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High-Speed Railway Earthquake Early Warning Testing System Based on LabVIEW

Haiying YU[a,1], Yingchun MA[a] and Tianyang YU[b]
[a]*Institute of Engineering Mechanics, China Earthquake Administration, Key Laboratory of Earthquake Engineering and Engineering Vibration of China Earthquake Administration, Harbin, China*
[b]*Guangdong Earthquake Agency, Guangdong Earthquake Disaster Risk Control and Prevention Center, Guangzhou, China*

Abstract. This paper mainly introduces a set of high-speed railway earthquake early warning test system based on LabVIEW, which serves for the indoor prototype test of high-speed railway earthquake early-warning system, which is used to simulate wave generation instead of seismic sensors. From the perspective of indoor prototype simulation, a high-speed railway earthquake early warning (EEW) test system based on virtual instrument (VI) technology is developed. Through the test system, seismic wave and non-seismic interference wave are simulated, generated and sent, so as to carry out test technology research on the current high-speed railway EEW system in China. Based on the virtual instrument development platform LabVIEW, the high-speed railway earthquake warning test system is developed. The function of the test system is verified by an example, and the consistency between the original waveform and the acquisition waveform is analyzed. The results show that the amplitude accuracy of the test system is 0.005 ± 0.002 gal and the acceleration peak time is no difference, that is, the high-speed railway EEW test system based on VI technology is accurate and reliable.

Keywords. High-speed railway, earthquake early warning, LabVIEW, testing system

1. Introduction

In recent years, my country's high-speed railway construction has achieved rapid development. The operating mileage of high-speed railways has reached 30,000 kilometers and is still being expanded. But a realistic problem that must be faced is that my country is a country with frequent earthquakes. There are as many as 23 seismic fault zones in mainland China. The construction of high-speed railways inevitably spans some earthquake-prone areas [1]. Although the earthquake event is a small-probability natural disaster event, its degree of harm to the safety of high-speed railway traffic cannot be underestimated. Especially when the speed of trains operating on orbit reaches or exceeds two hundred kilometers per hour, the impact of sudden earthquakes on the rails will cause

[1] Corresponding Author, Haiying YU, Institute of Engineering Mechanics, China Earthquake Administration, Key Laboratory of Earthquake Engineering and Engineering Vibration of China Earthquake Administration, Harbin 150080, China; E-mail: haiyingyu@126.com.

major safety accidents that seriously threaten the lives of passengers [2]. Therefore, how to ensure effective reduction of the damage and losses caused to my country's high-speed rail in the event of a destructive earthquake has become an important research direction in the field of my country's high-speed rail safety. my country's high-speed railway lines cover a wide range, and there are inevitably the existence of crossing or close to the seismic fault zone, and the trains in orbit are fast and dense. Therefore, the earthquake early warning and emergency response capabilities of the high-speed railway earthquake early warning system are real-time and effective. And accuracy and other aspects must meet relevant requirements [3]. Only by repeatedly testing the current high-speed railway earthquake early warning system and discovering its existing problems and continuously improving and perfecting can it meet the performance requirements of real-time, effectiveness and accuracy [4]. At present, there are roughly two ideas for testing the earthquake early warning system of high-speed railways: one is to conduct field testing in the comprehensive experimental section of the high-speed railway line; the other is to use computer software for simulation testing. Based on LabVIEW, a virtual instrument development platform, this paper develops a high-speed railway earthquake early warning test system with waveform signal generation and acquisition software and signal generator as the core software and hardware. The function verification of the test system is carried out through examples and the consistency analysis of the original waveform and the acquired waveform is carried out. Further, through the test system, the S-wave threshold alarm and P-wave early warning of the high-speed railway earthquake early warning system are verified and tested, and the test results are analyzed. Compared with the on-site test program, the software simulation test program based on virtual instrument technology adopted in this article has the advantages of low cost, good scalability and flexibility, and has a higher engineering reference value.

2. System Structure and Principle

In the development process of the high-speed railway earthquake early warning test system, this article implements the idea of "software as instrument", based on the virtual instrument development platform LabVIEW to realize the waveform signal generation and acquisition software as the core software of the test system, and the signal generator based on the PXI hardware platform. The core hardware of the test system is combined with distributors, data collectors, industrial computers and servers to build a complete test system for functional verification and testing of my country's current high-speed railway earthquake early warning system. The traditional scheme of relying on natural seismic waves for on-site testing of high-speed railway earthquake early warning systems is difficult to meet the requirements of high efficiency, low cost, and strong scalability, while the PXI hardware platform-based test system using virtual instrument technology has high test efficiency, high reliability and flexible operation [5]. Therefore, the test system based on the PXI hardware platform is an effective solution to realize the test of the high-speed railway earthquake early warning system.

