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Research Article

Research of Broken Wire Rope Detection System Based on LabVIEW

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Abstract: In this study, we introduce how to detect broken wires in steel rope based on wavelet transform and virtual instrument technology. By means of the powerful data analysis function of virtual instrument and wavelet transform, the singularity of wires can be found and it could help to improve ability of locating broken wires and determining breakage grade.

Keywords: LabVIEW, magnetic flux leakage, wavelet transform, wire rope

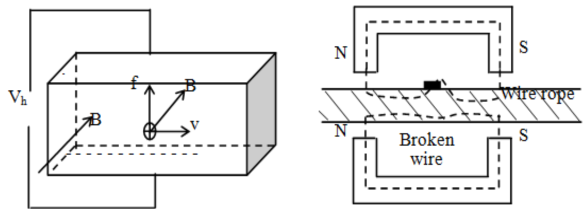
INTRODUCTION

Hoisting rope is one of an important component of the lifting equipment and whose safe and reliable operation is important guarantee of production (Lee and Grimson, 2002). At work, hoisting cable will be affected by static tension, bending, torsion, extrusion stress, broken wires would be appear after a period of time (Chai, 2006). Although great progress has been made in the research of detection and analysis technique for broken wires of wire rope, but original testing means which are still low efficiency, not high automation level and poor reliability, especially are not sufficient enough in terms of signal processing and analysis (Gorbatov *et al*., 2007; Wang *et al*., 2007). Wavelet analysis domain has good localization property in time and frequency, which is the most effective method of analysis and processing for broken wires of wire rope which have singularity detection signals (Sui and Zhang, 2012). Virtual instrument technology emphasizes software is the core and key of instrument, by which signal processing is done. Compared with the traditional instrument, virtual instrument has strong signal processing analysis and provides effective ways and methods to improve the test efficiency and reduce test cost (Zhu *et al*., 2012). In this study, the virtual instrument technology and wavelet transform which is used for characterization of signal mutation method is applied to the he detection and analysis for broken wires of wire rope, to improve the accurate ability to judge the position and size of broken wires (Zhou *et al*., 2011). It is known as Non-Destructive Testing (NDT) of wire rope, in which specific testing techniques and analysis methods may be applied to determine the state characteristics and Evaluation is given according to certain criteria (Cacciatore *et al*., 2007). At present, ultrasonic detection, infrared detection, radiation detection, acoustic emission detection, eddy current and magnetic flux leakage detection several methods such as have been proposed at home and abroad. The principle of magnetic flux leakage detection method with simple principle, low cost, on-line detection ability, surface cleanliness without strict requirements and more suitable for the damage of wire rope made of good magnetic properties of carbon steel, which represents a unique advantage in the detection of broken wire rope and is more NDT method currently in the research and use of wire rope damage (Zhou, 2009).

In this study, we introduce how to detect broken wires in steel rope based on wavelet transform and virtual instrument technology. By means of the powerful data analysis function of virtual instrument and wavelet transform, the singularity of wires can be found and it could help to improve ability of locating broken wires and determining breakage grade.

DETECTION METHOD OF BROKEN WIRE ROPE

Detection principle: The most primitive and simple NDT is the artificial visual detection method. When wire rope be running in detection speed, the testing personnel stands beside the rope and grasps cotton yarn to stroking and touching rope, If there exists hanging yarn, wire rope were suspected broken and to stop at that location which will be carefully observed. Since the method is very simple, it is still being widely used. However, with the development of wire rope production technology and materials, pre-stressing force was applied to wire in the use of rope, which makes the wire fracture with a Convergence without outside Alice; On the other hand, the lubricant of wire rope makes the surface of thick sludge, which are difficult to manual visual inspection. In this case, although rope was carefully examined paragraph by paragraph through manual visual inspection method, internal defects of wire rope cannot be found, wherefore, other detection methods of wire rope need to be studied.



(a) Principle chart (b) Detection chart

Fig. 1: NDT principle chart of broken wire rope

The method of magnetic flux leakage was used to detect broken wire rope, in which sensor consists of two parts: one part is exciter for magnetizing wire rope and the other part is probe for detecting leakage magnetic field of broken wire rope. Permanent magnet materials are made as the excitation source and induction coil and the Hall element is used to detect leakage magnetic field of broken wire rope. The NDT Principle chart of broken wire rope is as shown in Fig. l.

