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The Control Software Design for SECRAL System

ZHOU Wen-xiong[1,2], WANG Yan-yu[1], ZHOU De-tai[1], ZHANG Jian-chuan[1,2], LIN Fu-yuan[1,2], FENG Yu-cheng[1], LU Wang[1]

(*1. Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou 730000, China;*
2. Graduate University of Chinese Academy of Sciences, Beijing 100049, China)

Abstract: To improve the control efficiency of Superconducting Electron Cyclotron Resonance Ion source (SECRAL) for Heavy Ion Research Facility in Lanzhou(HIRFL), a remote control system was designed and set up in July 2011. The control software package, as a part of the system, was implemented by Visual C ++, which is able to control and monitor all of the equipments for the SECRAL system with about 110 parameters. And many kinds of control protocols were used for controlling different types of equipments in this software. Moreover, in order to prevent the misoperation which may cause the quench of the superconducting magnet, alarm and interlock-protection functions are added to the software and hardware too. If some errors occur during the running of SECARL, those functions should take effect within 1 s. Simultaneously, the data acquired from the equipments can be stored in disk every 1 s for following analysis.

Keywords: SECRAL; HIRFL; control system; alarm mechanism; interlock-protection

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1 Introduction

The SECRAL ion source, which was built to produce intense beams of highly charged ions for HIRFL[1], is a very complex and important system for HIRFL. There are various equipments which are need to be controlled, for example, Superconducting Magnet Power (SMP), High-Voltage Power(HVP), Liquid Helium Circulation System (LHCS), Beam Monitor System, Vacuum System (VS), Microwave Machine, Gas Inlet System, Water temperature and pressure System(WTPS), etc.. Most of the equipments are working in bad circumstance, such as electromagnetic radiation, microwave radiation, radioactivity and high voltage[2]. For purpose of generating intense beams of highly charged ions, it is inevitable to adjust the parameters of the equipments repeatedly and to monitor those parameters in real-time. And all of the equipments were controlled manually and monitored with the aid of video camera in the past. In that case, operating and maintaining the ion beam was a boring, tired and dangerous work which may lead to the quench the superconducting magnet. That is a very serious accident. Once the accident appears, it takes a long time to recovery. So it is imperative to set up a remote control system to improve the efficiency and safety of the work and reduce the misoperation.

The methods to achieve a control system for accelerator are different. For hardware part, the control system of BESⅢ and KEKB mainly consists of VME and CAMAC[3-4]. Those devices

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Biography: ZHOU Wen-xiong(1987—), male, Xiantao, Hubei, Doctor, working on Nuclear Technology and Applications; E-mail: zhouwenxiong@impcas.ac.cn

Corresponding author: WANG Yanyu, E-mail: yanyu@impcas.ac.cn

couldn't be adopted in SECRAL because the space of SECRAL is very small, and all equipments are distributed in different places. What is more, the cost is very high. The SECRAL control system is a distributed control system and all of the controllers which compose the control system are smart device. So if parts of the controllers or the control software break down, the others can still work normally, ensuring the SECRAL can be partial controlled when exception is generated. In order to reduce costs and shorten R&D (research and development) time, the software of SECRAL control system is decided to be developed from Visual C ++.

2 Architecture of the control system

Some different methods are needed to control and monitor the whole systems of SECRAL for their especial working conditions[5]. For example, some equipment should be controlled and monitored via RS232, RS485 and Ethernet. On the other side, many kinds of signals from some equipment should be specially treated, such as high voltage (Up to 40 kV) signal and the weak current of Microampere level signal. Furthermore, many other equipments work in high-voltage platform which may damage the controller without taking any safety measure. According to the above situation, the distributed control system, which formed by thread bus and function module, is designed for SECRAL[6].

Fig. 1 is the block diagram of this system.