2.1. System Structure

This paper uses a signal generator based on virtual instrument technology to replace sensors to simulate natural seismic waves or non-seismic interference waves to test the high-speed railway earthquake early warning system [6]. The overall architecture of the high-speed railway earthquake early warning test system based on virtual instrument technology is shown in Figure 1.

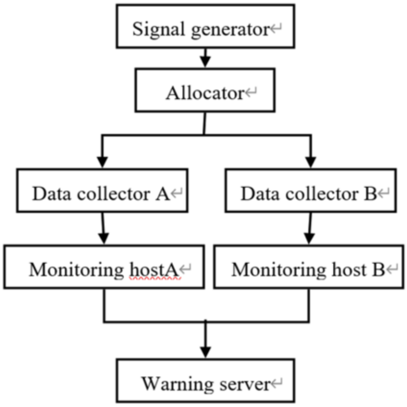


Figure 1. The overall architecture of the high-speed railway earthquake early warning test system.

2.2. Working Principle

Warning software in the monitoring host in real time. The high-speed railway earthquake early warning software processes the waveform data received in real time and picks up whether there are earthquake events, so as to efficiently and conveniently verify whether the seismic monitoring functions and performance of the high-speed railway earthquake early warning system such as S-wave threshold alarm and P-wave early warning meet the requirements of "High-speed Railway Seismic The relevant requirements of Q/CR 634-2018 "Test Method of Early Warning and Monitoring System" [7, 8]. The current high-speed railway earthquake early warning system in my country has both the functions of earthquake monitoring and distort triggering, and the distort trigger function involves on-site. Therefore, the test system based on virtual instrument technology in this paper only tests the seismic monitoring function of the high-speed railway earthquake early warning system. That is, through the LabVIEW-based waveform signal generation and acquisition software to simulate, generate natural seismic waves or non-seismic interference waves to replace the role of seismic sensors in the field test, and then send the generated waveform signals to the high-speed railway earthquake early.

First, select the waveform data file with the acceleration peak value greater than the alarm threshold from the seismic data query system database and the non-seismic interference data, and assign the latitude and longitude coordinates of the station in the header information of the waveform data file to the monitoring software running on the industrial computer to act as Virtual station. Then, use the waveform signal generation and acquisition software developed based on LabVIEW to read and parse the waveform data of the waveform data file data segment, simulate and generate the corresponding waveform signal and send it to the data collector. Finally, through the test system of this article, the threshold alarm function of the high-speed railway earthquake early warning system is tested to verify whether it sends out alarm information and realizes the continuous multi-level alarm mechanism, and the P-wave early warning function of the high-speed railway earthquake early warning system is tested to verify whether it sends out early warning information. And the realization of continuous magnitude estimation and continuous multi-level P wave early warning mechanism.

From the seismic data query system database, select the waveform data file that meets the requirements of eliminating the false alarm of earthquake P-wave early warning, and assign the longitude and latitude coordinates of the station in the header information of the waveform data file to the monitoring software running on the industrial computer to make it act as a virtual station , Use the signal generation and acquisition software to read, analyze, and simulate the waveform data of the waveform data file, generate the corresponding waveform signal and send it to the data collector, test and verify the seismic P-wave early warning cancellation function of the high-speed railway earthquake early warning system Does it issue false alarm cancellation information including alarm number, sending time, alarm type, etc.

3. System Software Design

3.1. Software Requirements and Functions

The waveform signal generation and acquisition software is mainly used for the simulation, generation and transmission of the test wave of the high-speed railway earthquake early warning system. It can provide a convenient human-computer interaction interface, realize the analysis and processing of the waveform data, and improve the test efficiency. Function requirements:

- Can read, analyze, load and display the header information and waveform data of the data file conveniently and quickly;
- Generate and display the original waveform signal according to the waveform data in the data file;
- Support manual wave sending mode That is, the user-defined channel transmission is realized by manually configuring the output channel;
- The continuous transmission mode is supported, that is, the full channel continuous transmission is realized by reading the pre-prepared form file;
- The original waveform signal has been sent in real time Stoping and loading display.

