Design of Strong-motion Monitoring System for Dam-reservoir

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Abstract: One strong-motion monitoring system for dam-reservoir strong motion observation was introduced in this paper. This system includes three parts, strong-motion monitoring devices, power supply instrument, communication devices and strong-motion monitoring software. It can measure dispersed earthquake signals and collected data to one point. Beijing Miyun dam-reservoir strong-motion monitoring system based on this technology was illustrated in this paper.

Keywords: dam-reservoir; strong-motion monitoring system; multichannel strong-motion recorder;

1 Introduction

China is abundant in water resources. In order to fully exploit these resources for hydroelectric, more and more dam-reservoirs and hydroelectric power stations were built in recent years. Almost all these dam-reservoirs act as hydroelectricity, preventing or controlling floodwater, irrigation and so on. Then the safety state of hydro power facility and nearby people life and their property rely on the safety of the dam-reservoirs. But most of the dam-reservoirs lie in the earthquake active belt [1]. And there are many earthquakes happened in China every year. So it is essential to built strong-motion monitoring system for dam-reservoirs. Through the monitoring data distributed on the dam-reservoir, we can capture and reproduce the earthquake information. For these information basis data for dam-reservoir security evaluation and aseismatic design check after earthquake. And they are the best valuable materials for building new dam-reservoirs and reinforcing old dam-reservoirs. The dam-reservoir strong-motion monitoring system should continuously monitor the dam-reservoir for we can't precisely forecast the arrival time of earthquake [2,3]. But most of the dam-reservoirs were built faraway from the resident area, so the earthquake monitoring system should be reliable, self-serviced and automatic switched to battery when out of AC electric power [2].

2 Traditional design of dam-reservoir strong-motion monitoring system

Before 1990, the old dam-reservoir strong-motion monitoring system is not central structure. One monitoring point has one suit of monitoring device, including one triaxial accelerometer and one three-channel strong-motion recorder. Many suits of devices constitute one dam-reservoir strong-motion monitoring system. In the strong-motion monitoring system, each recorder uses one modem to communicate with the monitoring center. The technology development in electronic design, computer manufacture and communication limits the innovation of multi-channel strong-motion recorder. The upper limit of channel number in one recorder is nine channels.

In the distributed strong-motion monitoring system of dam-reservoir, one suit of strong-motion device was installed on every measurement point. The device includes one three-channel strong-motion recorder and one triaxial accelerometer. Every strong-motion recorder was equipped with one modem and one GPS. Through modem, each recorder can communicate with central observation devices. Before 1990, the strong-motion recorder in the dam-reservoir strong-motion monitoring system only has 12bits analog-to-digital convertor. In order to improve the effective resolution of the recorder, after 1990, most type of strong-motion recorders were designed with 16bits analog-to-digital convertor and they can achieve 90dB dynamic range. At the same time, the memory volume of the recorders expanded from 64K bytes to 256M bytes. The new type of strong-motion recorder can automatically form, save and submit earthquake records. In one monitoring system, there are many suits of strong-motion devices and each has isolated communication cable. If we want to get all monitoring data from the system, there should be no any fault in each recorder and each communication cable. So compared with centralized strong-motion monitoring system, this kind of strong-motion monitoring system is not reliable.

3 Centralized strong-motion monitoring system for dam-reservoir

With the development of electronic technology and communication technology, the bottleneck of multichannel strong-motion recorder doesn't exist now. So considering the specifications of the dam-reservoir strong-motion observation, we designed a centralized strong-motion monitoring system for dam-reservoir based on the sixty-four channels strong-motion recorder. This strong-motion monitoring system includes two parts, hardware and software. The hardware comprises strong-motion device, vibration alarm device, computer and communication cables and other auxiliary devices. You can see the structure of the monitoring hardware in figure 1. The strong-motion device includes force balance accelerometers, multichannel strong-motion recorder and on-line UPS. The monitoring software is designed based on Windows operation system and wrote by language visual C++. It can supervise the strong-motion recorder and data collection.

