DETECTOR CONTROL SYSTEM OF BESIII

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Abstract

In the upgrade project of Beijing Electron Positron Collider (BEPC) II, a novel Detector Control System (DCS) for Beijing Spectrometer (BES) III is under developing. The principal task of the DCS is to supervise and control the status of the BESIII detector and to guarantee a safe operation to the detector. The DCS must provide a uniform and coherent interface to the detector operators even though there are a large number of distributed I/O channels from large variety of equipments. For this reason, the DCS is hierarchically organized and divided into three layers: Front End Layer (FEL), Local Control Layer (LCL) and Global Control Layer (GCL). In the FEL, ranges from simple sensors up to complex computer-based devices like embedded systems and Programmable Logical Controllers (PLC) are utilized. A LabVIEW based software framework has been developed for the LCL. Network communication and web server technologies have been used for the GCL. This paper will give a detailed introduction to the design and implementation of the DCS. Its performance and reliability will also be discussed in the last.

INTRODUCTION

The BESIII experiment [1] at the upgrading Beijing Electron Positron Collider (BEPCII) with an energy range of 2–5GeV, a peak luminosity of $10^{33}cm^{-2}s^{-1}$ at 3.78GeV [2] is designed for high-precision measurements and new physics searches in the tau-charm energy region. The BESIII detector has a cylindrical symmetry with a total length of 5.6m and a radius of 2.6m and consists of four subdetectors for different tasks like particle identification, track reconstruction, energy measurement and muon detection.

The BESIII experiment brought several special challenges to the design and implementation of the control system. First of all, there are about 9,000 data points covering dozens of physics parameters need to be monitored or control. To provide a uniform and coherent interface to the operators, the DCS must be organized in hierarchy and the different drivers in the bottom layer have to be wrapped into a uniform interface to communicate with the top layer. Secondly, the DCS must be able to work continuously and stably for more than ten years in the harsh environment due to radiation and magnetic field. Finally, the budget of the DCS is only 0.4% of the total cost of BESIII.

SCOPE OF THE DCS

The principal task of the DCS is to supervise and control the status of the BESIII experiment and to guarantee a safe operation to the detector. The status of the BESIII experiment includes not only the status of the subdetectors but also the readout electronics, the PC farms, the experimental hall environment and other parameters from external systems. The term external systems indicates that the control of these systems is outside the scope of the DCS although the communication with them is required, such as the DAQ, the BEPCII accelerator, the Superconducting Magnet and the Beam Pipe. The DCS is divided into six subsystems by the target to monitor or control: Temperature and Humidity (TH), Low Voltage (LV) power supply, High Voltage (HV) power supply [3], VME crates, GAS control and Safety Interlocking (SI).

DCS ARCHITECTURE

Even though there are thousands of distributed data points in the DCS need monitoring or control, only one or two operators will keep watch the whole BESIII experiment during concurrent physics datataking. So the DCS must provide a uniform, coherent, simple and friendly interface to the operators who may be physicist, engineer or student. On the other hand, the DCS must also provide the functionality required to operate the different BESIII detectors in stand-alone mode during building and commissioning.

For these reasons, the DCS has to be organized hierarchically [4] as shown in figure 1. The DCS is divided into three layers: Front End Layer (FEL), Local Control Layer (LCL) and Global Control Layer (GCL). Simple sensors up to complex computer-based devices like embedded systems and Programmable Logical Controllers (PLC) are utilized in the FEL to acquire the different parameters or execute control commands of the BESIII experiment. The LCL acquires data from the FEL and offers supervisory and control functions such as displaying, archiving and alert handling. Each Local Control Station (LCS) can work either in stand-alone mode or integrated mode to satisfy the different stages of the BESIII experiment. In the GCL, the Global Control Station (GCS) will gather the summery information from the LCS and provide a uniform and simple interface to the operators. All the data acquired by the LCS will be stored in the Database Server and published to the Internet by the Web Server. The GCL will only work in integrated mode during concurrent physics datataking

