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LabVIEW-based data platform and application of transient interference processing in high-speed railway

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ABSTRACT. *High speed railway signal system works in the complicated electromagnetic environment. During the interference analysis and data processing, a universal platform for various analog and digital signals should be established. An integrated data processing platform based on LabVIEW software was developed, consisting of data acquisition, data format conversion and signal processing. The platform can collect the signals of the analog source, and import the data stored in the recorder, thus constructing a universal processing platform. On this basis, the impact of the transient characteristics of high speed railway traction current on the signal was analyzed, and the detection of singularity of transient interference based on wavelet analysis was accomplished. Finally, by processing of the actual waveform recorded at the railway site, the validity of the platform function and algorithm were verified. The functions of the signal processing include real-time measurement in time domain, waveform display, filtering and spectrum analysis.*

KEYWORDS: *virtual instrument; LabVIEW; date acquisition; high speed railway; transient signal; wavelet analysis*

1. Problems and Background

Railway signal system is the infrastructure and control center of rail transit.With the development of high speed railway in China, the performance evaluation and fault analysis of railway signal system under the condition of complicated electromagnetic interference has become essential. Also they have important value in ensuring railway safety and efficiency. In the point of view of Electromagnetic Compatibility, efficient solutions are provided only if the interference source, coupling paths, and the cause of interference in railway signal equipment are mastered . Traditionally, the method for analyzing malfunctions of railway signal equipment, such as track circuit and cab signaling, is to record the actual waveforms on the scene by using multi-channel tape recorder firstly, then the time domain waveform recorded by the recorder can be manually analyzed. It is imperative to construct a universal data processing platform, by which the signals can be acquired, detected and processed in real time and the data recorded by the recorder can be also

analyzed. This platform is of great significance in developing reasonable countermeasures and providing guidance for operation and maintenance of signaling equipment.

2. The structure of virtual data processing platform

2.1 Hardware

The system is based on virtual instrument data processing platform, and its hardware is made up of current sensor, data acquisition card, and PC. Single channel maximum sample rate is 250kS/s, and the precision of A/D converter is 16-bit.For track circuit signal, the maximum carrier frequency of UM71 and ZPW2000A is 2600Hz with the accuracy of 0.15Hz; The minimum low frequency is 10.3Hz with the accuracy of 0.06Hz . So the data acquisition card can satisfactorily offer the sampling rate and precision we need.

2.2 signal source and the implementations of multi-channel data system

Data sources of this development platform include analog signal acquired by acquisition card and digital signal recorded by the recorder. Data collection module mainly controls data acquisition which includes the setup and control of channels, the inter-connection mode of signals, sampling rate, sampling number, and acquisition mode. It can use data acquisition toolbox, DAQmx, to acquire multiple channel signals continuously without coding.

Because LabVIEW can't directly process the source data, REC format data recorded by the recorder, so it needs further steps. First, REC format is converted to another data format that LabVIEW can process, such as TXT format or XLS format. Then, the data obtained in the previous step is loaded into virtual instrument data processing platform. Finally, the result from the previous step is converted to waveform, and then LabVIEW can be used to analyze and process sequentially. For multiple channel data acquired by the recorder in the same time, the data format and separator need to be set in Read From Spread Sheet File.VI respectively. Then each channel data can be taken out to analyze by indexed array. Figure 1 shows the flow chart.

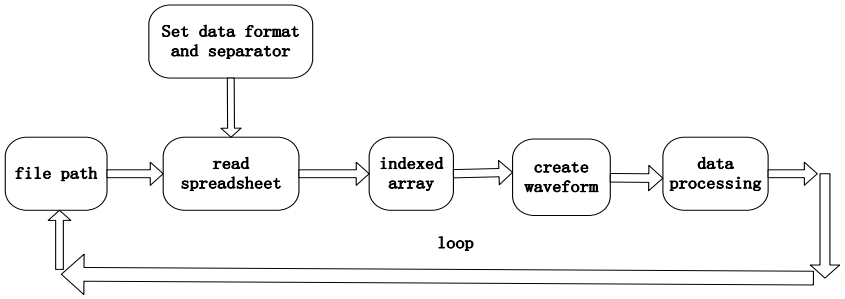

Figure. 1 Block diagram of reading TXT format data

2.3 Signal Processing module

LabVIEW is one of the most representative graphical programming software in the field of virtual instrument, and it has powerful Signal Processing Toolbox for users. Users can invoke the appropriate module to save time. When designing Signal Processing module in this platform, traction current and track-circuit signaling in the railway can be processed by using some functional modules in Signal Processing Toolbox, such as time-domain analysis, frequency-domain analysis, waveform display, waveform storage, and so on.

