The Research of the Intelligent Device Management and Diagnostic

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Abstract
By our research and implementation of intelligent device management and diagnostic system which are based on Wireless HART Technology. In this essay we focus on the application of the wireless HART intelligent devices, explaining the wireless HART protocol and its four-level model, putting forward the wireless HART-USB potable gateway, by which the operating personnel at the scene can obtain data for diagnosis and modification directly from the PC. Then we briefly discuss the design module of intelligent device management system. In the end, we mainly emphasize on the introduction of the mathematical model which is based on the pneumatic control regulator and is used for diagnosis. And we represent the steps of verifying its correctness.

Keywords: Wireless HART; Communication Technology; Instrument Management and Diagnostic; Wireless HART-USB portable gateway; Diagnostic model

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1. Introduction
Industrial wireless technology is a revolutionary technology which is aimed at reducing the cost of industrial measuring and controlling system and expanding the range of applying industrial control systems. Wireless HART is a wireless HART network protocol specifically designed for process automation applications. And wireless HART standard was launched by HART Communication Foundation on September 8, 2007. This paper discusses the research and realization of the intelligent device management and diagnostic based on Wireless HART technology. And in this paper, we also design a wireless HART-USB portable gateway which can bring convenience for the operating personnel at the scene to modify and diagnose the HART intelligent devices. Then we bring an end to the paper with a description of a diagnostic model and a validation of its correctness.

2. Wireless HART Protocol
Wireless HART is a wireless mesh type (Mesh) network communication protocol designed specifically for process automation applications. It is a core part of the HART field communications protocol HART7.0. As with all instruments and equipment conforming to the HART protocol, Wireless HART protocol is backward compatible with existing HART devices and applications [1-2]. Existing HART applications can take advantage of the wireless HART protocol.

The wireless HART network management is still centrally managed mode, the network structure is shown in Figure 1. Wireless HART provides three major network elements: the wireless HART field devices, the wireless HART gateway and the wireless HART network manager. Wireless HART Field Devices (WFD) that are connected to the process or to plant equipment. Wireless HART Gateways that enable communication between Host Applications and WFDs in the Wireless HART Network. Gateways support one or more Access Points. A Gateway and its Access Points must included in every Wireless HART network. A Wireless HART Network Manager that is responsible for configuration of the network, scheduling communication between Wireless HART devices (e.g., configuring super frames), management of the routing tables and monitoring and reporting the health of the Wireless HART Network. While redundant network managers are supported, there must be only one active Network Manager per Wireless HART Network. Network Manager is responsible for network
configuration, communication scheduling between the wireless HART network equipment, routing table management, and the report of the health status of the wireless HART network. This feature is significantly different with many wireless short-range network provides the gateway to bear network configuration, a better solution to industrial control systems require redundant mechanisms for reliable transmission [3].

3. Wireless HART Model Structure
Since the cable channel changed into wireless channel, the wired HART protocol which increased the network layer [4].

3.1 Physical Layer
Physical layer protocol is the lowest in the wireless HART network protocol stack, which defines the power and optical signal, line status, clock reference, data encoding and circuit about the data transmission and receiving, furthermore it provides a standard interface to the data link layer device, that is responsible for frequency selection, generated carrier, signal detection, data encryption, modulation and demodulation etc.

3.2 Data-Link Layer
Data-Link Layer provides addressing institutions, building data frame, data error checking, transfer control and provides a standard data interface to the network layer. It also establishes, maintains and releases the data link connection between adjacent network nodes and transfers data link service data unit. Wireless HART command structure is basically the same wired HART. With the network topology changing, HART frame structure is also changed to adapt to the needs of the wireless communication in the original frame.

3.3 Network Layer
When the network formed, communication path will be established. The network layer realizes command driver. Routing protocol is responsible for the data packets from the source node to the destination node through the network, it mainly includes two functions: looking for the optimal routing path between the source node and destination node, forwarding correctly data packets along the routing path.