In the system, all of the equipments are

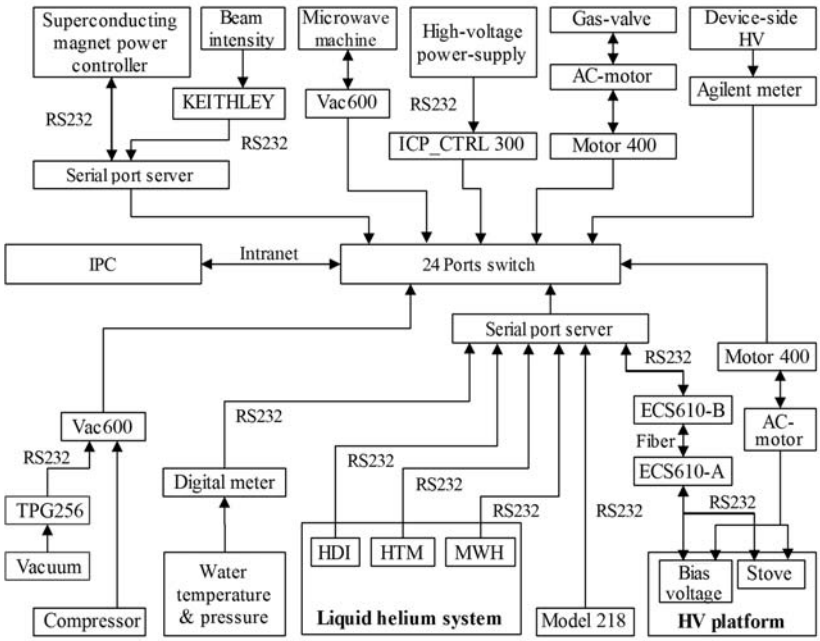

Fig. 1　Block diagram of SECRAL distributed control system.

controlled through a 24-Port-Switch which is connected to the industrial PC (IPC). Two serial port servers are used to control the equipments through RS232. So the related equipments can be controlled through RS232 port directly, for example, SMP, Helium Depth Indicator module (HDI), Helium Temperature Meter module (HTM), the meter to measure the weight of Helium (MWH), Model 218 Temperature Monitor, KEITHLEY (a meter used to measure weak current) and Digital Meter (used to measure water temperature and pressure).

At the same time, other equipments can be controlled through Ethernet. For instance, the TPG256 (six ports Vacuum gauge) and the controller of Bias Voltage/Stove. However, some kinds of equipments' interface are very special, such as Compressor, Bias Voltage, Stove, Device-side High-Voltage, AC-Motor, High-Voltage Power-Supply and Microwave Machine. As an example, the Bias Voltage and the Stove are in the complicated environment of High Voltage up to 40 kV, so the control signal must be translated through Fiber driven by ECS610 to avoid equipments damage by high voltage.

All of those equipments' status information and control signals are obtained and processed via the control software running in the center computer through intranet.

3 Architecture of the software

Fig. 2 shows the software architecture for SECRAL control system, and software package is composed of Get-Data module, Process-Data module, Display Module, File-Operate module, Interlock-Protection module and so on.

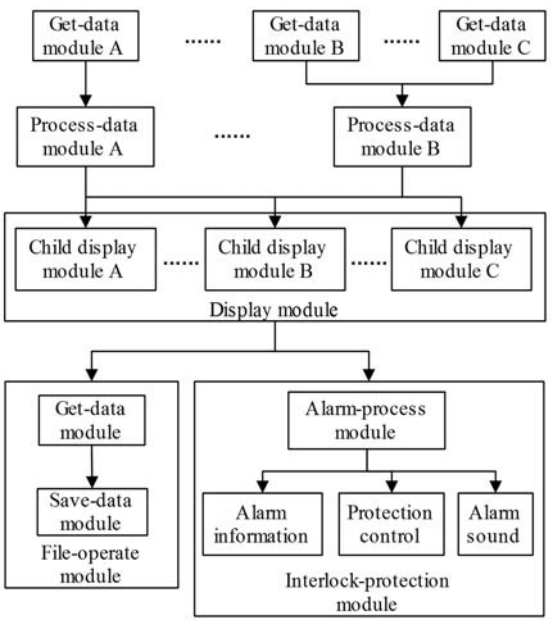

Fig. 2 Architecture of SECRAL control system software.

