AE Intelligent Sensor Networks System

Used in Tele-Monitoring of Civil Engineering

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Abstract

This paper introduces a novel AE intelligent sensor networks system. The system is composed of three parts: the wide band AE sensors, the real-time signal acquisition and processing nodes and an intelligent information terminal. This system acquires AE events from the reinforced concrete structure through its wide band AE sensors, and then extracts the AE characteristic parameters of the defects in the structure through DSP of the nodes. These parameters, including the number of hits, energies, relative AE hit rates and arriving times at the individual sensors on the different locations, etc., are transferred from the individual nodes to the intelligent information terminal. The main functions of the terminal are to organize and manage the distributed nodes, and to transfer the effective information to the users through wired/wireless manner. Since the system uses GPRS and Internet, it not only can real-time tele-monitoring the health status of the constructions, but also can reduce the complicacy and cost of the system. The practice of the networks on the Yiwu Shangbo Bridge shows that the system possesses the function of real-time, long-distance, non-destructive monitoring the health status of the reinforced concrete structures, such as the bridge, dam, tunnel, and so on. Furthermore, this system has the property of adjusting and controlling its own status. Therefore, it is suitable for real-time monitoring the health of the various new and in service civil engineering structures.

Keywords: Acoustic Emission, Structure Health Tele-Monitoring, Civil Engineering

In the recent years, the large-scale construction structures diversify day by day. Besides the static state load, they also withstand the repeated load frequently, and these structures possibly will have the fatigue damage. Especially, the significant civil engineering structures, such as the dam, the bridge, the power plant, the military installation, the high-rise construction and so on, have the potential risk when suffering from the natural or artificial disasters of earthquake, flood, detonation, and so on[1]. Moreover, since many civil engineering structures locate in the open country, in order to prepare for maintenance activities on these structures, it is necessary to carry on the long-distance real-time nondestructive monitoring to them in service. At present, the commonly used methods for the construction structure health monitoring are the electrical examination, flash ranging and optical fiber monitoring. However, these methods need to arrange the sensors in the structures with the defects of the complicated installment and the high cost.

Acoustic Emission (AE) is the rapid releasing of local strain energy by the form of the elastic wave when the material has a crack propagating, or its faces rub together under the outside or internal force[2][3]. The signal detected by the AE system comes from the structure itself, so it has the features of real-time, dynamic, convenient, wide coverage and so on[4][5]. Therefore, this paper designed and realized an AE intelligent sensor networks system for the civil engineering Tele-monitoring.

1．Design Philosophy of the system

The system includes three parts: the wide band AE sensors, the real-time signal acquisition and processing nodes and the intelligent information terminal. AE sensor acquires the AE signals from the structure, and sends to the real-time signal acquisition and processing node. The node extracts the AE parameters and then tele-transmits these parameters to the user's computer by the intelligent information terminal. At the same time, the user can also set the acquisition parameters to the individual real-time signal acquisition and processing node through the intelligent information terminal.

CAN bus is used to communicate information between the intelligent information terminal and the individual nodes to enhance the feasibility of the system. The effective information is transmitted to the users by the intelligent information terminal through the wired network or the wireless network of GPRS with Internet. The overall design framework of the system is shown in Figure 1.

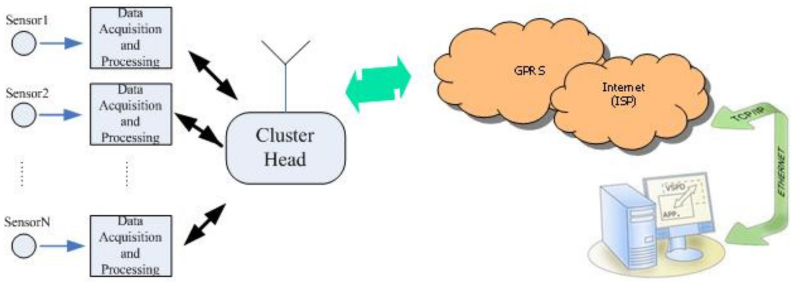

Figure 1. Structure health tele-monitoring system

The system has good extendibility. It can be easily expand to a multistage tree-like monitoring management system. Furthermore, due to the use of the mature Internet technology, it can reduce the investment cost for expanding the system.

2．System realization

2.1 Signal acquisition and processing node

The signal acquisition and processing node mainly completes following three tasks: First, acquires the AE signals from the wide band AE sensors and records the arrival time of each AE signal. Second, extracts the characteristic parameters of the AE signals, and then transmits these parameters as a data package to the intelligent information terminal. And last, receives the instructions from the intelligent information terminal, and completes the corresponding operation. The hardware module frame of the node is shown in Figure 2.