3.4 Application Layer
The application layer uses a standard HART application layer. HART command set is based on standard data types and processes. The application layer executes the commands,
which is main device requested. HART protocol commands are divided into three categories: general command, common command and special command. General command is the HART protocol with field instruments must be carried out by the function, and ensures the field instruments interoperability to some extent; command range is 0 to 30; common command applies to the most products in line with the HART protocol, but there may be small difference about the HART products of different companies, such as writing the main variable unit, fine-tuning of DA zero and gain etc, command range is 32 to 126. The special command only applies to a specific field device. The company's products has its own unique commands, which are not compatible with each other, such as characterization, and fine-tune the sensor head correction etc, command range is 128 to 253.

4. The design of the wireless HART-USB portable gateway

We design the wireless HART-USB portable gateway based on the wireless HART technology we had introduced. This gateway is mainly aimed at establishing the contact between the site operators and intelligent devices so as to realize the man-machine communication. The following presentation sheds light on its system framework and working principles[5-7].

The design of the wireless HART-USB portable gateway has made it possible for users to receive with a PC the data sent by the field instruments. Through this gateway, data can be viewed on the PC, launched via a PC, so users can control the instruments. Framework is shown as in Figure 2.

The hardware circuit mainly consists of wireless HART adapter and wireless HART control panel. The control panel is mainly responsible for the modulation and demodulation of wireless hart frame, realizing the communication between field devices and the PC.

Software part: mainly parsing and processing the data fields and command domain in the wireless hart frame. Flow chart is shown as in Figure 3.

5. The design module of intelligent device management system

The instrument management and diagnosis system based on the wireless HART communication technology uses Server/Client mode, and multiple clients can share the real-
time information of the server, which realizes remote management, operation and maintenance for the real-time field intelligent instrument, visually reflects state information and process information of the real-time field equipment through the wireless HART communication technology[8]. According to the user needs, the system has the following functions.

5.1 Device Access Function Module
This module obtains the devices attribute information such as manufacturers, device type. It also remotely modifies the device's range, PV units, damping, transfer function and other device configuration parameter information.

5.2 Field Device View Module
This module implements the devices organization according to the control circuit, provides network connectivity of field devices, and achieves each sequence arrangement of devices according to the manufacturer or device type or device station number.

5.3 Record Review Function Module
This module records the modify of field devices: such as device parameters, the reasons for the change and modification times, the operator information. Furthermore it can record live devices add / delete, record and print the alarm status of the equipment.

5.4 Device Configuration Function Module
This module establishes instrument management database, generates device describe files according to the input parameters of the device and configuration information. Then automatically generates the device user interface depending on the device description file, and verified data downloads to the field devices, and to realize the remote configuration of the equipment. Configuration data can be modified, copy and backup.

5.5 Intelligent Regulator Diagnostic Module
This module reads the locator input signal and the feedback signal of the regulator through HART commands. According to the locator's input signal and the opening deviation of the regulator, if beyond set offset value, will be warned. As shown in Figure 4.

![Figure 4. Intelligent regulator diagnostic.](image)

6. Diagnostic Model
From our perspective, online diagnosis is an essential part of the maintenance process of valves. It is universally acknowledged that regulator is one of the most important operating endpoints which plays a key role in the process control system[9]. Therefore, timely maintenance of regulators is particularly critical. However, in early days, people would not do the maintenance work until valves failed, which was very passive and not environmentally friendly for time and parts were wasted. To better this calls for a timely diagnostic system and online diagnosis of valves can be the most suitable one.

Taking the pneumatic control regulator as an example, we can explain the working principle of a kind of regulator shaft thrust model used in the diagnosis of valve failure.
We delivered the relational expression of the thrust, the process fluid pressure and the fluid flow of the regulator shaft by schematizing the manner of flow which takes place inside the regulator (as shown in Figure 5(a)). According to the results of theoretical analysis, the thrust of the regulator shaft is equal to the sum of the spool surrounding pressure of the fluid and the force generated by the change of the amount of motion of fluid between in the valve inlet portion and the orifice therefore the valve shaft thrust $F_j$ is delivered[10-11].