The modules' functions and working process are as follows:

(1) Get-Data module is used to obtain data from the controller via network (socket protocol) or RS232 port. This module performs 3 functions: setting the appropriate parameters, sending the right command when the corresponding equipment works and getting data.

(2) After data has been obtained, the Process-Data module would work immediately to decode the data according to the parameter format. After that this module gets the useful parameter information and sends it to the corresponding Display module for displaying.

(3) When the Display Module gets the parameter information and relevant data from the Process-Data module, it will call the Child Display module to display the corresponding equipment states or parameters. And the Child Display module would show the current parameters for the equipment.

(4) The File-Operate module uses a timer to sample the equipments' data and save it. When the time is out, the software would write the data to hard disk on the computer.

(5) The Interlock-Protection module is designed to detect the errors every one second, once the error occurs, the interlock protect function would take effect right away. In that case, the module would send the Interlock-Protection signal to the relevant controllers in case of the equipment damage. At the same time, the alarm would go-off, notifying the person on duty.

Overall, the control system software can not only get and display the data in real-time, but also has the functions of interlock protection and alarm.

3.1 Real-time parameters display

In the control system, there are totally about 110 parameters needed to be obtained and processed, including analysis, display, storage and interlock protection. Thirteen of the parameters have to be displayed by animation through Visual C++[7], which burden the software system, and lower the efficiency of the software and operation

system. If this persists, it is sure that some important date will be lost and the software or operation system will run more and more slowly. To solve the problem, message and multi-thread mechanism is adopted to improve the efficiency of the main thread[8−9].

Through the 6 TCP and 8 serial port connections, the SECRAL control system could obtain data and control all equipments. For TCP connections, data are obtained through the message mechanism which will notify the Graphical User Interface (GUI) thread to get and process data[10]. And for each serial port connection, data are got and processed by corresponding thread which would inform the GUI thread to display data when it arrives, otherwise the corresponding thread would be blocked[8, 11]. With the message mechanism and multi-thread, the GUI thread needn't obtain and analyze data at the same time anymore, which is the main task of the software.

Besides, even when equipment generates an error or the controller stops working, the software system is supposed to run normally. So the modular-design is adopted to solve the problem[12]. In order to achieve this design philosophy, each equipment is corresponding to a get-data module, so that it can ensure the stability of the software. To be specific, even if some of the equipment breaks down, others must work normally. Furthermore, to consider the long-term development, if new equipment is needed, it will be easy to modify the software and meet the needs.

3.2 The parameters storage

All of the data acquired for the parameters can be stored in disk every day in the list form[13]. As we know, the read/write speed of the disk is much slower than memory, and frequent disk-operating will shorten its life. So all of the parameters should be stored to the memory firstly, and then stored to the disk every few minutes. The speed of parameters stored into memory can be synchronous with the speed with which it is displayed.

3.3 The interlock protection and alarm

Some equipments need to be protected when some errors occur in case of the quench of the superconducting magnet. So the alarm and interlock protection functions are needed in the control software. And the alarm mechanisms and parameters are set as Table 1.

Table 1　Alarm parameters

Parameter	Alarm	Protection	Delay/s	Interval/ms
SMP	Yes	Yes	5	600
LHCS	Yes	No	5	1 000
VS	Yes	No	5	600
HVP	Yes	Yes	5	300
WTPS	Yes	Yes	5	1 000
Bias Voltage	Yes	No	5	300
Stove Current	Yes	No	5	300
Low Temperature	Yes	No	5	1 000
Beam	Yes	No	5	300
Water Status	Yes	Yes	5	1 000

For interlock protection, the alarm module must be triggered when some parameters are outside the safe range. Furthermore, the equipments have to be protected immediately when some important parameters are abnormal. There are 3 examples here, firstly, when the water system and the SMP generate an error, the Microwave Machine must be closed at once. Secondly, when weight and height of the LHCS are abnormal, the controller must open the Helium container gate to add fresh helium. Thirdly, if the HVP generates an error, the HVP must stop working.