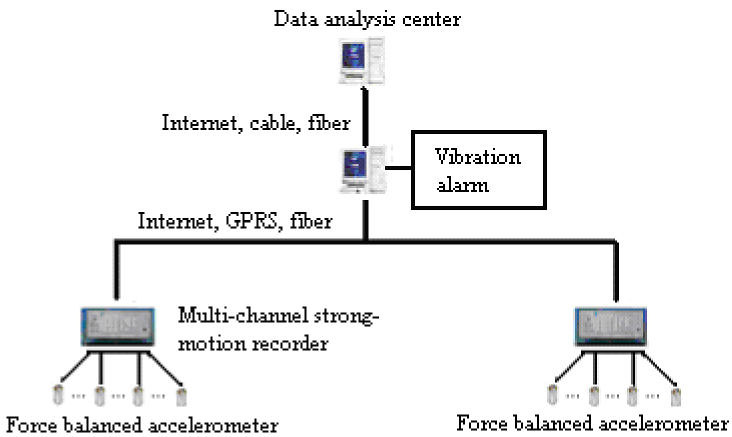

Fig. 1 Structure of dam-reservoir strong-motion system

In the strong-motion monitoring system, force balanced accelerometers distributed at every monitoring point are responsible for detecting vibration signal. Through one multi-core cable, the output signal of the accelerometer was output to the input port of the multichannel strong-motion recorder. At the same time, the multichannel strong-motion recorder provided DC electric power to accelerometers through the same cable. In the whole monitoring system, only one GPS module was embedded in the multichannel strong-motion recorder. The GPS module can provide precise UTC time for all channel's vibration signal. One on-line UPS work as a spare power supply for the multichannel strong-motion recorder. If the AC power supply is out of service, the UPS automatically startup and continuously provides electric power for the recorder about ten hours. The multichannel strong-motion recorder communicates with dam-reservoir monitoring center by communication cable. If one earthquake happened and an alarm message reached the vibration annunciator, many kinds of alarm messages were send out immediately, such as mobile telephone messages, phone call, voice, sound, light et al.

Compared with traditional decentralized strong-motion monitoring system, in order ro measure accelerometer's signal distributed on different location, the centralized strong-motion monitoring system has to use a large amount of multi-core cable. So cable cost will increase. But only one multichannel recorder was need in this kind of system, the cost of recorder will decrease. So the system cost would not increase. For there is only one communication cable in the centralized system, in contrast with decentralized strong-motion monitoring system, the daily communication expanse of the centralized system is very low. And the centralized system is reliable and easy to be managed.

3.1 Design of multichannel strong-motion recorder

Many kinds of technology were used in the design of multichannel strong-motion recorder, such as mature computer technology, advanced electronic design technology and signal anatiliasing pre-filter technology, over-sample and digital signal processing technology, time data alignment technology. So the multichannel strong-motion recorder can meet all demand of strong-motion observation. In the multichannel strong-motion recorder, one standard industrial computer mainbaord was used as a core electric circuit board. Through the self-defined BAB bus, the computer mainbaord coordinated the communications between three main electric circuit boards of the recorder. These three main circuit boards are industrial mainbaord, DSP data sampling circuit board and analog-to-digital converting electric circuit board. At the same time, through different address to recognize different analog-to-digital converting electric circuit boards, The recorder can expand the sampling channel number. Figure 2 displays the principal structure of the multichannel strong-motion recorder.

