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Data Acquisition Technology of Chemical Equipment Based on Wireless Sensor Network

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Study the data acquisition technology of chemical equipment using wireless sensor technology. Various processing functions of the status of equipment were simulated based on the virtual instrument software developed and designed combining wireless sensor network, wired Ethernet and the Zigbee technology, and through simulation signals. The Data Acquisition System of Chemical Equipment Based on Wireless Sensor Network was designed. The accuracy of the data results was high, and Zigbee ad hoc network was achieved for collecting of network data. The result shows that the system designed in this paper can meet the needs of real-time monitoring of the operational status of chemical equipment and is practical.

1. Introduction

Chemical companies are important in advancing the development of modern society and economy. People's work and life depend on chemical products, which facilitate human work and life. Under the background of continuous innovation in science and technology, scale, intensification, systematization and standardization are trends in the production of chemical equipment. The performance and function of chemical equipment become more complicated, and more difficult to use, requiring chemical companies to strengthen internal management and link with all aspects closely. Major failures in production may cause "domino effect", which will lead to the interruption of production of the lines or the entire station, and even a serious threat to human life and property. The direct/indirect losses caused by major accidents in chemical companies will be enormous. Relevant data show that between 2015 and 2016, there were about 50 major safety accidents in the domestic chemical industry, resulting in dozens of deaths. The safety of production equipment in chemical companies in China is not optimistic.

Based on this, the data acquisition technology of chemical equipment is studied using wireless sensor technology. Various processing functions of the status data of equipment were simulated based on the virtual instrument software developed and designed combining wireless sensor network, wired Ethernet and the Zigbee technology, and through simulation signals. The Data Acquisition System of Chemical Equipment Based on Wireless Sensor Network was designed.

2. Literature review

Interactivity and inquiry-based learning science are effective ways of helping students overcome their perception of chemistry as an alien and abstract topic and instead approach the subject as a creative way of understanding ideas and applying mastered concepts to new contexts. Data acquisition systems are an extremely useful form of educational technology that can be used alone or in conjunction with other technologies to bring about active learning and enable students to move beyond memorization to the verification strategies and knowledge base they need to successfully master chemistry concepts. This article describes the use of data acquisition systems and analysis software in combination with other technologies such as electronic response systems and online video. The technologies were used for laboratory activities, online learning, and lecture hall demonstrations and allowed for cross-disciplinary experiments. They also brought an element of interactivity to each instructional setting that proved to be an excellent avenue for engaging student interest and ensuring comprehension of chemistry topics (Milnerbolotin, 2012).