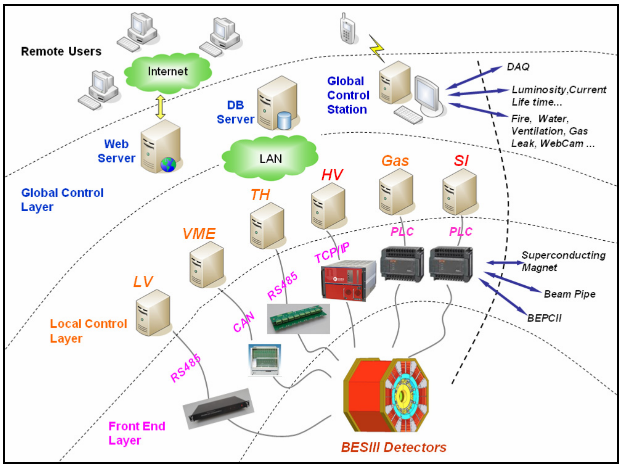

Figure 1: Architecture of the BESIII DCS.

Front End Layer

The FEL includes all the hardware components of the DCS, which are used to convert the physics signal such as temperature and pressure into digital data or execute control commands sent from the LCS, such as remote ON/OFF of the VME crates or the HV power supply.

For the Temperature and Humidity (TH) monitoring, about 1,000 temperature and humidity sensors are distributed over the subdetectors, electronics, PC farms, cavern and control room. Both the temperature and humidity sensor are digitized sensor, in which the temperature sensor is DS18B20 from DALLAS and the humidity sensor is SHT75 from SENSIRION. Both of the sensors have been qualified for the long lifetime operation in the harsh environment due to radiation and magnetic field according to a strict radiation test.

To collect the data from the sensors and transmit it to the LCS, three customized boards have been developed by the DCS team at a low cost. Two of them are DAQ boards which are used to gather the data from DS18B20 and SHT75 separately [5]. The third board is an USB/RS485 adapter [6] to transduce the data from RS485 to USB. Fieldbus RS485 is selected to transmit data from the DAQ boards to the LCS because of its high reliability in transmitting data over a long distance up to 1,200m. A quasi-Modbus protocol has been implemented to define the transmission format of the data. Because of the unaccessible of the boards during experiment, a bootloader program is resident in the boards for firmware reloading or upgrading online.

For the LV monitoring, the same technologies as in the TH monitoring system have been adopted except the TH sensors are replaced by amplifiers.

In the HV monitoring and control system [3], the CAEN SY1527LC HV power supply mainframe [7] has been adopted and it supplies an approach of remote monitoring and control via TCP/IP. So no hardware and software need to be implemented in the FEL and the communication program on the LCS side can be developed based on the CAEN HV Wrapper [7].

Similarly, in the VME monitoring and control system, the W-Ie-Ne-R VME crate [8] also provides a way to access the crate remotely via CAN bus. To make the communication with computer easier, an OPC server for the W-Ie-Ne-R VME crate has been developed by the IT-CO-FE group at CERN [9].

Both of the Gas and SI system selected SIEMENS PLC S7-200 for control operation and data acquisition due to its high reliability. The OPC server for this PLC has also been provided by SIEMENS.

Local Control Layer

The LCL is composed of several LCS to provide the full monitoring and control of the subdetectors and other support systems. There will be a unique LCS per subdetector during detector building and commissioning and each LCS can work independently, which provides the maximum flexibility for the operation of the subdetectors. During concurrent physics datataking, the LCS will be rearranged by subsystems as figure 1 showed.

To acquire data from the FEL and offer supervisory and control functions, a software framework for LCL has been developed based on LabVIEW [10]. LabVIEW is a graphical development environment, which not only simplifies and accelerates the development of the framework dramatically but also has a low cost compared with other commercial SCADA software such as PVSS-II, iFIX and WinCC. The architecture of the LCL software framework is shown in figure 2.

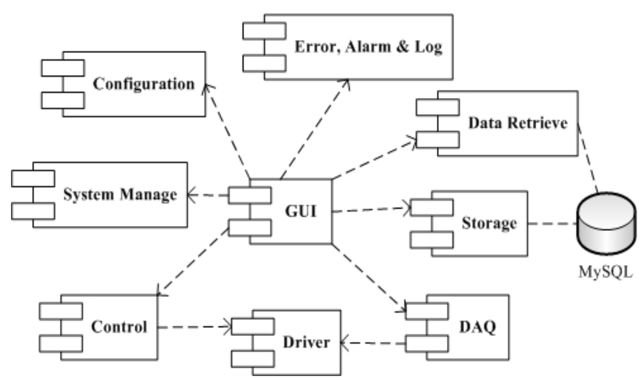

Figure 2: Architecture of the LCL software framework.