During the process of delivering the regulator shaft thrust, the inspection surface was used as shown in Fig. The integral force above the inspection surface is known as the force $F_p$ acting on the spool. We can obtain the formula from the relationship between the output and input of fluid exercise on the inspection surface which is shown in Figure 5(b).

![Figure 5. Schematizing the manner of flow](image-url)
\[ F_p = S_p (P_i + P_a) + \mu (\rho Q V_1 - \rho Q V_v \cos \psi) \]  

\[ (1) \]

\( Q \): Fluid flow;  
\( P_i \): Pressure of the regulator's inlet (peak pressure);  
\( S_p \): The cross-sectional area of the regulator's port;  
\( P_a \): The Atmospheric pressure;  
\( V_1 \): Flow rate of the regulator's inlet;  
\( V_v \): Orifice's flow rate;  
\( \psi \): Fluid outflow's direction;  
\( \mu \): A coefficient related with the fluidal;  
\( \rho \): Fluid's density.

Since orifice cross-section area is very small when compared to the cross-sectional area of the regulator's port, the area of the inspection surface can be regarded as equal to the cross-sectional area of the regulator's port. Moreover, with the influence of the pressure of the regulator's outlet and the atmosphere pressure, the areas of the regulator's spool and the cross-sectional being the same, regulator's shaft thrust is released as \( F_j \):

\[ F_j = F_p - (S_p - S_s)(P_2 + P_a) - S_s P_a = S_p \Delta P + S_s P_a + \mu (\rho Q V_v \cos \psi) \]  

\[ (2) \]

\( \Delta P \): Differential pressure of fluid;  
\( P_2 \): Pressure of the regulator's outlet;  
\( S_s \): The cross-sectional area of the regulator's shaft.

In addition, considering the rapid expanding from the regulator's orifice to outlet head that occurs loss (pressure drop), by the Bernoulli's theorem we can obtain that:

\[ \Delta P / \rho = \left( \frac{V_v^2}{2g} \right) \left( 1 - \frac{S_v}{S_p} \right)^2 = \left( \frac{Q^2}{2} \right) \left( 1 - \frac{S_v}{S_p} \right)^2 \]  

\[ (3) \]

According to the formula (3), and the principles of quality preservation, the formula (2) becomes:
Using formula (4) which expresses the regulator shaft thrust model, and the relationship between the regulator operator and the input-output of regulator's portion to diagnosis is namely to diagnosis by monitoring state of equilibrium of the force of the regulator's shaft:

\[
P_d S_d = K_1 x + F_0 \pm B_0 + S_p \Delta P + S_p P_2 + \mu \left\{ \frac{\rho Q^2}{S_p} - \left( \frac{\rho Q^2}{S_p} + \sqrt{2\rho \Delta P} \right) \cos \psi \right\}
\]

where:
- \(P_d\): Operator's air pressure;
- \(S_d\): Baffle's effectively basal area;
- \(x\): regulator opening;
- \(K_1\): Modulus of elasticity;
- \(F_0\): Spring pre-pressure;
- \(B_0\): Gasket's friction.

Next, we tested the proposed model, and the test results are shown in Figure 6.

7. Conclusion

The instrument management and diagnosis system, which based on the wireless HART communication technology, realizes information management of the HART intelligent instrument. Not only does the application of the wireless HART-USB portable gateway make it convenient for operating personnel to accomplish their work, it cuts the cost of enterprises to a large extent, as well as realizes informationization in management of on-site wireless HART intelligence devices. The validation of the diagnostic model has laid foundation for the online diagnostic system.

Acknowledgements

This work was financially supported by the National Natural Science Foundation of China (No.61070121, 60973094).

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