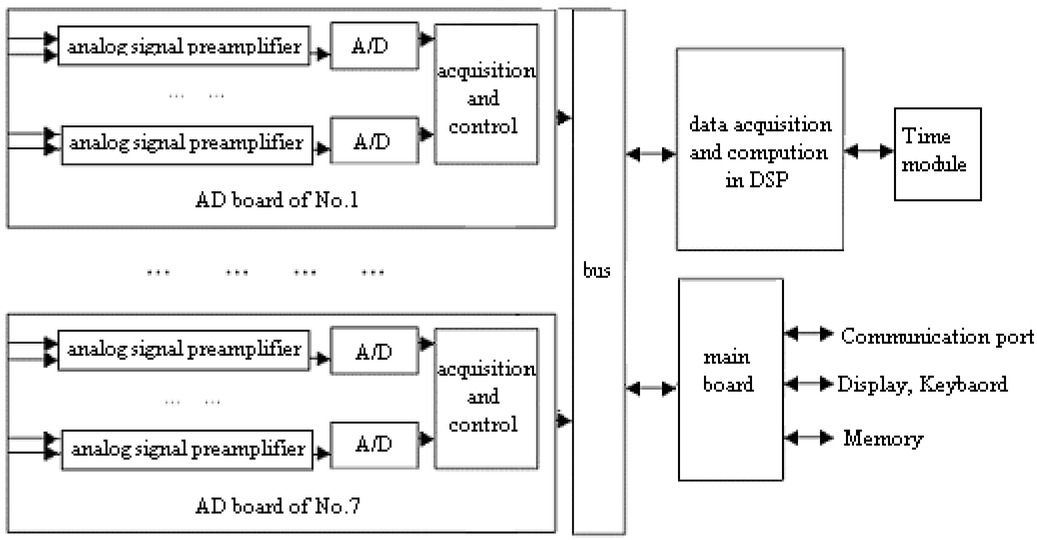

Fig. 2 Schematic diagram of multichannel strong-motion recorder

In order to get high resolution sampling data, one high precision 16bits A/D converter was used as a analog-to-digital converter in the multichannel recorder. One hard disk with IDE interface and high capacity was used to deposit data. So the multichannel strong-motion recorder has enough memory to save earthquake data. The multichannel strong-motion recorder provides many kind of communication interfaces, so it supports several kind of communication modes, including three RS232 ports, one external modem, RS232-to-optical fiber interface and TCP/IP network interface.

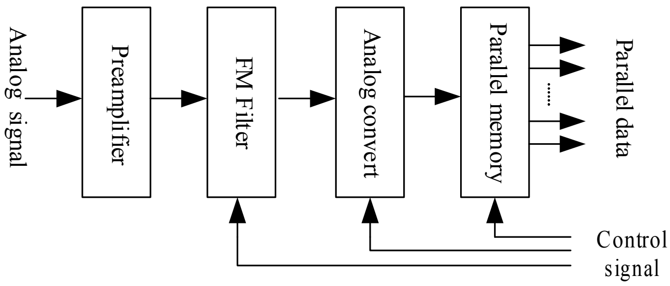

Fig.3 Logic structure of analog signal channel

The multichannel strong-motion recorder includes four important parts. The data sample circuit board, DSP sample mainbaord, computer mainbaord and power supply. Among them, computer mainbaord and power supply are standard industrial components. While the analog-to-digital converting board and DSP sample mainbaord are high precision data sampling circuit board designed for strong-motion measurement. In the analog-to-digital converting board, every channel has one isolated converter. So all channel s sample data are synchronous and there is no time delay between different channel s. The analog-to-digital converter has 16bits resolution so the recorder can achieve 96dB dynamic range. Figure 3 is the logic structure of the measurement channel of the analog-to-digital converting circuit. The logic control signal displayed in figure 3 was controlled by the DSP data sampling circuit. The parallel data from the analog-to-digital converter was read by the DSP data sampling circuit. Through different addresses of each data sample circuit board and different channel's number, DSP can read all channel data one by one.

The DSP sample mainbaord includes four components, CPU control circuit, time service circuit, data saving module and logic control circuit. All components cooperated with each other and were controlled by the CPU TMS320VC33. They completed the logic control and dispatching work, including startup and stop of analog-to-digital conversion, reading and transmission of all channel 's data, data filtering and calculation, reading of two kinds of time and time calibration, communication between DSP sample mainbaord and computer mainbaord, data transmission. Figure 4 gives the flow chart of data sampling.