The Hall was used as the detection element, strong permanent magnet as exciter in paper. Control current I through the two end of the Hall and wire rope to be seized was magnetic saturation. When the rope appears broken wire, leakage magnetic field B appears in the fracture because of magnetic medium changes. Hall potential generated in the magnetic field is as follows:

$$V_h = R_h I B_r = R_h I_B \sin\theta$$

θ : Angle of magnetic field lines and the Hall
R_h : Constant of proportionality
I : Control current
B : Magnetic field through the Hall

Size and changes of Hall potential relates leakage magnetic field B, Therefore, the Hall potential may measure leakage field at the wire rope fracture and to determine the conditions of broken wire rope.

The analysis method of the signal: When there was a broken wire rope, this output signal mutation occurs. Signal singularity and irregular mutations are often compared with important information. Fourier transform is the main tool of function singularities and through the study of attenuation function in Fourier transform domain to predict whether the function has the singularity and the size of the singularity. The lack of space locality, Fourier transform can only determine the overall properties of a function singularities and difficult to determine the location and distribution in space. In addition, there are many factors influencing the detection for broken wires of wire rope, Such as wire rope diameter, wire diameter, distance of fracture, dislocation broken wires, desirable degree of broken wires and the location of the broken wire in wire rope cross section, etc. Usually the smaller magnetic field was leaked out, the smaller hall voltage is formed, there is no obvious broken wires signal waveform characteristics. So there aren't obvious characteristics of broken wires on signal waveform. Wavelet transform, time-frequency localization characteristics, can effectively analyze the signal singularity, determine the location of the singular point and the size of the singular degree (He and He, 2004).

The application of wavelet transform in broken wires: Wavelet theory shows that the amplitude of Modulus maxima with the change of scale is decided by local Lipschitz exponent of the signal's mutation point.

Lipschitz exponent which is defined as function x (t) near the t_0 has following characteristics:

$$\left|\chi(t_0+h)-p_n(t_0+h)\right| \le A\left|h\right|^{\alpha}, n<\alpha<n+1 \quad (1)$$

It said Lipschitz exponent of x (t) at t_0 for α.

Type: h is a sufficiently small and p_n (t) is n polynomial of x (t_0) point (n∈Z)

Assumes that the wavelet function Ψ (t) is continuously differentiable and attenuation rate is 0 ($\frac{1}{1+t^2}$) in the infinite distance, when t is (a, b), if wavelet transform of f (t) meets:

$$\left|W_\alpha f(t)\right| \le k\alpha^{\alpha} \quad (2)$$

That is:

$$\log_2\left|W_\alpha f(t)\right| \le \log k + \alpha \log \alpha \quad (3)$$

The k is constant, Lipschitz exponent of f (t) in (a, b) is α, When a = 2j, Formula (3) to:

$$\log_2\left|W_{2^j} f(t)\right| \le \log_2 k + j\alpha \quad (4)$$

Scale features of wavelet transform is related with Lipschitz exponent α by j α. The numerical of wavelet transform is given with the changing rule of the j or α. Obviously, modulus maxima of wavelet transform of the corresponding signal singularity also satisfies the rule along with scale change. Conclusion by Eq. (4): when α is greater than zero, wavelet transform maximum will increase with the increase of j; when α is less than zero, wavelet transform maximum will decrease with increasing of j; when α is zero, the wavelet transform maximum does not change with scale (Li, 2006).

In the broken wire detection of wire rope, signals are often accompanied by strong noise signal. Wavelet transform extreme of the corresponding noise will decay quickly with the increase of scale; wavelet transform extreme of the corresponding signal's edge will increase or remain the same with the increase of scale. In this way, the continuous wavelet transform is used to accurately isolate edge of broken wires signal from the noise background.

CONSTITUTION OF WIRE ROPE DETECTION SYSTEM

Programming language: Virtual instrument technology is a product of the infiltration between computer technology and measurement and control technology. With the computer and appropriate hardware environment, virtual instrument development platform is introduced to accelerate the design, debugging and development of practical monitoring and control systems, so that measurement, metering and control system in industrial process is more flexible, more economical, more efficient, more powerful and faster updating technology.

The most important and core technology Virtual instrument is software development environment of virtual instrument. LabVIEW is the most widely virtual instrument development environment internationally and in which the powerful Graphical Language (G Language) is used when programming. Because the knobs, switches, graphics and so on which engineers are familiar with are adopted, programming interface is very intuitive. Furthermore, it is for oriented professional programmers rather than engineers and is a convenient programming method and the human-computer interaction interface is amicable and has powerful data visualization analysis and control capabilities and has provided a good environment to construct their own control system quickly for consumers.

Therefore, the system selects virtual instrument development platform LabVIEW 8.20 of National Instruments (NI) Company to develop visual software package, so that data acquisition, analysis and display can be realized.