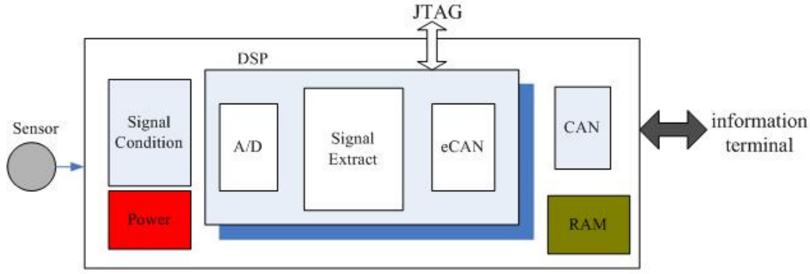

Figure 2. Hardware module frame of the signal acquisition and processing node

AE sensor used in this system is the AE-03 wide band AE sensor which is produced by Shanghai Covorda Electronic System Company, with its response frequency from 100kHz to 2MHz. AE sensor gathers the AE signals and transmits them to the real-time signal acquisition and processing node through the cable. Thereafter, these signals are amplified and converted into digital data. The threshold of the A/D conversion is set by the user through the intelligent information terminal. When the AE signal crosses the threshold value, an AE event is detected and digitized, its converted digital data will be saved in the RAM of the real-time signal acquisition and processing node and then the consequent 2047 data will be acquired and saved in the same frame (total 2048 data). When a frame data is acquired, DSP starts to process the group of signals by its formidable data-handling capacity. After being filtered by the soft digital filtering, the characteristic parameters of the acquired AE signals are extracted real-time, such as the number of AE events, the hits number, energy, amplitude, rising time and so on. These parameters will be packed as a data package attached with the information of arriving time of the AE event. The flow chart of extracting the AE characteristic parameters is shown in Figure 3. A/D conversation of the system uses the manner of interrupt triggering to ensure the AE data will not lost. Once a new AE event is detected, the present signal processing will be interrupted, and the new AE signal will be acquired and saved immediately. After the new AE event frame data are saved, the DSP will return to process previous interrupted procedure of the data processing.

The eCAN module of DSP used in the system is an enhanced controller area network with 32-bit CPU. It is compatible with CAN2.0B standard, and it uses established protocol to communicate serially with other controllers in electrically noisy environments [6]. The eCAN module has 32 fully configurable mailboxes and each can be configured as receiving or transmitting mailbox. When the packed AE characteristic parameters are searched in the buffer, the eCAN module will start to send instruction and thus transmits data to the intelligent information terminal. In addition, this module also intercepts whether there is a configuration instruction from the intelligent information terminal. Once it receives a configuration instruction, it will do the corresponding operation immediately.

2.2 Intelligent information terminal

The intelligent information terminal, on the one hand, as a master machine in the monitoring region, organizes and manages distributed real-time signal acquisition and processing nodes, receives the AE characteristic parameter packages from each node, and then transmits them to the user’s computer through the combination network of GPRS-Internet. On the other hand, as a slave machine, it receives the configuration instructions from the user and executes these instructions. At the same time, the synchronization clock for the real-time signal acquisition and processing nodes is also managed and controlled by the intelligent information terminal.

The data transmission speed between the terminal and the individual nodes is 125 Kbps.

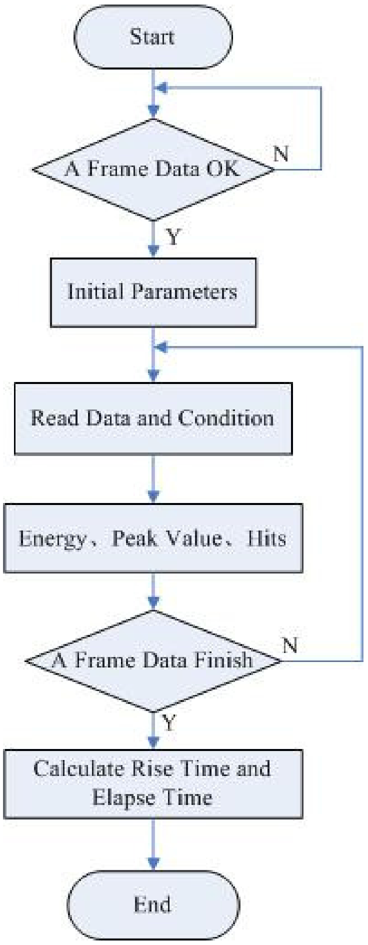

Figure 3. Extraction of characteristic parameters

30 mailboxes among the 32 mailboxes of the eCAN module are set to receive the AE characteristic parameter packages. The rest 2 mailboxes are set to transmit the configure information to the nodes. When the data are received, they can be accepted only if the identifiers in the received package match with the ones in the receiving mailbox. Otherwise, the data will be discarded. After the terminal receives the data from the slave signal acquisition and processing node, it will saves and combines the data as a fixed form. When its transmission buffer is not empty, it will start the tele-transmission procedure.