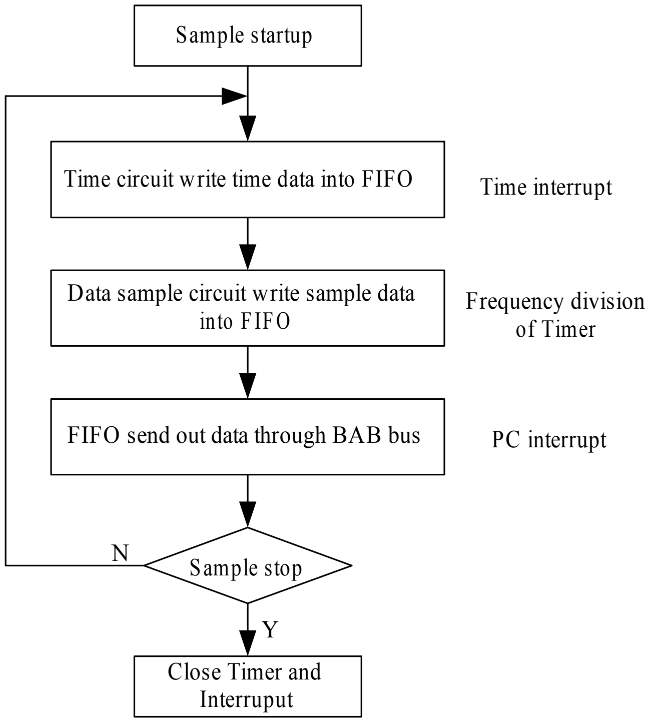

Fig.4 Flow chart of the data sampling of the DSP sample mainbaord

3.2 Force balanced accelerometer

Force balanced accelerometer is one kind of strong-motion signal detecting sensor which technology is very mature. The accelerometer used in the strong-motion monitoring system has many merits, such as low noise, high sensitivity, stable quality and durability. It has two output sensitivities, low sensitivity for low frequency strong-motion measurement and high sensitivity for low frequency earth pulse measurement. For example, its' measurement scale of 90V/g high sensitivity can be used to measure normal pulse of the dam-reservoir. So it can provide basic data for the structural health monitoring of the dam-reservoir.

3.3 vibration alarm

Vibration alarm is one kind of earthquake alarm device designed for strong-motion monitoring. It was embedded with several kind of alarm interfaces, such as sound, light, electric, voice, on-watch telephone, GPRS message, switch value, et al. One kind alarm type or more than one type can be used at the same time in one strong-motion monitoring system. After earthquake, the monitoring center will immediately receive the alarm messages from the vibration alarm and startup the alarm actions. Switch value from the vibration alarm can be used to control important line engineering. It can automatically shut off relevant lines if there is a strong earthquake happen and protected people's life. So the strong-motion monitoring system can run automatically.

3.4 Software design of the strong-motion monitoring system

In the dam-reservoir strong-motion monitoring system, the software of the monitoring center is responsible for management of strong-motion recorders, receiving and disposing messages from each strong-motion recorder. In this software, all strong-motion recorders located at different place of one project were listed in one project tree. There are four main key functions in the software, they are network management, devices management, communication management, and alarm management. You can see it in following figure 6.

Network management supervised the project, including create new project, open a project, close a project and modify project. Such as add device in a project, delete device from a project.

Device management managed devices in the project, including open recorder, parameters settings and control recorder. Open recorder contains two operations, open recorder and close recorder. Parameter settings includes sampling parameter setting, trigger mode setting, trigger parameter setting, recorder status setting and so on. Control recorder includes upload record file directory, read record file, delete record file, read or set real time of recorder, read GPS time of recorder, startup and stop sample of recorder and so on.

Alarm management takes charge of all kind of alarm messages, including earthquake trigger, time trigger, GPS location errors, low voltage alarm of power, recorder reset, full memory, self-check error and so on.

