Design and implementation of the detector control system for the BESIII drift chamber cosmic ray test

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Abstract After the construction of the BESIII drift chamber, a long period of cosmic rays test is necessary to verify its performance. This also provides a good opportunity to integrate the detector readout electronics and Detector Control System (DCS) into a unified working system. The goal of the DCS is to guarantee reliable physics data quality and the safe operation of the detector. It monitors and controls the HV, gas, VME crates and the environmental variables. The upper-level system is mainly developed from LabVIEW and the lower-level system mainly uses MCU and PLC technology. The system is designed to be highly flexible and scalable so that it can be applied to other detectors with little or no change. In the immediate future, it will be integrated into the entire BESIII Slow Control System.

Key words Detector Control System, drift chamber, LabVIEW

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1 Introduction

The BESIII experiment[1] at the upgraded Beijing Electron Positron Collider (BEPCII) with peak luminosity of 10^{33} cm^{-2}·s^{-1}at 3.78 GeV over the 2.0 to 4.5 GeV energy range[2] is designed for high-precision measurements and new physics searches in the tau-charm threshold energy region. The drift chamber is the central tracking device of BESIII, and occupies the radial region between 53 and 810 mm with an axial extent that is 2.3 m in length. A total of 7000 gold-plated tungsten wires (3% Rhenium) with a diameter of 25 μm are arranged in 43 layers, together with a total of 22 000 gold-plated Al wires for field shaping.

The construction of the drift chamber was finished over five months ago. To verify its construction quality, the drift chamber is currently undergoing a long period of comic ray tests. These tests also provide a good opportunity to integrate the detector, readout electronics and Detector Control System (DCS) and study how well they work together. This is also a trial operation of a detector subsystem for the BESIII experiment.

The purpose of the DCS is to guarantee safe operation of the detector and provide the ability to make most of the operating functions able to be done remotely via computer. It has to monitor and control about 1000 variables from dozens of different devices, such as the high voltage, gas flow, VME crates on/off, fan speed, environmental variables, etc.

The DCS design is not specific to the BESIII drifter chamber. It can be also applied to the other detector subsystems of BESIII, such as the Electromagnetic Calorimeter (EMC), Time of Flight (TOF) counters, Moun Identifier and Superconducting Magnet. Ultimately, the DCS will be integrated into the overall BESIII Slow Control System, where nearly 9000 parameters have to be monitored and controlled. Thus, the system must be designed to have high flexibility, scalability, availability and stability.

2 The system architecture

The DCS is divided into four subsystems according to the functions it performs: the high voltage system, the VME crates system, the gas system and the environmental system. The hardware architecture of

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the whole system is shown in Fig. 1. To meet the different functionality requirements and reduce the cost, both commercial and customized devices are used in the low- level system, in which MCU, PLC and embedded technology are adopted. The top level supervisory and control software is mainly developed from LabVIEW, MySQL and OPC Server. A detailed description of the subsystems is presented in the following sections.

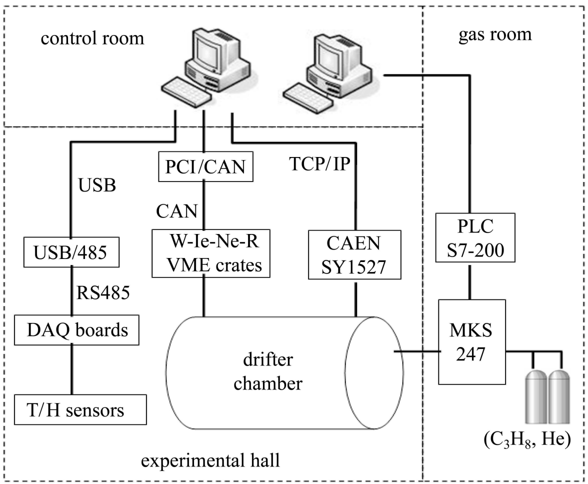

Fig. 1. Schematic diagram of the system hardware architecture.

2.1 The high voltage monitoring and control system

In the high voltage system[3], a CAEN SY1527 HV crate with six HV boards resident is employed to supply the 2000 V bias to the 43 layers of signal wires of the detector. Each board has a digital thermometer mounted on it. An Ethernet connection is used for communication between the HV crate and the top level software.

There are five status levels for the HV bias for each layer: Vwork, Vpre, Off, Trip and Abnormal. When the status is Vwork, it means that all the voltages of the wires in the layer are in operating status which is about 2000 V. Vpre means that the voltages are in stand-by status which corresponds to a bias of about 200 V on the signal wires. The Off status means no bias at all on that layer. When the leakage current of a layer is higher than the preset-limit, I0Set, the power will trip and the corresponding voltage will be reduced to a lower level automatically. When the difference between the read value and the preset-value is higher than the allowed tolerance of about 5 V, the Abnormal status for the corresponding layer will occur. A sound alarm and a graphic display will be generated when either of the last two status levels happens for any layer. The first three status levels can be set by DCS either for a single layer or groups of layers. When an emergency happens, the user must kill the power to all layers directly, which means that the bias on all layers will be ramped down at the maximum rate possible, regardless of the Ramp-Down or other parameters. In addition, all of the other parameters related to the HV can be set via DCS; these include: I0set, Ramp-Up/Down, Trip and the upper limit of temperature. All the configurations are saved in XML files for a variety of operation modes.