3.2. Development Software Introduction

This paper develops waveform signal generation and acquisition software based on LabVIEW, a virtual instrument development platform. LabVIEW uses an object-oriented graphical programming language. The front panel is composed of various display controls, and the back panel is composed of block diagrams. The sequence of block diagram code execution is determined according to the flow direction of the block diagram data on the back panel, eliminating the need for complicated syntax definition. Therefore, it is widely used in the development of test and measurement systems [9, 10]. At the same time, the virtual instrument development platform LabVIEW has built-in formula nodes of high-level programming languages such as MATLAB and C, which can realize mixed programming with other high-level programming languages by calling the corresponding API interface, which is convenient for the calculation and processing of complex data [11]. This article will mainly introduce the design and development of simulated wave sending software for high-speed railway earthquake early warning system based on LabVIEW, so as to realize the automatic processing of test data and improve wave sending efficiency, real time stopping and loading display.

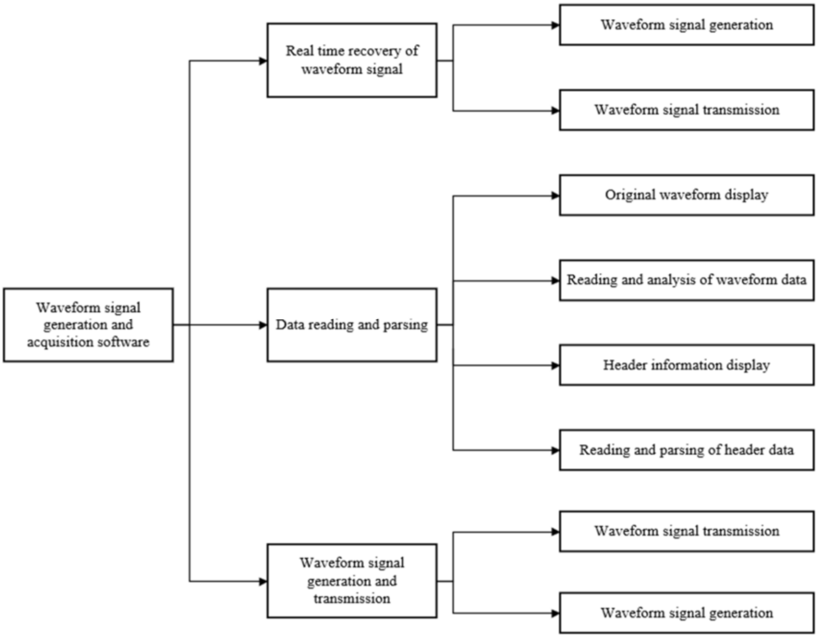


Figure 2. Software specific function module composition.

3.3. Software Composition

In order to reduce the difficulty of the development of the system and facilitate the subsequent expansion and maintenance of the system, the waveform signal generation and acquisition software in this paper adopts the modularization concept for design and development [12]. According to the analysis of software function requirements, this paper divides the waveform signal sending and acquisition software into three functional modules: data reading and analysis, waveform signal generation and sending, and waveform signal real-time recovery. Furthermore, based on the hierarchical idea, the three functional modules are decomposed into several sub-functional modules to facilitate the realization of software programming and future expansion and maintenance [13, 14]. The specific functional module composition of the waveform signal generation and acquisition software is shown in Figure 2 below.

In this paper, the LabVIEW-based waveform signal transmission and acquisition software should have the main functions of reading and analyzing waveform data files, and generating and sending waveform signals, and it can realize both independent configuration channel wave mode and continuous wave mode. The specific operation flow of the waveform signal generation and acquisition software in this article is shown in Figure 3.

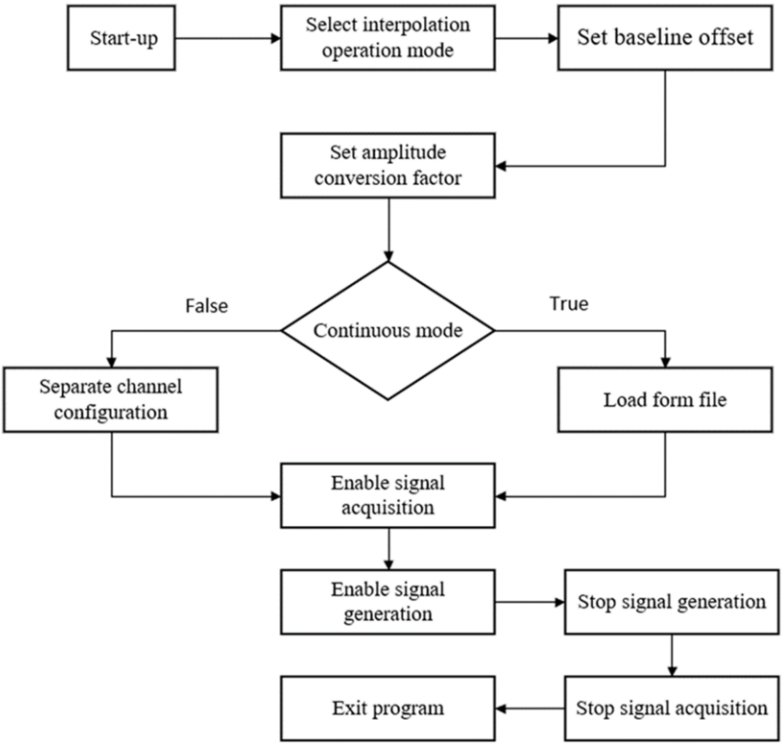


Figure 3. Operation flow chart.