Unfortunately, the environment of the SECRAL is very complex. When the control system is working, all the equipments are in the circumstance of electromagnetic radiation, Microwave radiation, Radioactivity and High Voltage. So the signal transferred to computer may be wrong in this environment, and the interlock protection may encounter an error. Fortunately, the error occurs in few hours, even few days and an error only can maintain one or two seconds every time.

To avoid this, it is very necessary for us to take some measures to filter the false alarm. When an alarm signal generates, a timer is supposed to

delay the alarm within 5 s. After that, the software will check the error again and decide whether alarm and protection is necessary. If the alarm signal still exits after the delay, the control system will validate the error and start up the interlock protection module to handle the error. Otherwise, it will ignore the alarm single, as well as the error.

4 Performance and reliability

Fig. 3 and Fig. 4 show the interface of the software, and the software has been running normally in the control room. It was proved in practice that the control system can monitor all the parameters and control most of them.

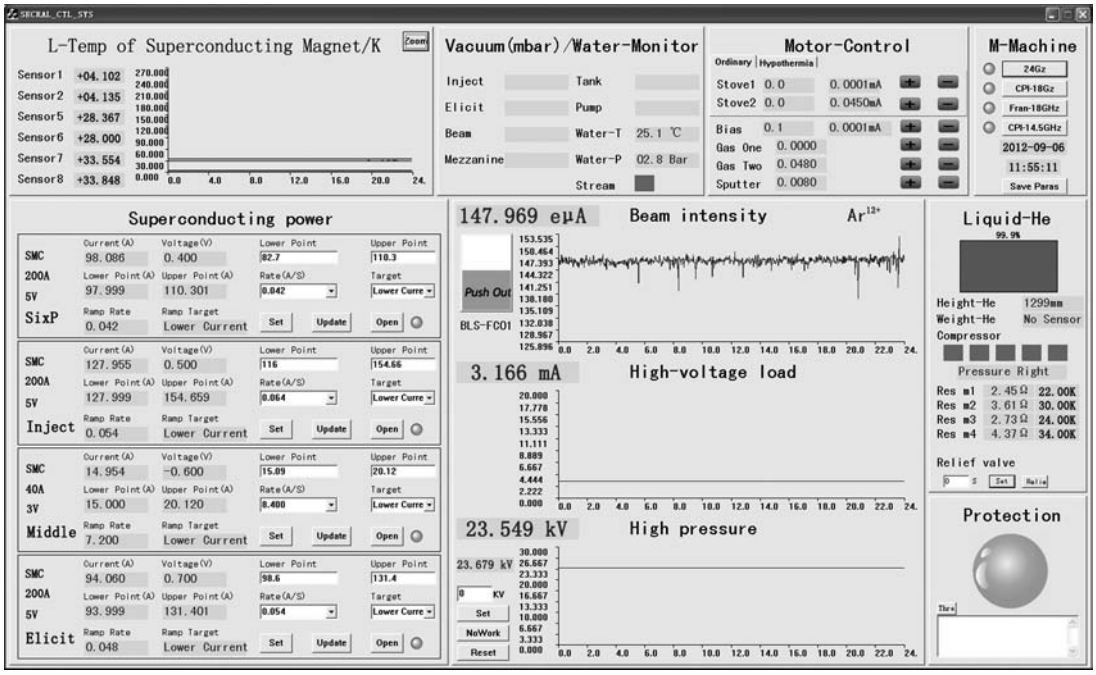

Fig. 3 The main interface of the software.