3. Using harmonic analysis to detect pulse singularity

The operation of high speed railway will result in significant increase of traction current. Because the catenary is sometimes separated from pantograph and the train driver switch train operating mode at times, there will be pulse current. It will interfere with communication system and will even lead to malfunction [4]. In the record of pulse current and signal, this transient interference tends to present the high order singularity.

The saltation point of signal, named singularity, usually contains quite important information. Its detection and positioning have important implications for many practical matters. Generally, Fourier transform can't solve these problems, but it's able to detect the saltation points of signal and the higher order singular points through one method based on wavelet analysis that has good time-frequency localization characteristics. So, it becomes a powerful tool to detect signal singularity.

3.1 The selection of decomposition scale and wavelet basis

The position of catastrophe point is sometimes reflected by the zero-crossing point of wavelet transform, and it is sometimes reflected by the extreme point of wavelet transform insteed. In general, it is detected by the extreme point because the

zero-crossing point is easy to be disturbed by noise and the zero-crossing point sometimes doesn't reflect the catastrophe point. It is suitable to use antisymmetric wavelets on the edge of detection, and it is suitable to use symmetric wavelets when detecting spike pulse. Firstly, the wavelet should be the first-order derivative or second-order derivative of one smooth function in order to make the detection effective. Secondly, the scale a must be appropriately chosen. On the one hand, the catastrophe point after wavelet transform can reflect the catastrophe point of signal basically. On the other hand, the wavelet transforms caused by all catastrophe points won't interfere with each other only if it is at one proper scale. Therefore, it is necessary to consider multiple scales when processing signal.

Generally, signal singularity behaves as the positive singularity, noise behaves as the negative singularity. So, it is easy for signal to be covered by noise if the scale parameter is two small; When the scale parameter is too large, the amplitude of wavelet transform modulus maximum that comes from the extreme point of signalattenuates greatly. This can make the abrupt change caused by trouble spot unconspicuous, even disappeared. As a result, it is unable to pinpoint the trouble spot.

3.2 The sourses and features of transient interference in high-speed railway

When the electric locomotive crosses the phase-splitterregion, lifting up or bringing down the pantograph, poor contact with catenary due to the ice on catenary, instant open or close of the overcurrent protection switches, and the train status switch could all cause pulse current. The transient interference brought by this pulse current has some characteristics, such as short time and high energy. It can enter the signal system by conductive coupling, and it can possibly cause malfunctions of signal system . In the record of propulsion current and signal, this transient interference often behaves as the high order singularity.

To analyze the transient interference with high order singularity by wavelet analysis, the wavelet basis should have enough order of vanishing moments. At the same time, the waveform of wavelet basis should stay the same as that of transient interference. The wavelet basis with symmetry can detect the spike pulse better, and the transient interference is mainly made up by impulse input. Therefore, it is better to choose the wavelet basis with symmetry.

4. Software design

The program development of this platform is based on LabVIEW2013. The platform consists of the data acquisition module, the data processing module and the human-computer interface module. Each module can be divided into sub-VIs and it is designed to be invoked as sub-VI at the same time.In this way, the program can be modified easily . Then all function modules are placed insidethe while loop and controlledby the front panel so that the data can be loaded into the platform and processed.In signal processing, wavelet transform function was adopted from Advanced Signal Processing Toolkit(ASPT).