3.4. Software Interface Design

The front panel of the main program (i.e. the main interface) of the waveform signal generation and acquisition software is shown in Figure 4. The front panel of the main program is composed of software control area and waveform data file information display area. Among them, the software control area is composed of text display control, button control, drop-down list box control and numerical input box control; the information display area of waveform data file is composed of tab control, including three sub tab controls, which are used to display the original waveform in-formation, header information and real-time recovery waveform.

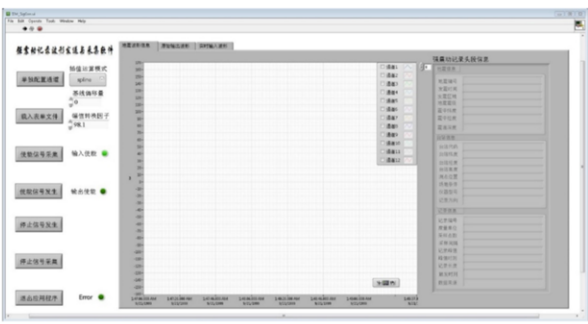


Figure 4. Front panel of main program.

4. Functional Verification and Test Results

Use the LabVIEW-based test system in this article to read and analyze the strong vibration acceleration records, and simulate to generate and send the corresponding strong vibration acceleration record waveform signals. By checking whether the high-speed railway earthquake early warning system on the monitoring host and the front-end early warning server has issued a threshold alarm and P Wave warning information to verify whether the software part (waveform signal generation and acquisition software based on LabVIEW) and hardware part (signal generator, distributor and data collector) of the test system can achieve the expected functions.

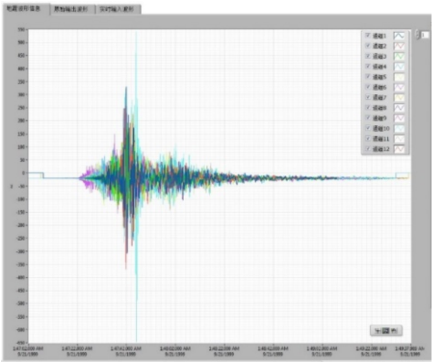


Figure 5. Seismic waveform.

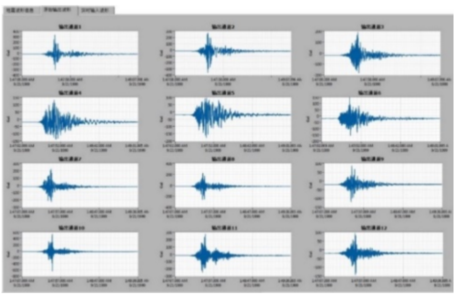


Figure 6. Raw output seismic waveform.

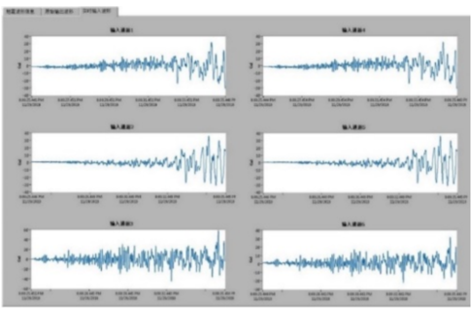
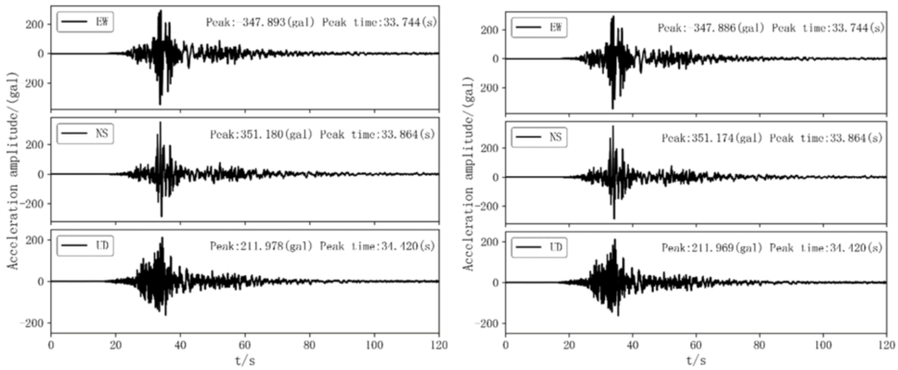


Figure 7. Real-time input seismic waveform.



