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Study on Monitoring System for Pipeline Security Based on Multi-sensor Data Fusion Technique

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Abstract. Based on multi-sensor data fusion technique, monitoring system for pipeline security is designed. Many sensors and processing modules are used to acquire early warning signals when pipes are threatened. The non-stationary signal analysis method based on empirical mode decomposition is used to process the signals. The normalized kurtosis extracted from the decomposed results is composed of the feature vectors. Because separate sensors gathering modules are in the monitoring system, the multi-sensor data fusion technique is used to fuse these individual recognition results for improving recognition rate. With software development platform, LabVIEW virtual instrumentation, the final decision is obtained. With the test, recognized police rate of system is superior to 85%, rate of false alarm is 15% below. The system can also provide a friendly human-machine interface. In addition, it is convenient for the system maintenance and function expansion.

Keywords: pipeline; multi-sensor data ; fusion technique; LabVIEW virtual instrumentation

1. Introduction

In the gas and oil pipeline operation, offenders often drill in the pipeline to steal oil and gas. If these things are not discovered and not restrained in time, that will not only seriously affect upstream normal production and downstream transmute production to cause serious economic losses, but also the leakage products of gas and oil pollutes the environment and generates the related secondary disasters. More seriously, the gas and oil products supply of great cities along pipeline cannot be guaranteed, energy supply shortages will cause even more serious social and political problems [1]. Therefore, the safety monitoring system can report the scope and extent of the accident timely and accurately, can decrease the economic loss and reduce environmental pollution in the maximum. It is great significance to protect the security and reliability of production.

Regular leakage detection technology and existing mechanism is used in general only to find oil leakage or to call the police after these things occur. As a result, the questions, act of invading is realized timely when pipeline security is at stake, or pipelines are being destroyed but not cause damage, are pressing problems [2]. Based on multi-sensor data fusion technique, a new type of pipe safety monitoring system is designed. Many sensors and processing modules are used to acquire early warning signals when pipes are threatened. The non-stationary signal analysis method based on empirical mode decomposition is used to process the signals. The multi-sensor data fusion technique is used to fuse these individual recognition results for improving recognition rate. With LabVIEW virtual instrumentation, the security system is obtained. With the test, the leakage in the pipe can be found before destroy occurs. The gas and oil products and environmental pollution greatly reduced. The system can also provide a friendly human-machine interface. In addition, it is convenient for the system maintenance and function expansion.

2. The basic principle of system

2.1. The Basic of Multi-sensor Data Fusion

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The basic principle of multi-sensor data fusion is like the process of human brain to comprehension and to handle with information. It is in full use of many sensors resources, by controlling and using these sensors and observational information reasonably, redundancy or complementary signals in time or space of these sensors are combined according to some guidelines to acquire consistency explanation or description of measured objects. With this, the performance of total information system is more superior to those of subset system. Redundancy data between sensors enhances system reliability and complementary data between sensors expands single performance. The essential difference between multi-sensor data fusion technique and classic signal processing is that multi-sensor information has more complex forms and can be in different information hierarchy.

2.2. The Process of Multi-sensor Data Fusion

The process of multi-sensor data fusion is composed of many sensors, data preprocessing, data fusion centre and result output. The process can be seen in figure 1.

Figure 1. Data fusion process

Because the object is non electrical quantity with different characteristics largely, firstly those are converted to electrical signals, and then with A/D conversion, those are converted to digital quantities. The digital electrical signals are added with some interference noise inevitably because of the random environment factors. By preprocessing, the interference and noise can be filtered to get useful signals [3]. After this, the feature extraction of signals is done, data fusion of feature vectors is worked out, and the fusion output is gained.

*1) Signal acquisition:*The methods of sensor signal acquisition are many, according to specific conditions, the signals of objects are gained with different sensors. The pressure and the flux of pipelines changes when the leakage occurs. Criminals want to steal the crude oil, usually drilling in the oil pipeline first. When they use tools in the pipeline to drill, the special stress wave is generated by interaction friction between drilling tools and metal in the pipeline. By using corresponding sensors, the different elements of alarming signals can be received. With A/D conversion, the different signals can be converted to electrical signals, and then they are delivered to computer system.

*2) Signal preprocessing:*In the process of signal acquisition, because of the two reasons, the measuring signal is often added with some noise. One is some objective factors; the other is that, after A/D conversion, the accessional quantized noise is added in intrinsic noise. As a result, before data fusion, sensor output is in the preprocessing to filter these noises and to enhance Signal-to-Noise. The ways of signal preprocessing is mostly averaging, filtering, removing trend term and so on.