Communication management supervise communication interface of hardware and software, including communication mode, communication interface type, communication parameters.

In order to get a high compatibility and extended software, the network monitoring software supports extended standard communication protocol for managing all kind of strong-motion recorder in one monitoring system. The strong-motion recorder which embedded with the special protocol can be embedded into one project of network system. So in one network system, three-channel strong-motion recorder, six-channel strong-motion recorder, nine-channel strong-motion recorder and other kind of multichannnel strong-motion recorder can work well together. And analog-to-digital converter of these different kinds of strong-motion recorder can be 16-bits resolution or 24-bits resolution.

4 Strong-motion monitoring system for Miyun dam-reservoir

The strong-motion monitoring system be introduced in this paper were widely used in China. One example is strong-motion monitoring system for Miyun dam-reservoir in Beijing. There are two sub-systems in Miyun dam-reservoir strong-motion monitoring system. One is Baihe dam-reservoir sub-system, another is Chaohe dam-reservoir sub-system. Each sub-system includes one optical fiber communication terminal. Through the optical fiber communication terminal and optical fiber cable, the strong-motion recorder can communicate with automatic controlling center of Miyun dam-reservoir. So the Baihe dam-reservoir strong-motion monitoring sub-system, the Chaohe dam-reservoir strong-motion monitoring sub-system and the automatic controlling center of Miyun dam-reservoir form one large dam-reservoir strong-motion monitoring system.

In each sub-system, there are four triaxial and two biaxial force balanced accelerometers, one eighteen-channel strong-motion recorder. These accelerometers were used to measure earthquake of bottom dam(one triaxial sensor), top dam(two triaxial sensors), middle dam(two bixial sensors) and free-field of dam(one triaxial sensor). And the eighteen-channel strong-motion recorder collected signal from all these sensors and communicated with the automatic controlling center of the Miyun dam-reservoir. Figure 5 displays the force balanced accelerometer position in Baihe dam-reservoir sub-system. In this figure, the green-square represents the strong-motion recorder, the red line is the multi-core cables of the system, the black-square nearby the red line represents the forced balanced accelerometers. Figure 6 is the strong-motion monitoring software.

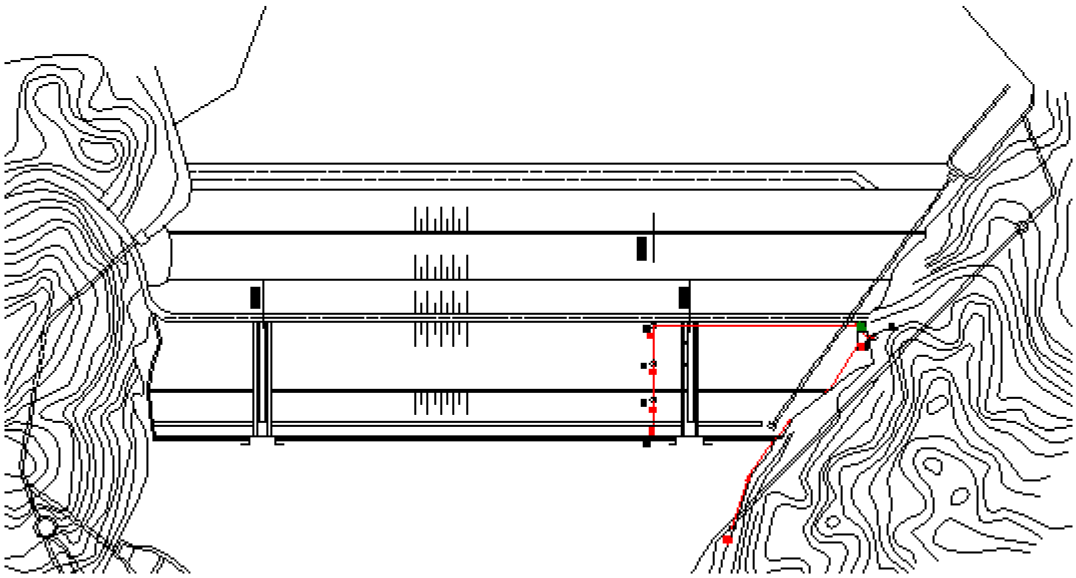

Fig 5. Schematic of Strong-motion monitoring system of
Beijing Miyun Baihe Auxiliary -dam