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To overcome disadvantages of complex wiring and difficult maintenance for traditional wired sensor networks, a data acquisition system for chemical equipment monitoring based on wireless sensor network has been put forward. The proposed data acquisition system has functions of real-time data acquisition, transmission, storage, query and remote sharing of history data, and provides favorable technical supports for real-time chemical equipment monitoring. First, the system framework, EMBV210 hardware are introduced. Then, in the LabVIEW platform, the data acquisition system is developed, and the remote sharing of equipment operating status by Data Socket is realized. Finally, the proposed data acquisition system is simulated and verified. The work provides a feasible way for chemical equipment monitoring and useful references for the development of other similar integrated measurement and control systems (Cao et al., 2013).
ISSN data acquisition technology is a new kind of oil exploration seismic acquisition technology. It is the first application of ISSN technology by the East Geophysical Company to make oil exploration in Iraq. This paper analyzes the difference of SSOffice3.0 between Iraq project and other projects. Then this paper introduces the automatic data wireless transmission, image processing, integration of GIS spatial analysis and digital elevation model and other functions applied in Iraq project (Han, 2013).
This paper focuses on the implementation of various diagnostics for optimizing chemical oxygen iodine laser. This paper also dwells on the measurement methodologies and instrumentation employed in these diagnostic systems. The prime diagnostics are for the measurement of vital species in form of iodine, singlet oxygen, and chlorine. Iodine concentration measurement, chlorine utilization, and singlet oxygen yield have been implemented based on optical absorption/emission principle. Furthermore, online Mach number determination, which is critical for supersonic gas flows, laser pulse detection, and flow rate measurement and control over wide range, have been carried out. A dedicated diagnostics and data acquisition system customized for parameter monitoring have been developed. The developed DDAS also serves the purpose of precise operation sequencing and parameter control. It is a 168-channel personal-computer-based system with customized interface electronics employing Visual C++ programming language with user-friendly graphical user interfaces. A detailed uncertainty analysis of various critical parameters has been also presented (Mainuddin et al., 2012). According to the requirement of multi-devices access to the computer in intelligent building monitoring system, combined with the principle of the upper computers data acquisition and the principle of configuration software, this paper proposes a upper computer data acquisition model by simulating the equipment into channels and the model is based on double buffers sampling technology. The model adopts the principle of device drivers; different equipment computer modules access to the model in the form of plug-ins (Lai et al., 2013).
The advent of initiatives like Industry 4.0 promises increased operational efficiency through smart services and interconnected devices (Lesjak et al., 2014). To solve the problems of dispersion, various test items, and low automation level of test data acquisition for the test instrument for a certain type equipment, a test data automatic acquisition system based on local area network(LAN)is proposed according to the requirements of personnel division and operating rules for post. For the large difference of intelligence degree of various test equipment, the instruments are divided into three categories, and different methods are used to obtain test data respectively. The coordinated control was realized by using PDA handheld device and wireless LAN technology creatively, which enhanced the adaptability and flexibility of the system. On the basis of local operation for the test equipment, the automatic acquisition of test data and storage management in My SQL database were realized by remote industrial personal computer.
The article focuses on the development of a data acquisition system (DAS) working in a noisy and hostile environment for an arc-operated hydrogen fluoride/deuterium fluoride (HF/DF) chemical laser. PC-based DAS has been configured using Advantech plug and play modules with fiber link connectivity. This article also focuses on implementation of an orifice-based precise gas flow control system. The plasma arc discharge in an arc heater/generator is essentially employed for inducing thermal dissociation of sulfur hexafluoride SF_6 for production of fluorine atoms, and DAS has been used for performance optimization of the composition of the lasing mixture by independently varying the flow rate, pressure, and temperature of its constituents. Since arc load is complex with high voltage transients and electromagnetic noise, an optical fiber link has been implemented for data transmission. This article also discusses digital output interface circuitry for various electro-pneumatic actuators/solenoid valves. The developed DAS has been used for monitoring and performance evaluation of parameters for 50kW arc tunnel (Kant, 2012).
To meet the requirement of the data acquisition for the remote fault diagnose system of the large-scale railway maintenance equipment, this paper proposed a vehicle-carried data acquisition and monitoring system based on embedded Linux and 3G technology. In the proposed system, the hardware design for realizing the data acquisition function is based on CAN bus, and monitoring function is based on wireless sensor networks (Yu et al., 2014).
Aiming at the characteristics of boundary in-situ monitor, an in-situ chemical element data acquisition system was proposed, which could be used on deep-sea environment. The data acquisition system based on ARM9

could collect multiplex analog and digital signals and has the ability of large capability memory, current communication modes, basic data process and analysis, which has the practical application signification for boundary monitor. High pressure test, stability test in lab and sea trial results demonstrate that the proposed chemical element monitoring system could work properly in deep sea.

3. Method

Figure 1 shows the typical architecture of a wireless sensor network, consisting of sensor nodes, convergence nodes and task management nodes. Nodes are randomly arranged in the monitored area, and an ad hoc network is constituted. Monitored data is sent to the nodes via multi-hop routing. The data in the entire monitoring area is transmitted to the remote center for centralized processing via the satellite link or the temporary link established by the UAV. It is possible to send data in the opposite direction to manage the sensors, issue monitoring tasks and collect monitoring data through the management node. The sensors, the perceptual object and the observer are the three basic elements of the sensor network. These three elements establish a communication path through the wireless network, and cooperatively perceive, acquire, process and issue perceptive information.

Figure 1: Wireless Sensor Network Architecture

The IEE 802.105.4 standard focuses on low power consumption, low transmission rate and low cost, and aims to provide a uniform standard for low-speed interconnections between different devices in an individual or a home. Its features are similar with wireless sensor networks in many aspects. Many research institutions regard this standard as a practical international standard. The physical layer and media access layer protocols were developed.
The user login and privilege management module is used to set user's privilege, so that the user can run and modify the program only after legally logging into the system, to avoid illegal tampering and intrusion, and to register the information of the user. The account management module is designed to add/delete users. Different user privilege can be set for convenient user management (Figure 2).