*3) Feature extraction:*The feature extraction is done to original sensor information. The feature vectors can be gained according to specific pipeline measuring signals.

*4) Data fusion:*The data fusion is a lot of, such as data correlation technique, estimated theory and recognition technique.

2.3. The Gradation of Multi-sensor Data Fusion

In the process of multi-sensor data fusion, because of signals diversification, the fusion is done with definite gradations and steps according to data types and means of collection. Based on this, the gradation of multi-sensor data fusion must be introduced into. By means of level of abstraction, and means of circulation and transportation of data, data fusion is divided to high-level process and low-level process. The low-level process is composed of data preprocessing, target measuring, classification, identification and target tracking. The high-level process is composed of situation and threat assessment and extraction of total fusion [4]. The three basic frames of identification are data-level fusion, characteristic-level fusion and decision-making level fusion. Because of alarming pipeline signals are heterogeneous, such as pressure, flux and special stress wave, the fusion is only done in characteristic-level or decision-making level.

*1) Characteristic-level fusion:*The representative feature is extracted from data, and then is fused to single feature vectors, and those are handled with by pattern identification.

*2) Decision-making level fusion:*In this method, the collecting information of every sensors exchanges to get preliminary results of measuring target. In the end, according to definite guideline and every judgemental reliability, the optimal decision is worked out. Some methods are majority vote method, bayesian method and generalized evidence theory. In the monitoring system for pipeline security, the D-S (Demp-ster-Shafer) evidence reasoning is used to fuse these individual recognition results for improving recognition rate. By receiving and analyzing the different elements of alarming pipeline signals, the characteristics, nature and location information of damage source can be obtained.

3. System Structure

3.1. System Architectural Design

In monitoring system, at the destruction pipeline area, high sensitivity sensors are fixed on the pipeline with certain distance to gather corresponding signals when pipeline is destroyed. The signal is enlarged, regularized, handled with synthetically by built-in Digital Signal Processor (DSP) to judge whether pipelines are threatened in the monitoring units.

When pipelines are threatened by on-site unit' judgment, signal character of threatened events is uploaded to the monitoring units by GPRS communications network. In the junction center, the multi-sensor data fusion technique is used to fuse these individual recognition results for improving recognition rate and for different types of events different alarms are called. At the same time, in monitoring channeling interface, position and time of threatened events are recorded for management information and data analysis. System diagram is seen in figure 2.

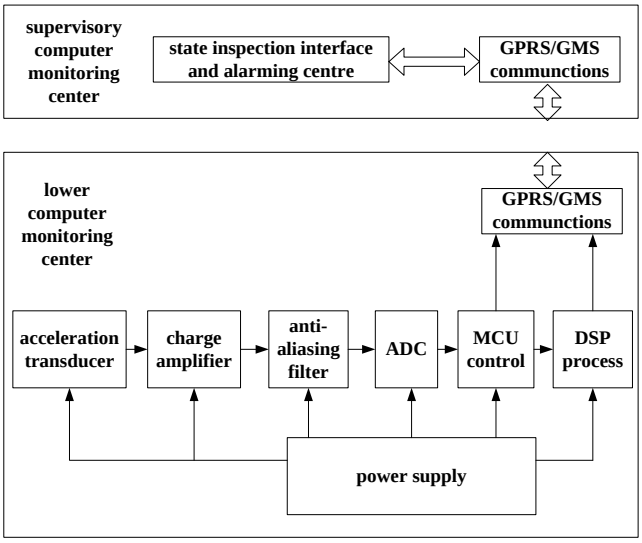

Figure 2. System construction diagram

3.2. System Hardware Design and Realization

1) High sensitivity sensors: The dissemination is decayed, considered the supply and low power consumption, high sensitivity sensors are selected to receive signals in this system.

2) Signal conditioning module: According to type of sensors, the corresponding charge amplifier is used; signal is anti-filtered when frequency analysis, the low pass filter is fixed whose cut-off frequency matches with frequency of measured signal. With a series of process, the signal is gathered availably in monitoring units obtained by sensors.

3) Digital signal processing module: The collected signals is on time-frequency analysis to extract characters of signal in the time domain and frequency domain, and then first judgment is used integrated with the parameters of system. Once the signal is same as information in threatened events database, the infinite communications unit in the system is activated to upload information to monitoring centre to avoid real-time data traffic jams and the electricity wastage.

