 年 1 月 HIGH ENERGY PHYSICS AND NUCLEAR PHYSICS Jan., 2007

BEPCⅡ Magnet Power Supply Control System

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Abstract Two rings will be constructed in the current tunnel to increase the luminosity of BEPCⅡ. There will be approximately 460 magnet power supplies in the rings and transport line. Most magnet power supplies require 1×10^{-4} control precision and stability. Only the dipole power supply requires 5×10^{-5} control precision and stability. Using a PSC/PSI for the control of a high precision prototype PS, it has been proven that the PSI can meet the requirement of 5×10^{-5} precision and stability. For easy integration and maintenance, we decided to use the same hardware and software for the control of all PS in the rings and transport line. So, the control of all power supplies will be based on the PSC/PSI modules and the EPICS toolkits. This paper describes the application of the PSC/PSI for the BEPCⅡ power supply control. The status of application software development and power supply control is discussed.

Key words BEPCⅡ, magnet power supply control, PSC/PSI, EPICS

1 Introduction

BEPCⅡ[1] is the upgrade of BEPC, which will provide two rings in the existing tunnel serving high energy physics (HEP) (1.5GeV) and synchrotron radiation (SR) (2.5GeV) research. It uses a full energy linac for injection. The transition from colliding mode to SR mode requires energy ramping. The control and monitoring of the power supplies must meet the physical requirement in the two modes. Besides the basic functionalities (setpoint, readback, control and status) all power supplies should do synchronous ramping from the colliding mode to the synchrotron radiation mode.

There are about 360 power supplies in the two rings and 60 power supplies in the transport lineas shown in Table 1. Most power supplies require 1×10^{-4} long-term stability. Only the dipole power supplies require 5×10^{-5} long-term stability. We studied the applicability of the PSC/PSI[2—4] set-up (developed by BNL, manufactured by Apogee Lab) for the power supply control of the BEPCⅡ rings and transport line. The performance of the PSI has been tested at BNL[5]. The PSI has one 16-bit DAC and four 16-bit ADCs with 15-bit stability. At the beginning, we ordered a few PSC/PSI units from Apogee Lab. Then we built a prototype using the PSC/PSI control unit. In the year of 2004, the PSC/PSI had been successfully used to control a prototype of chopper-type power supply[6]. Extending the test we used one PSC and two chassis PSIs to implement the control and monitoring of two chopper power supplies. The control stability of the PSI has also been tested, and the result showed that the PSI can reach the stability of 5×10^{-5}/28800s. It meets the requirement of 5×10^{-5} stability of dipole power supplies. The new control system equipped with the PSC/PSI for the insertion device[7] in BEPC had been accomplished and ensured the successful BEPC running during 2004—2005, this is the first EPICS based control system

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Received 9 May 2006, Revised 6 July 2006

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part put into operation for BEPCⅡ. The successful running of the new control system proved that PSC/PSI are applicable for the control of the big power supplies. It has laid a foundation for the BEPCⅡ power supply control system set-up.

Table 1. PS families for the rings and transport line.

	two rings								transport line		
name	dipole	quadrupole	sextupole	SKQ	other Q	SC magnet	kicker	corrector	dipole	quadrupole	corrector
number	4	116	36	9	20	16	4	140	5	31	24
stability $(\Delta I/I_{\mathrm{R}})/(\times10^{-6})$	50	100	100	100	100	100	1000	100	100	100	100

2 Hardware architecure

The control system of BEPCⅡ power supplies follows the “three-layer” standard model[8] of a distributed architecture as shown in Fig. 1. The front-ends consist of VME-64x crates, Motorola PowerPC750 CPU boards and PSC/PSI modules. A SUN workstation and a PC/Linux are used for the EPICS development.