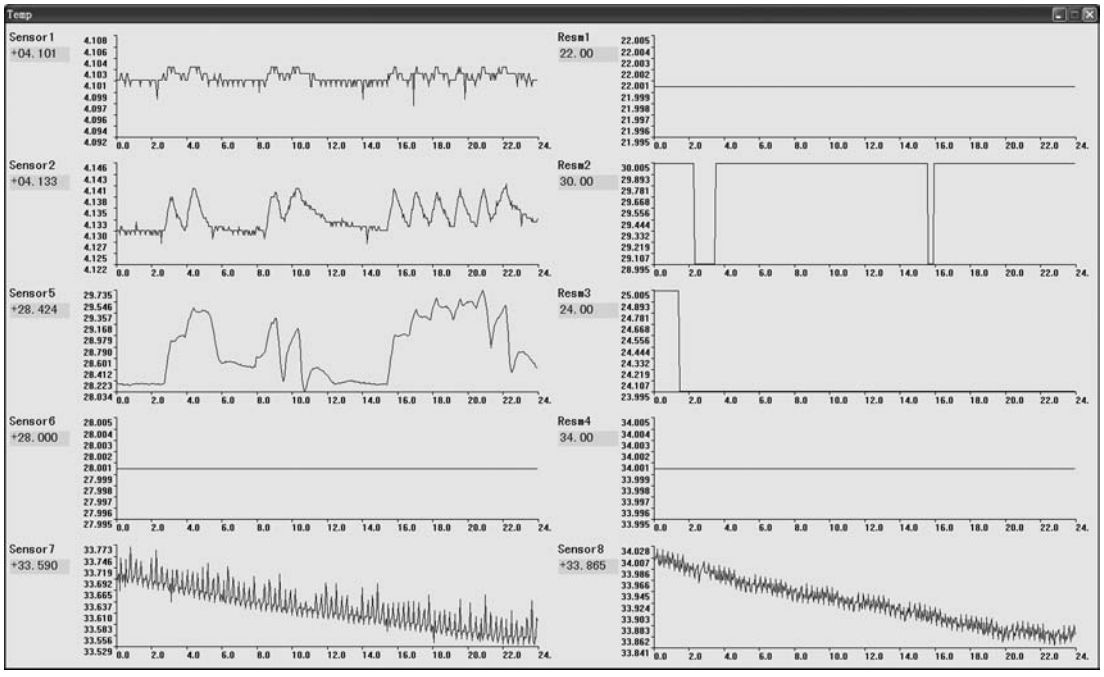

Fig. 4 The child interface of the software.

5 Conclusion

In summary, the software has some advantages. Firstly, it is a robust system developed from C++ with low cost and high efficiency. Secondly, the software could save data in disk for further analysis in real time. Thirdly, once the errors or exceptions occur, the software could record them immediately. Furthermore, it has complete interlock protection mechanism, which can protect the main equipments from the quench of the superconducting magnet, and reduce the burden of the operator on duty. Besides that, the software could avoid false alarms. Now, the SECRAL control system software is running well. With its assistance, the Uranium beam had been generated successfully for HIRFL-CSR after the software come into use.

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SECRAL 控制系统软件设计

周文雄[1,2]，王彦瑜[1]，周德泰[1]，张建川[1,2]，林福元[1,2]，冯玉成[1]，卢 旺[1]

（1.中国科学院近代物理研究所，甘肃 兰州 730000；
2.中国科学院研究生院，北京 100049）

摘要：为提高兰州重离子加速器 HIRFL 的超导离子源 SECRAL 的控制效率，2011 年 7 月份设计和建立了一个远程控制系统。作为该系统的一个部分，这个控制软件使用C++来实现。它能够控制和监视SECRAL的所有设备，大概 110 个参数。而且，为了控制不同种类的设备，该软件使用了很多不同的控制协议。除此以外，在 SECRAL 的运行过程中，若有误操作发生，便有可能导致超导离子源的失超。为了不发生这样的误操作，在硬件和软件中都增加了报警和连锁保护功能。该软件能够在 1 s 内进行报警和连锁保护。同时，为了以后的分析，该软件能够将从控制器上每隔 1 s 获取的数据存储到硬盘上。

关键词：SECRAL；HIRFL ；控制系统；报警机制；连锁保护

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通信作者：王彦瑜，E-mail：yanyu@impcas.ac.cn