Data acquisition program: Wire ropes detection system is based on PC in substation grounding grid and which can effectively use rapidly developmental hardware and software resources of PC. Secondly, the system needs its own hardware circuit and in order to achieve signal acquisition. One of channels of obtaining data for virtual instrument is to use data acquisition card and which is the most fundamental way also. And data acquisition card PCI-MI0-16E-4 of NI 6040E series of NI Company is chosen and its main performance index are as follows:

- Channels: 16 single-ended or 8 difference
- Maximum sampling frequency: 200 k/s
- Range: ±10 V and 0~10 V
- Resolution: 12 bits
- Data transmission method: programming control
- Input impedance: 150 GΩ

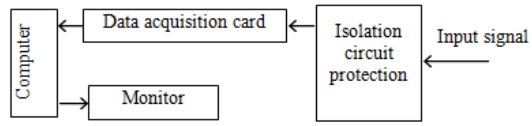


Fig. 2: The hardware structure of detection system

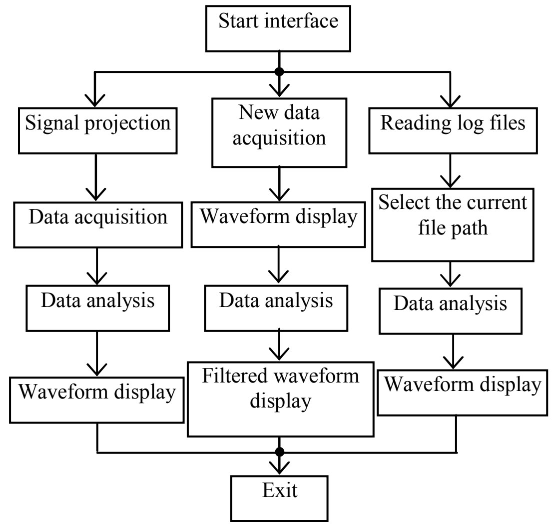


Fig. 3: The flow chart of software

Wavelet transform: In LabVIEW 8.20, FFT.vi is located in Transforms Palette of Signal Processing of the Functions Palette. In which the x-port is the input time-domain signal, fft (x) -port is the input signal spectrum. Through the spectrum, the frequency component of input signal can easily be observed and analyzed signal as well as processing.

The hardware structure of detection system of broken wire ropes: The hardware structure is constructed of computer, data acquisition card and the external circuit and as shown in Fig. 2. Main functions of the external circuit are isolation and over-voltage and over-current protection for the input of data acquisition card.

The software structure of detection system of broken wire ropes: According to function, software of the system can be divided into data acquisition module, data storage module, the signal waveform processing and display module. The flow chart of Software is as shown in Fig. 3:

- Signal projection is the simple forecast for the actual measurement that would to carry out, of which includes display of time-domain waveform and amplitude spectrum for measurement signal and display of calculation results. And report files can come about for predicted value so as to prepare for later use, therefore, the speed of program execution is accelerated. When the user just wants to find out characteristics of time-domain and