*4) Monitoring module:*The GPRS+GSM communication modules, audible alarming equipment and computer are composed of the system monitoring center. Based on the virtual instrument technology, safety controlling interface of pipes is designed to display real-time pipeline information, that facilitate the operating personnel make a quick decision and revise parameters of system operation and alarming procedure in the monitoring unit to accomplish real-time remote monitor and control.

*5) Efficient bulk recharged:*The system uses the bulk batteries and designs capacity for work half year, which all system is hidden in the ground.

3.3. System Software Design and Realization

*1) Data Collection:*Data collection module is the based part of system, that is realized by MPS-01020T multi-purposes card and data collected procedure. With software of upper monitor supposed and sub-VI and examples offered, according to the configuration of the various arguments system applications software is written.

2) Data Processing: The time domain analysis, the frequency domain analysis, multi-sensor data fusion is realized in data processing module. The true features and frequency distribution of effective signal is extracted from noised signal. The D-S (Demp-ster-Shafer) evidence reasoning is used to fuse these individual recognition results for improving recognition rate. By receiving and analyzing the different elements of alarming pipeline signals, the characteristics, nature and location information of damage source can be obtained. Analyze-Signal Processing sub-template, of LabVIEW, has many functions, those are signal generator, time domain analysis, frequency domain analysis, the wavelet analysis, measuring functions, window functions of digital filter and other features [5]. The libraries can set a desired data analysis functional module.

*3) Data storage:*The module is to store data collected, and by the computer screen it shows the signal at the various stages for the management for further enquiries, data processing, analysis and comparison, typed, etc [6].

*4) System configuration:*The module deploy major parameters of system, such as the argument, etc [7].

4. Experiments

In testing process, the pipeline is 1.5 kilometers from the base station, and buried deep to the area of about 1.5 meters. Eleven points are grubbed in the pipeline, then the sections of pipe are bare, by the means of drilling and knocking test, it is be seen that destroyed signals will be passed to a kilometer, by multi-sensor data fusion technique corresponding signals can be gathered, recognized police rate of system is superior to 85%, rate of false alarm is 15% below. The damage signal touching to the pipeline can be alarmed accurately. The background noise, those are people's walk, car through, wind and rain, and so on, may be effectively removed. In addition, all units of the system are put in the ground, the high energy battery is operated, no surface goals and the system have self-shield function to effectively prevent damage to the system itself.

5. Conclusions

Based on multi-sensor data fusion technique, a new type of pipe safety monitoring system is designed. This method has a lot of advantages, those are response speed is fast, positioning accuracy is high, and the leakage loss of crude oil can be reduced effectively. Simple structure, reliable pump performance, high capacity of resisting disturbance, low rate of false alarm, and base station can meet the guardless demand in the field. Owing to pipeline without electricity and communication facilities and system needs to be buried in whole, therefore, the supply, communication issue, embedded software reliability and the measurement of weak signal in this system, are needed to be further improved.

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7. References

[1] D.N.Alleyne, B.Pavlakovic, M.J.S.Lowe, P.Cawley, "Rapid Long-Range Inspection of Chemical Plant Pipework Using Guided Waves," Insight, 2001.43, pp.93–96.

[2] M.J.S.Lowe, D.N.Alleyne, P.Cawley, "Modeconversion of Guided Waves by Defects in Pipes," Review of Progress in Quantitative Nondestructive Evaluation, 1997.16, pp.1261–126.

[3] Smith D, Singh S, "Approaches to Multisensor Data Fusion in Target Tracking,"A survey, IEEE Transactions on Knowledge and Data Engineering, 2006, 18(2), pp.1696-1710.

[4] Tafti A D, Sadati N, “Novel Adaptive Kalman Filtering and Fuzzy Track Fusion Approach for Real Time applications,” Proceedings of the 3rd IEEE Conference on Industrial Electronics and Application, Singapore, 2008, pp.120-125.

[5] Liang Hongsheng, Zhou Junwei, Li Yujun, “Implementation of Oil Pipeline Leak Monitoring and Location System Based on Virtual Instruments,” Computer Measurement & Control, 2005.13, pp.415–417–433.

[6] Wayne Wolf, “Computer As Components Principles of Embedded Computing System Design,” Morgam Kau & nann, 2001.2, pp.34–35.

[7] Li Jia, Yang Dianfu, “Embedded Remote Monitoring System development," Process Automation Instrumentation, 2002.4, pp.58–60.