(a) Original wave (b) Acquisition wave

Figure 8. Waveform comparison before and after test.

Figure 5 shows that the waveform signal generation and acquisition software based on LabVIEW in this article can normally load the original strong vibration acceleration record waveform; Figure 6 shows that the software can normally realize the waveform transmission and display of 12 output channels, and also explains the signal generator signal The output module works normally; Figure 7 shows that the software can load the recovery waveform, and also shows that the signal input module of the signal generator works normally. Finally, since the transmission and recovery of the waveform signal of the test system in this article need to pass through the distributor, the normal realization of the above functions also shows that the distributor in the hardware part of the test system in this article is working normally. Figure 8 shows that the test system in this article can ensure that there is no waveform distortion before and after the test.

In order to study the accuracy of the test system, this paper uses 10 sets of seis-mic waveforms as the input data of the test system to analyze the consistency of the original waveform before and after the test and the acquired waveform. It can be seen from Table 1 that the average error of the acceleration peak before and after the test is about 0.005 gal, and the standard deviation is about 0.002 gal. That is, the amplitude accuracy of the test system in this paper is 0.005±0.002 gal; in addition, from Table 2, the acceleration peak time before and after the test It is consistent and indistinguishable. Therefore, the accuracy of the test system in this paper fully meets the performance requirements of the high-speed railway earthquake early warning system test.

Table 1. Acceleration peak comparison before and after test

	Acceleration peak time								
Serial number	**EW**			**NS**			**UD**		
	Original value	**Collected value**	**Error**	**Original value**	**Collected value**	**Error**	**Original value**	**Collected value**	**Error**
1	-347.893	-347.886	0.007	351.180	351.174	0.006	211.978	211.969	0.008
2	-496.035	-496.026	0.009	313.324	313.317	0.007	-232.329	-232.323	0.006
3	-157.877	-157.872	0.005	152.132	152.129	0.003	168.880	168.871	0.009
4	-333.461	-333.458	0.003	390.529	390.521	0.008	162.123	162.116	0.007

5	793.905	793.897	0.008	846.084	846.077	0.007	716.795	716.790	0.005
6	-624.268	-624.264	0.004	-751.542	-751.540	0.002	340.808	340.805	0.003
7	-211.425	-211.418	0.007	184.150	184.145	0.005	-128.494	-128.491	0.003
8	-149.644	-149.639	0.005	160.511	160.508	0.003	-131.972	-131.966	0.006
9	86.248	86.246	0.002	87.281	87.277	0.004	-106.742	-106.739	0.003
10	139.594	139.588	0.006	186.437	186.432	0.005	132.524	132.522	0.002
index	Average error		0.006	Average error		0.005	Average error		0.005
	Standard deviation		0.002	Standard deviation		0.002	Standard deviation		0.002

Table 2. Table captions should be placed above the tables

Serial number	Acceleration peak time					
	EW		NS		UD	
	Original value	Collected value	Original value	Collected value	Original value	Collected value
1	33.744	33.744	33.864	33.864	34.420	34.420
2	28.355	28.355	30.270	30.270	30.750	30.750
3	40.175	40.175	41.495	41.495	35.170	35.170
4	36.970	36.970	36.885	36.885	34.150	34.150
5	38.045	38.045	38.080	38.080	38.030	38.030
6	37.920	37.920	36.180	36.180	35.255	35.255
7	34.515	34.515	36.645	36.645	37.395	37.395
8	38.745	38.745	55.030	55.030	28.165	28.165
9	30.136	30.136	44.660	44.660	38.312	38.312
10	35.640	35.640	34.005	34.005	34.865	34.865

5. Conclusion

This paper mainly develops the research on the high-speed railway earthquake early warning test system based on virtual instrument technology. Firstly, develop a high-speed railway earthquake early warning test system based on LabVIEW, a virtual instrument development platform. Then, the test system is verified by test examples and the consistency between the original input waveform and the recovery waveform is analyzed, and then it is determined that the high-speed railway earthquake early warning test system based on virtual instrument technology is accurate and reliable. Compared with the on-site test program, the indoor prototype simulation test pro-gram used in the test system based on virtual instrument technology in this paper is cheaper and more efficient, while maintaining the validity and reliability of the test results, and has a higher engineering reference value.

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