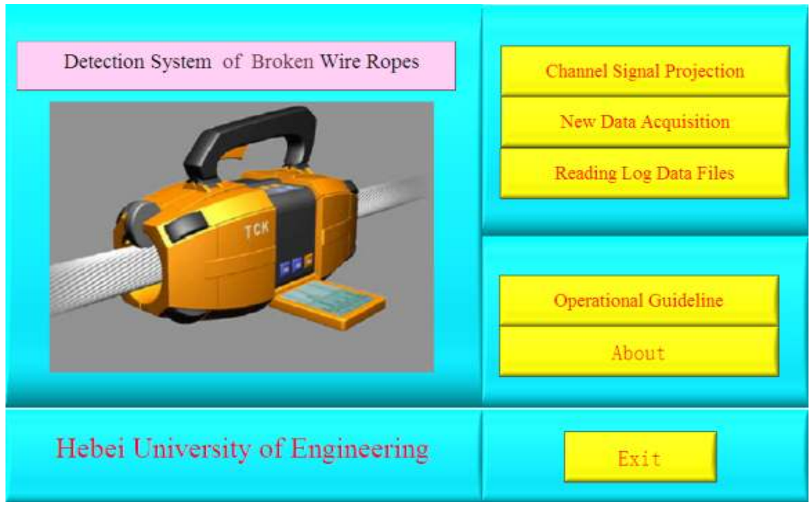


Fig. 4: The interface design of detection system of broken wire ropes

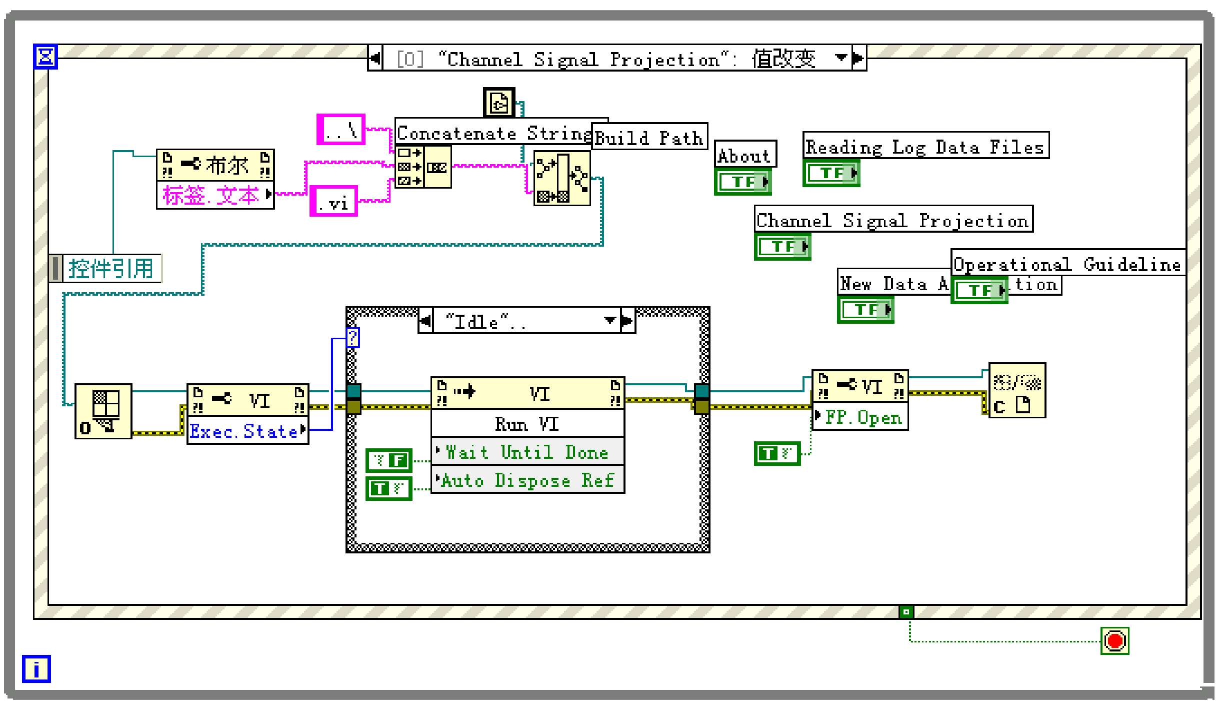


Fig. 5: The diagram program of detection system of broken wire ropes

frequency-domain of measurement signals, you can choose the operation mode, at the same time, the acquisition of new data is ready also.

- New data acquisition is the process of data acquisition. New acquisition data must be stored and time-domain waveform and amplitude spectrum of measured background signals should be showed, moreover, the waveform after filtering and the current time should be showed also.
- **Reading log files:** In this operation mode, the user can analyze and process the stored log files and their various waveforms can be showed, so that the test system has been improved further.

The interface design of detection system of broken wire ropes: The interface of detection system of broken wire ropes is as shown in Fig. 4. After the beginning of program execution, by the button of main interface, sub-interface is recalled to carry out operation which is the forecast of channel signals, background noise measurements, new data acquisition and reading log files and so on and operational guidelines and version information of program can be shown also.

The diagram program of detection system of broken wire ropes is as shown in Fig. 5. Event Structure and VI Reference node is used in program diagram and trigger condition of the Event Structure derives from any one of five buttons in the user interface and sub-panels and the main program run independent of each other.

CONCLUSION

This study has studied the detection system based on LabVIEW in broken wire ropes. The system consists of sensors, data acquisition card and computer and so on, because flux leakage testing method and wavelet transform is used, interference from measurement results can be removed. Therefore, accuracy of the system measurement has improved. Furthermore, detection software based on LabVIEW in broken wire ropes. Which has the function of data acquisition, storage, analysis, processing and display? Finally, a low-cost, simple operation, easy-to-use, easy to maintain and extend, speed-testing grounding resistance measurement system is realized. The system function is more complete, strong generality and has provided a new control thought for computer measurement field. However, with the constant maturity of the network control and remote control, this system need further refinement and to achieve remote monitoring.

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