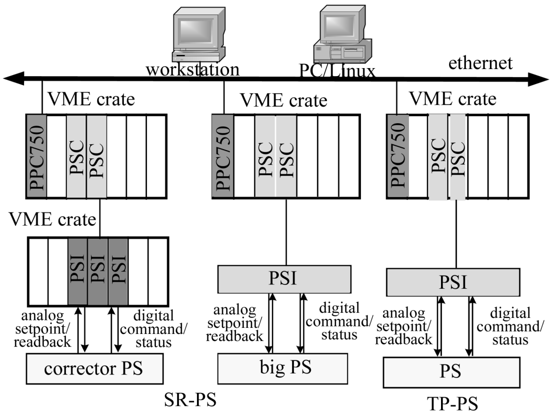


Fig. 1. The power supply control hardware architecture.

After the successful PSC/PSI prototype tests we chose the chassis PSI for the big PS control, and economical VME-PSI for the corrector PS. The chassis PSI and the VME-PSI have the same functionality and features, the difference between them is only in style. The chassis PSI is powered independently in a 1U rack, and the VME-PSI is a VME bus-sized module inserted in a dedicated VME crate with +/−15V voltage input from the backplane. So, we customized a transition module for bringing digital and analogue signals from the backplane to a DB37 connector and a DB9 connector at the rear of the card cage. The main goal for the transition modules is to have the same connectors as the chassis PSI. Therefore, the corrector power supplies have the same remote interface connectors as the big PS. The connections between chassis PSI or VME-PSI and a PS use the same analogue and digital cables. We use the same hardware for all PS to make installation and integration simple, thus the development time and men power can be saved.

3 Software structure

The software platform of the control system is EPICS. The application software is developed on a PC/Linux. The EPICS base and extensions are installed on this PC with VxWorks cross-compiler. The software structure is shown in Fig. 2. OPI is created by EDM. The database template is created by VDCT. We use extensive macro-substitution scripts to expand the database template to the full database. We also plan to use Oracle to create IOC database later so that the IOC database can be browsed on the web. This is very useful for long-term maintenance. The PSC/PSI driver from BNL has been modified to match our power supply interface requirements. Since a DC PS enables 10 chopper PS, the DC On/Off operation should be interlocked with 10 chopper PS. The DC PS has only a digital interface with a PSI with an initial state: normal and four operational states: ON, OFF, Aux ON and Aux OFF. The DC will change from one state to another in response to four commands: ON, OFF, Aux ON and Aux OFF. After every command is sent out to the DC, it will keep the state for 10 clock ticks and then change to normal state. Each chopper PS has a digital and analogue interface with a chassis PSI. Each chopper has an initial state: normal and two operational states: Start and Stop. The operational status resulting from a command is shown in Fig. 3, state diagram. Whenever DC on/off or chopper start/stop, all operations should be interlocked with the chopper current. That is if the chopper current is not zero, all command operations will automatically make each chopper current go down to zero. This is programmed using SNL.

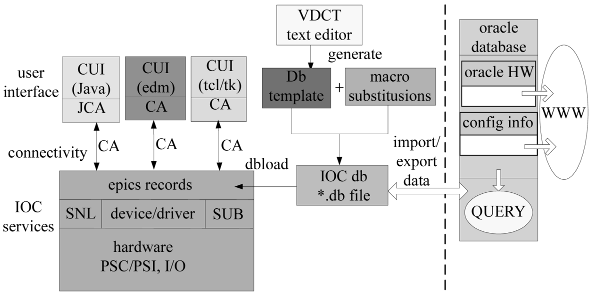


Fig. 2. The software structure.

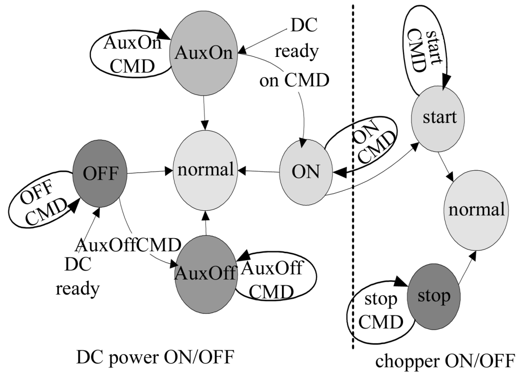


Fig. 3. The DC/chopper operational state.