Data tele-transmission of this system is based on the mature Internet technology combining with the wireless GPRS network. GPRS provides the wireless IP connection in the wide area and has the features of the wide coverage and the high data transmission speed. It can transmit the real-time data acquired and extracted from the monitored scene to the information analysis center assigned by the user. [7] The GPRS Modem of this system is H7118 module. Intelligent information terminal of the system connects the GPRS network through its SCI interface and GPRS modem. The data will be transmitted by the intelligent information terminal, and then be packed as an IP package by the H7118 module. Data package format in the system to be sent through GPRS is shown in Table 1. Thereafter, it will be transferred to Internet from the wireless network by the mobile service provider. The connection between the GPRS modem and the data center (server) is built by UDP or TCP.

Finally it will be sent to the user's monitoring center through gateway and router.

The wireless data transmitting network connection status is controlled and maintained by the intelligent information terminal. The terminal transmits the maintenance data packages to H7118 in a rule interval, and waiting for the response data, judging the network is active or inactive.

Table 1 Data package format

Format segment	Frame head	Channel	Time	Arriving time	AE signals	Check sum
Bytes	5	1	1	5	16	2
Content	"AESHM"		Hour		AE parameters	Sum

3．Application in the test of the segment of Yiwu Shangbo Bridge

This system has been used in monitoring the reinforced concrete segment structure health of the Yiwu Shangbo Bridge. Yiwu Shangbo Bridge is a reinforced concrete cable stayed bridge with single tower. The tested segment is the model of a main component of the bridge. The picture of the AE networks system used in the scene is shown in Figure 4. In this experiment, there are ten Model AE-03 wide band AE sensors and ten real-time signal acquisition and processing nodes distributed on the surface of the segment. There is also one intelligent information terminal to organize and manage these ten nodes. This terminal is also in charge of the data tele-transmission. Part of the AE parameters information received by the user's computer is shown in Table 2. After the monitoring test in the scene and comparison with the minute gaps and cracks of the segment, it is shown that this system can monitor the AE events produced by the cracks propagating of the segment, and can real-time online extract the AE characteristic parameters, and then can transmit it to the monitoring center of the user's office through the tele-transmission..

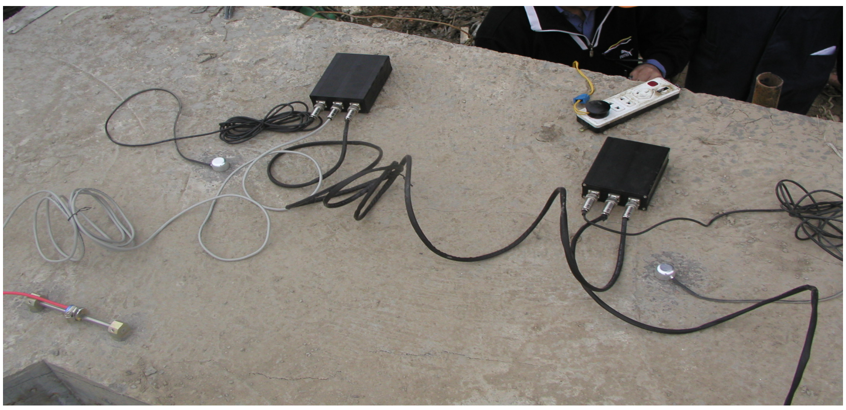

Figure 4. System used in the acquisition

Table 2　　Part parameters of the AE events

Receiving time	Channel	Ringing number	Amplitude	Energy	Rising time (us)	Duration time (us)
20071029_172310	0	58	3159	51278	19.2	81.0
20071029_172617	0	29	2363	20063	47.6	46.8
20071029_172618	4	31	2506	15009	2.8	46.1
20071029_172350	7	79	2672	98378	28.8	155.1
20071029_172618	7	29	2427	47440	2.8	46.1
20071029_172310	8	42	2768	41060	25.2	58.3
20071029_172310	9	46	2875	37493	25.2	72.5

4．Conclusion

AE technology, as one kind of the dynamic nondestructive testing technology, can detect the energy generated by the structure itself. The AE intelligent sensor networks system in this paper uses the AE nondestructive monitoring technology to realize the tele-monitoring for the civil engineering structures in service. This AE intelligent sensor networks system can be applied in the monitoring of the structure health situation, such as the bridge, the dam, the tunnel, and so on. It can also solve the difficult problems when the scenes in the far open country where people can not stay to monitor for long time. Furthermore, the users can monitor the operation status of the communication among the individual nodes and the whole sensor networks system through the intelligent information terminal. Due to the application of the mature GPRS-Internet network technology, the cost of constructing the system also can be reduced. Hence, it provides a good solution for the real-time online structure health monitoring for various new-built or in service civil engineering.

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