The framework provided all the basic functions for the subsystems on LCS such as configuration, data acquisition, error and alert handling, logging, data storage and retrieve, system management and GUI. Each function is represented by a package of SubVIs, which makes the framework highly flexible and scalable. It needs only little modifications on the configuration and driver package when apply the framework to a new specified subsystem.

Global Control Layer

The GCL includes a GCS, a database server and a web server. The overall supervisory and control of the BESIII detector will be performed from the GCS. In normal situation, the GCS will only display the summary information from the LCS and some key parameters such as run number, luminosity, current and lifetime. However, when abnormal status occurs, the corresponding alarm or error messages will be popped up. The network communication between GCS and LCS is implemented by Shared Variable which is a new feature of LabVIEW 8.20, for the reason that both of the programs on LCS and GCS are implemented from LabVIEW. On the other hand, the network communication between GCS and external systems such as BEPCII, DAQ and luminosity monitoring system are implemented based on the Distributed Information Management System (DIM) [11] because of its availability both in Linux and Windows. DIM is a communication system for distributed / mixed environments, it provides a network transparent inter-process communication layer.

The database server in GCL will store all the data of the DCS, which not only includes the original data but also the summery and configuration information. MySQL [12] has been selected as the database management system (DBMS) because of its fast performance, high reliability and free of cost. A dedicated web server is used to publish the DCS data to the Internet and PHP based program has been written for the generation of the dynamic web pages, so that the remote users can access the real time or history data in graph or text.

PERFORMANCE AND RELIABILITY

Because of the parallelism of the readout chain, we just need to study the performance of the heaviest loaded readout chain of each subsystem. From the real-size prototype tests, we got satisfactory results. For the TH and LV system, the maximum update cycle is 10s corresponding to a load of 600 temperature sensors. For the VME and GAS system, the maximum update cycle is 30s due to the heavy load on OPC server. The update cycle for the HV system can reach less than 1s because of the fast transmission speed on TCP/IP. The response time of SI PLC system is less than 1ms for electric connection.

The risks that weaken the system reliability are mainly from three aspects as follows, and corresponding efforts have been made to minimize these risks: 1) Ageing and brokenness of the sensors and circuit boards in the harsh environment due to radiation and magnetic field: the sensors and DAQ boards which will be assembled in the radiation district have passed a strict radiation test; To assure the long lifetime of the purpose-built boards, all of them have passed a 24-hour thermal ageing test with a temperature of 60 centigrade. 2) Database crash or brokenness of hard disks: to recover the database in the shortest possible time, all the database files will be backed up automatically at regular intervals and RAID 5 has been adopted to enhance the reliability of the hard disks. 3) Virus and hackers' attack: in the network architecture of the DCS as shown in figure 1, only the web server will be connected to the Internet. The operating system of the web server and database server is Linux, which means less possibility of virus infection. In addition, firewall will be installed on every machine and the IP filtering mechanism will be employed also.

By far, a full function LCS for the Main Drift Chamber (MDC) cosmic rays test has been established and kept running stably for more than four months. The result from the test shows that the LCS is highly stable, flexible and scalable and the GUI is very friendly to the operators.

CONCLUSION

The special requirements and limits of the BESIII experiment brought several challenges to the design and implementation of the DCS. To provide a uniform and coherent interface to the operators, the DCS is hierarchically organized and divided into three layers for different functions. Large variety of equipments ranges from sensors up to embedded systems and Programmable Logical Controllers (PLC) have been utilized in the FEL. A LCL software framework has been developed based on LabVIEW to simplify the implementation of new subsystems. The GCS will provide a uniform and simple user interface to the operators for the overall supervisory and control of the BESIII experiment. The performance of the readout chain and the reliability of the DCS have been tested and the results satisfy the requirements of BESIII experiment.

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