3.1 PS control program

This program running on an IOC is responsible for monitoring the command operation requested from the OPI. It has five state sets: Initiation, Check DC-ON, Check_DC OFF, Check_Start and Check_Stop as shown in Fig. 4. For example, when the DC ON button is pushed, the program will check if 10 chopper PS currents are zero, if one is not zero, it will let the related current go down to zero, then send out the ON command to the DC. The DC OFF is the same. After the DC ON is valid, when the start button of any chopper is pushed, the program will check if the related chopper current is zero, if it is not zero, it will let the related current go down to zero. Then it will send out the Start command to the chopper.

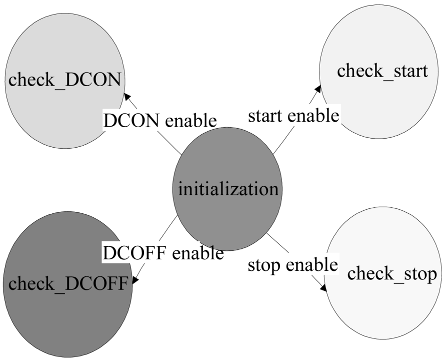


Fig. 4. The PS control state diagram.

3.2 Ramp program

The desired current values of every power supply depends on accelerator physic mode. All PSs need to ramp to their desired values synchronously step by step in order to achieve the desired magnetic fields for all magnets on the route from colliding mode to synchrotron radiation mode. In general, the desired values of various power supplies are different. To make all power supplies to reach their desired values simultaneously, we select same steps (same time interval) and defferent setpoints (delta setpoints) as shown in Fig. 5. This ramp program is created using SNL[9] and running on an IOC. It is responsible for monitoring the ramp trigger record and ramp speed record. Then it sends different setpoints to every power supply step by step.

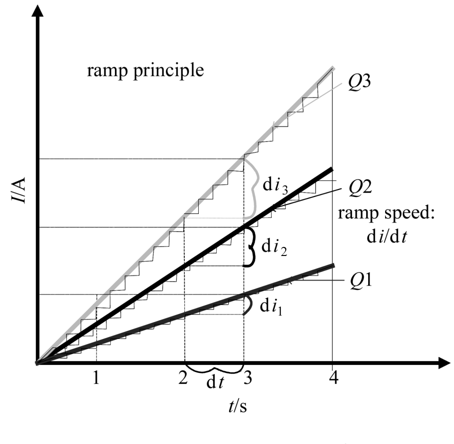
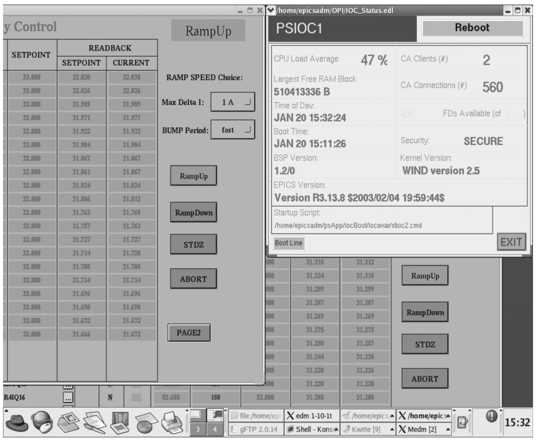


Fig. 5. Ramp principle.

During ramping, this program can be aborted by the Abort button. It has six state sets: Initiation, RampUp, RampDown, Standardize, Abort and END. One thing should be clear before the PSC/PSI assembly, that is the maximum amount of PSC modules can be inserted in one VME crate. This issue is related to the front-end CPU and momery usage. We put 11 pieces of PSC modules in one VME crate for 60 chopper-type PS with simulation signals. Fig. 6 shows the front-end CPU usage of 47% when the 60 chopper PSs do ramping. Meanwhile, we used EPICS IOC monitoring tools vxStats and Save&Restore to implement the EPICS IOC bumpless reboot from the console in the central control room.