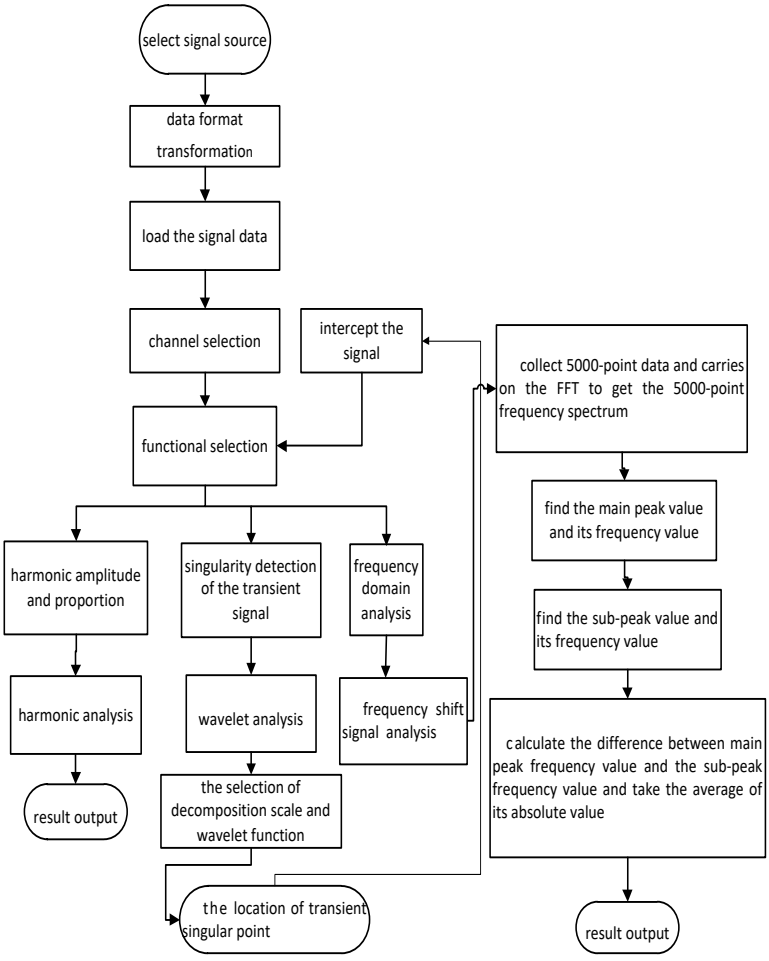

Figure. 2 Flow chart of system

System program flow chart is shown in Figure 2. Considering that mass data processing in the program design can lead to too long time and over long waveform may increase error of spectral analysis, the functionality of intercepting any piece of data has been added.The interested signal point can be intercepted on a small scale to analyze the data of the signal point accurately.

5. Experiment and result analysis

This group of data is the recorded data about traction return current in a high-speed rail station under the condition that the carrier frequency is type 2600-2 (2598.7Hz) when the high-speed train passed the station. The 4-channelsignal recorder records the waveform respectively,the channel 1 recordstotal traction current (contains signal current), the channel 4 records the rail current. Twenty seconds test data are intercepted and analyzed, as shown in Figure 3.

Based on the platform, the data of the total traction current recorded by the channel 1 of the recorder can be processed, by which we can analyze the size of the fundamental current at any time and each harmonic current. In addition, we can also analyze the carrier frequency and low frequency of the total current.

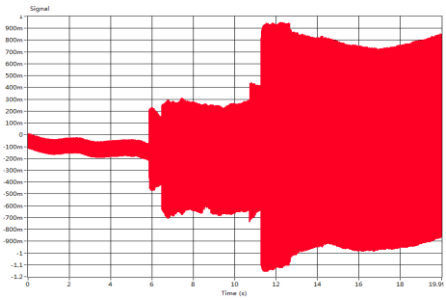

Figure.3 Signal waveform of recorder

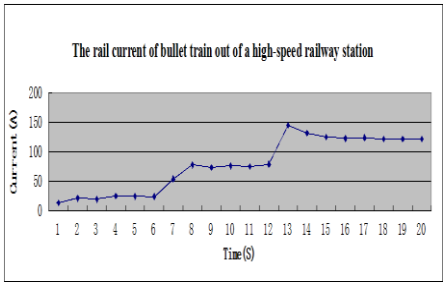

Figure.4Total current trend

The figure 3 shows current curve in the rail when the train-set drew out of the High Speed Rail Station, and the figure 4 is about the variation trend of total current.

It could be seen that the total current changed rapidly in a short time. The traction current in the process that the train-set drew out of the station has transient characteristic. The overlarge impulse current would seriously influence the equipment connecting to the rails, such as track circuit, and so on.

The 3-level of wavelet decomposition of the data recorded by channel 1 is carried out with the wavelet base of Coif5. D3 part is shown in Figure 5. According to the principle of wavelet modulus maximum, three singular points were detected. After intercepting three singular points and analyzing in detail separately, it is found that the three singular points are determined as transient current. The total current of the first point increases from 24.6 A to 54.5 A within 0.05s; the total current of the second point increases from 49.8 A to 76.6 A within 0.05s; and the total current of the third point increases from 79.35A to 148.86 A within 0.05s.The details of transient behavior of the third point is shown in Figure 6.