Figure 2: User login screen

Zigbee is a short-distance, low-power, low-data-rate, low-cost and low-complexity wireless communication technology; the technology is based on standards. The Zigbee Alliance standardizes the network layer protocol in the standard. The protocol architecture refers to the OSI seven-layer model. The framework of the network layer, the security layer and the application layer are developed based on the physical layer and data link layer defined in the standard, including application support sublayers, Zigbee device objects, and device vendor custom applications (Figure 3). Figure 3 shows the structure and division of Zigbee protocol. The network layer provides the following services: (1) Configure new equipment; (2) Create a new network; (3) log into/out the network; (4) Address assignment; (5) Neighbor discovery, route discovery; (6) Receive control.

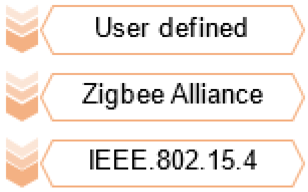

Figure 3: Zigbee protocol structure and division

With the hierarchical structure of the network, the complexity of the network is reduced, facilitating the dynamic topology of the network and the reconstruction of the cluster. We can divide wireless network nodes into three types in view of functions: cluster member nodes, cluster head nodes and Sink nodes. The cluster member node is responsible for the bottom layer of data collection and forwarding, which is composed of RFDs; the cluster head node is responsible for the establishment and management of this cluster, and the data within the cluster is processed by fusion and sent to the Sink node; the Sink node is responsible for the management of multiple clusters and collection of data. According to the functions of factory management, production process and monitoring system, the communication network of an enterprise can be divided into three levels: field-level, shop-level and enterprise-level. We can divide the communication devices in the wireless sensor network of the equipment status monitoring system into two types: field-level wireless sensor nodes and shop-level gateway nodes.

Due to the limited electrical energy of a single sensor node, in order to prevent node failure, improve the reliability of monitoring data and prevent external factors from interference, in general, two or more homogeneous sensor nodes are set to monitor the measuring points of a certain device. Suppose a number of sensors acquire the consistency data of the measurement point within a certain period. Set the measurements after eliminating random errors as x1, x2, x3,..., xn. Divide the n measurements in two groups randomly, and calculate the average of each group. Then, based on the average, a batch estimation algorithm is used to estimate the fusion value that is close to the true measurement, obtaining an accurate measurement and eliminating the uncertainty of the measurement process. This process can also be considered as two sets of consistent measurement collected by two homogenous sensors within the same time period.

Let m+k=n, the arithmetic mean and standard deviation of the two sets of measurement are:

$$\overline{X}_{(1)} = \frac{1}{m}\sum_{i=1}^{m} X_{1i}$$
$$\overline{X}_{(2)} = \frac{1}{k}\sum_{i=1}^{k} X_{2j} \qquad (1)$$

Collect dynamic signals and display real-time dynamic changes of signals on the collecting equipment. The real-time status of an object's movement is represented via the dynamic changing waveforms of signals, so that the staff can quickly understand and master the operating status of the object, which is the most important means for understanding the world and is also the simplest method. Each signal acquisition and testing system should have a waveform display module. This system is set with a waveform display module that not only display the real-time waveform of the signal, but is reflected in the signal analysis and processing module. In this module, the signal's amplitude can be analyzed to obtain the signal's characteristics (such as signal mean, peak-to-peak value, maximum value, root mean square, etc.), and the threshold alarm function can be realized according to the peak value of the signal. Figure 4 shows the original waveform display screen and the amplitude domain analysis function of sample signal. The amplitude domain analysis of the acquired signal mainly includes the peak value, mean value, variance value, and root mean square value of the acquired signal. The peak value of the signal is divided into a positive peak (the maximum value of the waveform above the zero mark line at a certain moment) and an inverse peak (the minimum value of the waveform below the zero mark line at a certain moment), and the peak value directly reflects the maximum deviation of the signal, directly related to the damage to the mechanical structure. The mean value of the signal describes the static component of the dynamic signal, which is the average of the signal over a certain period of time. The variance of the signal describes the distribution of the random signal around its mean, which reflects the fluctuation component of the dynamic signal and is the mean of the signal's deviation from the square of the mean. The rms value of the signal represents the effective value of the signal, describes the square root of the average power of the dynamic signal, and reflects the effective energy of the signal.