PSIOC1

CPU Load Average 47 %

CA Clients (#) 2

Largest Free RAM Block 510413336 B

CA Connections (#) 560

Time of Day: JAN 20 15:32:24

Boot Time: JAN 20 15:11:26

Security: SECURE

BSP Version: 1.2/0

Kernel Version: WIND version 2.5

EPICS Version: Version R3.13.8 $2003/02/04 19:59:44$

Startup Script: /home/epicsadm/psApp/iocBoot/iocexai/stioc2.cmd

Fig. 6. 60 chopper PSs with ramping.

There is an IOC configuration file created by EXCEL for 60 PSs. The Initiation state will read this configuration file to get the PS name, then dynamically assign variables to the PVs corresponding to the setpoint and current record. The advantage of dynamic assignment of channels is to make the program flexible and expandable. RampUp is to make the power supplies go to their own desired values at the same time. RampDown is to make them go to zero at the same time. Standardize is to make them first go to their own maximum values, then to zero at the same time. Abort is to let the program stop any action. By testing, we found that a single setpoint update of the PSI needs a few milliseconds. 180 setpoint steps during a ramp update will cost around 300s.

4 Current status

The power supply control is going well now. All PSC/PSI modules have been assembled in the VME crates and the PS. All hardware including the PSC/PSI modules, CPU boards, VME crates, racks and cables are installed on-site. 17 sets of chopper PS(164) have been tested using PSC/PSI including stability measurement. All corrector PSs have also been tested using PSC/PSI-VME. The superconducting magnets PS are in the stage of testing with PSC/PSI on-site. Some functions have been exercised: remote on/off control and status monitoring, remote setpoint ramping and current readback, stability measurement. The result showed that the PSI control stability is better than 5×10^{-5}. As the next step, we will do system integration including hardware and software testing with the magnet load on-site. 11 VME IOCs with 10,000 signals will implement the control and monitoring of all power supplies of BEPCⅡ.

5 Schedule

On the BEPCⅡ project schedule, the PS control testing with the magnet region by region will start from May, 2006. The whole PS control system testing with all magnets will need 3 months after all magets will be installed and prepared ready. If everything is OK, the commissioning with beam will start in October.

*During the first PSC/PSI prototype set-up test on the control of chopper-type PS, we faced problems with noise introduced from the PS through the analogue cables. The sale representative of Apogee Lab, Mr. Raymond E. Claflin III had a lot of long-distance telephone discussions with the first author covering PSC/PSI technology, analogue connector pin definitions on the PSI and cable connections between PSI and the power supply. This was very helpful for us to solve the problem of noise from the power supply. We are very grateful for his support and great help. Meanwhile, we would like to thank the BEPC*Ⅱ *power supply group for its cooperation and help during the PSC/PSI installation on-site. Moreover, we are grateful for Dr. Roland Mueller from BESSY to review and revise my paper during ICALEPCS2005.*

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BEPCⅡ磁铁电源控制系统

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摘要　BEPCⅡ约有460台磁铁电源分布在储存环和输运线上. 绝大部分电源要求万分之一的控制精度和稳定度, 只有二极磁铁电源要求十万分之五的控制精度和稳定度. 所有电源均采用SNS电源控制器PSC/PSI进行控制. 在将PSC/PSI用于BEPCⅡ磁铁电源的控制之前, 搭建了PSC/PSI控制样机, 对电源工程样机进行了开关机、升降电流的控制, 并对PSI的DAC/ADC控制精度和稳定度进行测量, 结果证明其控制精度和稳定度均满足要求. 采用PSC/PSI的优点是控制硬件相同, 软件相同, 系统集成简单, 便于安装. 从而缩短控制系统研发周期, 节约人力资源. 介绍了BEPCⅡ储存环和输运线磁铁电源PSC/PSI控制系统体系结构和功能、电源控制软件的开发以及所取得的阶段性进展.

关键词　BEPCⅡ　磁铁电源控制　电源控制器PSC/PSI　EPICS

2006 – 05 – 09 收稿，　2006 – 07 – 06 收修改稿

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