2.2 The VME crate monitoring and control system

There are 16 W-Ie-Ne-R VME crates used as the power supplies for the read-out electronics of the drift chamber. The monitoring and control of theses crates is one of the main DCS tasks. The crates have a CAN-BUS interface for communication with the computer. An OPC server for this power supply was developed by the IT-CO-FE group at CERN[4], which simplifies the development of the DAQ program substantially.

For each VME crate, there are 18 parameters that need to be monitored or controlled as shown in Fig. 2, which is the GUI for a single crate. To guarantee the safety of the read-out electronics, in the event of a fatal error occurrence, the VME crates will be switched off automatically. The main reasons for a fatal error include a bias current or voltage for a module that is higher than a certain limit, a module temperature that is higher than the alarm limit or a failure of one or more of the cooling fans.

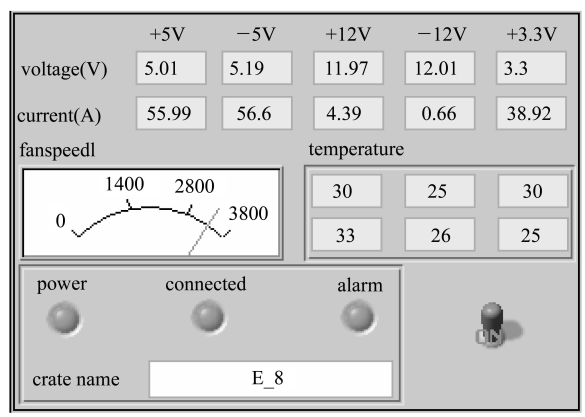

Fig. 2. Graphical user interface for a single VME crate monitoring and control.

The first results using this system showed that the OPC server with 300 tags for 16 crates had a CPU usage of 30% and a readout was possible every 30 s. The latency of the control was less than 1 s.

2.3 The gas control system

The main task of the gas system is to provide the detector with properly mixed and regulated gas. The BESIII drifter chamber uses a gas mixture of 60% He and 40% propane as the working gas. The gas mixture is stored in a 600 l tank from which it is supplied to the detector at a rate of approximately 6000 ml/min and a pressure of 1.4 bar.

The gas system will monitor the pressure and flow rate of each gas output, the pressure of the buffer tank as well as the pressure at the input to the detector. Each of the parameters has an upper limit and lower limit set as alarm conditions. When a low pressure at the output of any of the gas supply lines is detected, the gas supply bottle will be switched to another one for continuous gas supply. If the pressure of the buffer tank exceeds its upper limit, the gas outputs will be switched off. When the pressure is lower than the lower limit the outputs will be switched on (see Fig. 3). The control of the gas supply can be in automatic or manual mode as set by the user. In practice, the system was in automatic mode for most operation phases other than the initial debug phase.

In the system, an MKS 247 mass flow controller is used to mix the gasses from the two sources and a Siemens PLC S7-200 is used to control solenoid valves and read the signals from flow meters and pressure transducers. The communication between LabVIEW and the PLC is based on PROFIBUS-DP. An OPC server is used as the communication driver that supplies a unified interface to the top level software, which is similar to that for the VME crate monitoring and control system.

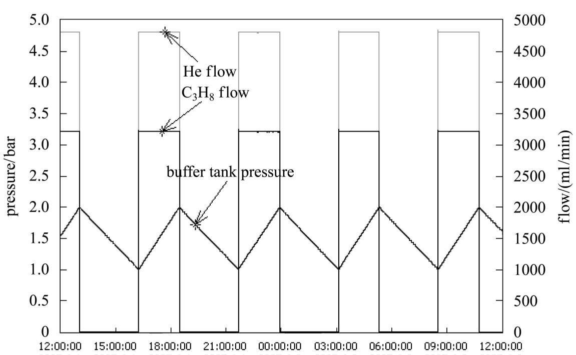

Fig. 3. History graph of the flow rates and pressure.

2.4 The environmental monitoring system

This system monitors the air temperature and humidity inside the detector and at the front-end electronics. The environmental conditions are very important for the safety of the detector and the aging rate of the front-end electronics. The detector signal wires could be break if the gas temperature inside the chamber changed faster than 1 degree/hour. In the case of such a situation, the HV and VME crates must be switched off manually by the operator.