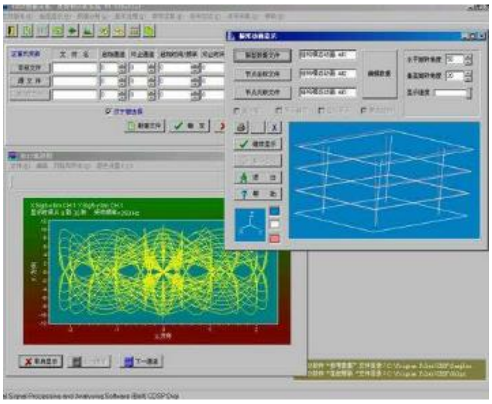

Figure 4: Program of amplitude domain analysis function of sample signal

4. Results and discussion

The purpose of data fusion is to eliminate the uncertainty in the measurement based on limited data collection and to obtain a measurement result that is more accurate, more reasonable and reliable than the arithmetic mean of a limited number of measurements. The results obtained by online performance calculation using the state parameters after data fusion as the original data can better reflect the conditions of the monitoring information in the equipment operating status monitoring system. Further, multi-sensor data fusion technology can be used to handle the fusion of spatial distribution data and time distribution data.

Taking a simulation experiment as an example, according to the alarm data recording and query results, the alarm temperature data in seconds are taken out and divided into two groups, as shown in Table 1.

Table 1: Analog alarm temperature data

	1	2	3	4
X1	16.36	15.53	15.58	15.50
X2	15.35	15.54	145.57	15.50

steps are required for fusion of 8 measurements. The average of the sampling when the fusion granularity is 8, 4, 2, and 1 in each step is shown in Table 2.

Table 2: Data Fusion Process of Nodes

Fusion granularity	Fusion results	Detail factor
8	[16.36,15.53,15.58,15.50,15.55]	
4	[15.95,15.54,15.55,15.54]	[0.41,0.04,0]
2	[15.74,15.54]	[0.21,0]
1	[15.64]	[0.1]

The weighted average batch estimation algorithm based on arithmetic mean and batch estimation theory is suitable for the fusion of network data. After obtaining two sets of highly reliable measurement, i.e., two reliable initial measurements, the variances of both measurements are weighted and fused. The measurement with larger variance is given smaller weights, and the data with smaller variance is given with larger weights. In this way, measurements with higher confidence than the pure arithmetic mean method can be obtained. This fusion algorithm is significant for reducing or eliminating the uncertainty of the network data (such as the impact of noise on the DC amplitude), so as to improve the credibility of the data.

The data fusion algorithm based on Haar wavelet transform is suitable for the fusion of sampling data of a sensor node at a certain time, and the final fusion result is sent to the upper application or user. Via analyzing the data fusion algorithm based on Haar wavelet transform, we know that the algorithm will perform fusion of 8 temperature values to get the data of the granularity of. The energy consumption of sending the fusion data to d distance is 1/8 of that to send 8 data to d distance. With this algorithm, the amount of data sent can be effectively reduced without reducing the credibility, thus saving the energy of sensor nodes.

5. Conclusion

The data acquisition technology of chemical equipment is studied using wireless sensor technology. Various processing functions of the status data of equipment were simulated based on the virtual instrument software developed and designed combining wireless sensor network, wired Ethernet and the Zigbee technology, and through simulation signals. The Data Acquisition System of Chemical Equipment Based on Wireless Sensor Network was designed. The research results show that the accuracy of the data results was high, and Zigbee ad hoc network was achieved for collecting of network data. The result shows that the system designed in this paper can meet the needs of real-time monitoring of the operational status of chemical equipment and is practical.

In view of the research results, future work should focus on improving the function modules of the integrated system, improving and stabilizing the performance of the system. In addition, we should actively study the intelligent computer system for fault diagnosis of chemical equipment, design the health diagnosis of chemical equipment, build a 3D configuration composite client, and provide better convenience for chemical companies and customers.

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