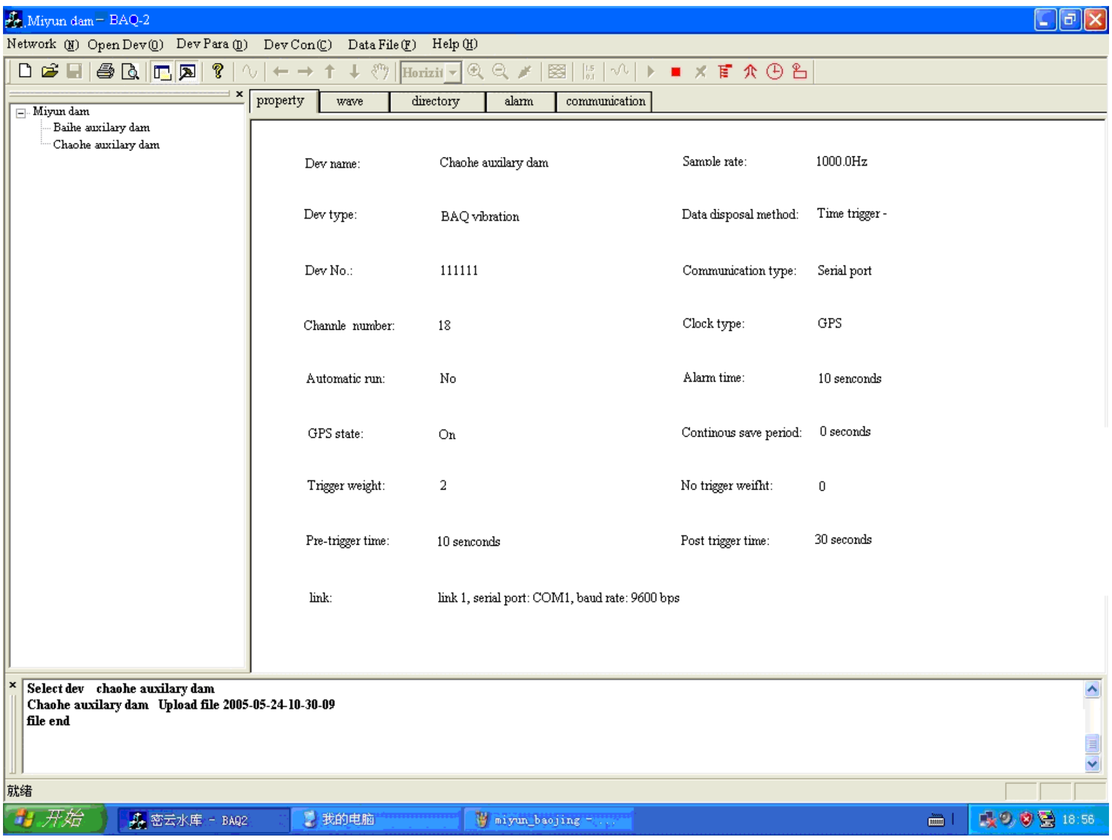

Fig 6. Window display of Strong-motion software

5 Conclusions

In order to complete strong-motion monitoring of dam-reservoir in large water and electricity engineering, one strong-motion monitoring system was designed in this paper which based on distributed measurement and centralized monitoring technology. In this strong-motion monitoring system, high-precision multichannel strong-motion recorder and forced balanced accelerometer were used to collect earthquake signal. This kinds of system has serveral merits such as high precision, high reliability, low running fee and easy maintains. So it will be widely used in future.

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