The temperature and humidity are measured by two types of digital sensors: DS18B20 and SHT75. The former is a low-cost-type temperature sensor[5] and the latter measures both temperature and humidity but has a higher cost. Both of the sensors have passed radiation tests, so they can work properly in the BESIII experimental hall, where the radiation level is 5 Gy/year on average, for tens of years. To acquire data from the sensors, two types of DAQ boards and a USB/RS485 converter have been developed. In the DAQ boards, RS485 is used as the transmission protocol and C8051 MCU is used as the controller to collect and process data from sensors. A 16 bit CRC check is appended at the end of each message to guarantee reliable data transmission.

3 The top level supervisory and control software

The top level software was developed with LabVIEW 8.20 for the Windows XP platform and about 300 VIs have been created in total. The main functions of the top-level software are similar to the Supervisory Control and Data Acquisition (SCADA) software as follows.

1) Data acquisition and process: periodically acquire data from the various devices and translate the data to real world values.

2) Control: send control commands to devices either automatically or manually.

3) Data display: display data in graphic user interface, and track things such as real-time trends.

4) Alarm and Error process: sound alarms and graphic display information are generated when alarm or error conditions occur.

5) Configuration: set the name, hardware address, alarm limit, DAQ period and other parameters for each variable; set the database configuration, database backup strategy and manage user accounts.

6) Data storage: insert data into the MySQL database.

7) Data retrieve: query historical data from the database and display the returned data graphically or save it into a datasheet file.

8) System maintenance: a daemon thread that monitors the running status of the system and does regular maintenance work, such as database backup and garbage file deletion.

9) Running log: record alarms, errors and event information into a log file.

10) User account management: there are four levels of privilege for the target users: administrator, expert, operator and no user. The user must login to get privileges for corresponding operations. For example, only the expert and administrator account have the privilege of control of the gas system.

Since the basic functions for all the subsystems are similar except those specific to the monitoring and control functions for a given subsystem, a DCS top level software template was initially developed. Each subsystem software can be developed starting with this template, in which one only needs to add their subsystem specific functions. In this way the template simplifies and accelerates the development of new subsystems substantially and also makes the software easy to learn and maintain.

The template is divided into several modules as shown in Fig. 4. Each module has a set of programs with standard communication interfaces. Most of the modules run independently in different threads, so the other modules will still function properly even one module failed. When new functions have to be added to the system, it is only necessary to integrate the new modules into the system without making any changes to the other parts. For future integration of different subsystems, a standard communication interface has been designed. The modular design of the template makes the system very flexible and scalable, so the system can be easily expanded or integrated to a large system.

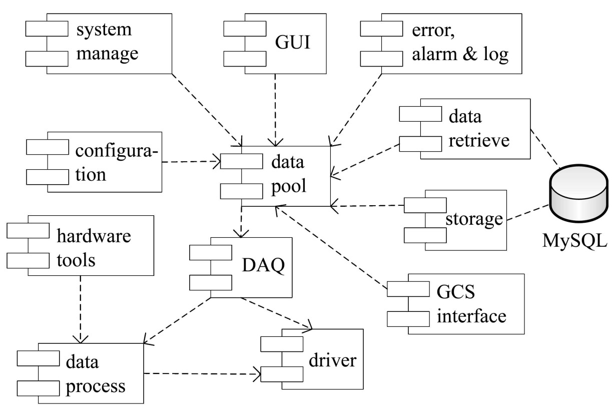

Fig. 4. Architecture of the top level supervisory and control software.

4 First results

The DCS has being running successfully for more than 4 months and it has been used to perform nearly all the functions needed to operate the detector. It not only simplifies the operation process, but also protects the detector from mis-operation or abnormal conditions. The PLC, CRC check, OPC server, modular design and auto database backup made the system highly reliable and available.

Nearly 1G bytes of historical data are stored in the database, which will be very useful for evaluating the detector's performance and the offline analysis of physics data. Fig. 5 shows a historical graph of the temperatures over a three weeks period, which shows that gas temperature inside the chamber was more stable than that of the environment. The observed temperature fluctuations were mainly caused by the On/Off operations of the VME crates.

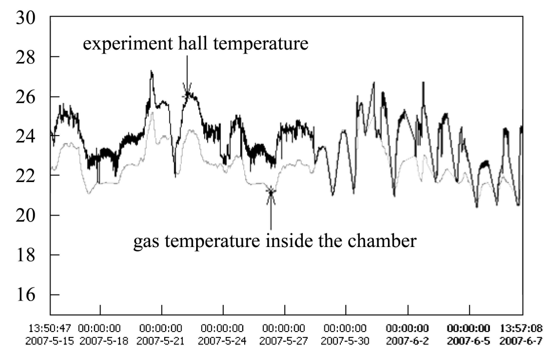

Fig. 5. Temperature of the chamber inside and the experimental hall.

5 Conclusions

The DCS played a very important role in the BESIII drift chamber cosmic ray test and the first results were very satisfactory. Many useful results, experiences and users' feedback were obtained for further refinements. The modular design made the top level supervisory and control software highly stable, flexible and scalable, and it can be applied to other detectors with little or no change. In the immediate future, it will be integrated to the entire BESIII Slow Control System, which will be several times large than this original version.

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