The spectrum of the central carrier frequency after filtering and FFT transformation is shown in Figure 8. Compared with the normal signal spectrum shown in Figure 7, the transient current produces bandwidth interference in frequency domain. It is unable to determine the modulation signal (side frequency) adjacent to the central carrier frequency. According to the principle of frequency shift signal demodulation,long timeinterference within pass-band may cause the failure of the low frequency demodulation.

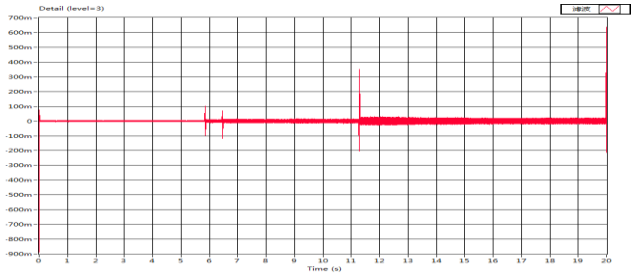

Figure.5 3 levels of wavelet decomposition part

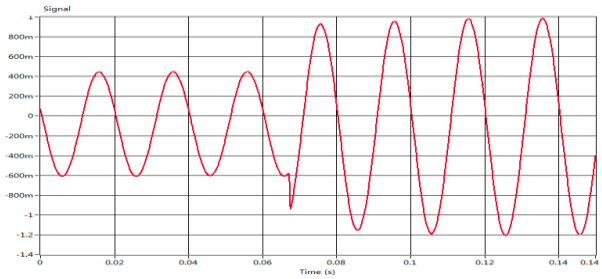

Figure.6 The 3th transient current

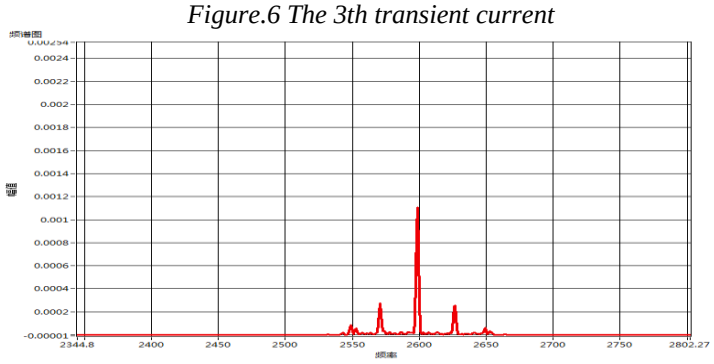

Figure.7 Center carrier frequency and side frequency of 2600-2

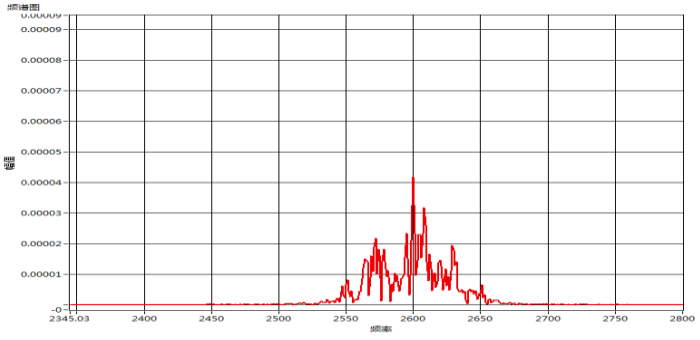

Figure.8 Signal spectrum of transient current

6. Conclusion

In view of the deficiency of conventionalmethods for the analysis of railway signal, a newmethod of signal processing by the data acquisition and analysis system based on virtual instrument is put forward. The design of the data acquisition and analysisplatformcan be divided into two parts, software and hardware.The platform can be applied to the real-time dataacquisition as well as analysis and processing of multi-channel analogsignals and the data.. This paper implements the detection of special signal and transient interference of traction current based on the wavelet transformation.Firstly, this paper introduces the principles of signal singularity points, the wavelet function and the selecting principle of decomposition scale; Secondly, it introduces the sources and features of transient interference in high-speed railway, and it gives some suggestions about how to choose the appropriatewavelet function and decomposition scale. It also proves thatposition of distorted signal can be positioned accurately in the huge amount of raw test data. In the data analysis of traction current, both the stable interference and the transient can

be processed, and the signal components contained in the rail current can be extracted and analyzed as well.

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