Research on safety information terminal of household gas

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Abstract: In this study, the important role of the household gas safety information terminal in the gas supply industry is introduced, and the necessity of studying the new type of the household gas safety information terminal is pointed out. Then, the function and specification of the terminal are introduced. The system design scheme of the terminal is described, including gas, photoelectric reading conversion device, valve, wireless communication module, pressure detection unit, gas leak detection unit, and control unit; the characteristics, functions, and performance indexes of each part of the system are described in detail. Finally, the practical application effect of the terminal is given.

1 Introduction

Gas supply service is one of the public utilities; because of the flammable and explosive nature of gas, safe and stable gas supply is the top priority of the fuel industry. Traditional gas companies rely mainly on human and material resources to complete home security inspections, pipeline patrols, and emergency repairs. This way of working is time-consuming, and it does not allow gas supplier companies to monitor the state of gas pipelines in real time. In recent years, the rapid development of sensor technology [1–5] and Internet of things technology [6–10] has provided technical means for real-time monitoring of gas operating conditions. A household gas safety information terminal with overpressure, pressure loss, overcurrent, and combustible gas detection functions is installed indoors to collect real-time abnormalities in the use of indoor gas, and when abnormal conditions occur, lose the terminal's built-in valve, and send alarm information to the centre at the same time. In this way, the gas company’s requirements for safe gas use can be satisfied. Therefore, it is very important to develop a household gas safety information terminal [10–15] with multiple functions, network communication, and linkage.

2 Terminal requirements

2.1 Functional requirements

As shown in Fig. 1, the terminal includes pressure sensors, external gas leak detectors, photoelectric direct reading counters, General Packet Radio Services (GPRS) modules, intelligent valves, and micro-processing controllers.

The pressure sensor can detect the gas pressure and alarm to the control centre via the GPRS module under overpressure or low pressure. The external gas leakage detector can detect the leakage of external gas. Under abnormal conditions, it can also alarm the monitoring centre through the GPRS module. Under the condition of alarm, the intelligent valve can automatically cut off the gas supply and ensure indoor safety. The photoelectric direct reading counter can convert the gas metre readings into digital signals and upload the readings to the monitoring centre through the GPRS module.

2.2 Technical specification requirements

(a) Methane alarm set value: 1–25% lower explosive level
(b) Carbon monoxide alarm set value: 50–300 ppm;
(c) Methane response time: ≤30 s;
(d) Carbon monoxide response time: ≤30 s;
(e) Pressure acquisition error: Undervoltage: +0.20 kPa; overvoltage: ±0.35 kPa.

3 System design scheme

3.1 System architecture

Fig. 2 is a system architecture diagram.

The terminal consists of valves, mechanical character wheels, pressure detectors, CO and CH₄ gas detectors, wireless communication units, reading conversions, and control units. Using the GPRS/code-division multiple access (CDMA) network, command and data is exchanged with remote management and control systems through SMS. The following section describes the design of each module of the terminal.
3.2 Gas metre
The terminal is composed of a universal gas metre and a control unit. The control unit can be used with the universal gas metres of many manufacturers at home and abroad.

3.3 Photoelectric reading conversion device
Reading conversion is the conversion of the mechanical reading of the gas metre to the electronic reading. It is the most basic and the most essential part of the terminal; its reading accuracy and stability directly affect the practicality of the terminal control system.

The terminal adopts the principle of an absolute photoelectric encoder and directly recognises the character wheel number of the gas metre display window by measuring the absolute angle of the character wheel.

3.4 Valve
Valve is the executing mechanism of the gas metre to realise the function of no card prepayment and the safety switch valve command.

3.5 Wireless communication module
The wireless communication module mainly includes the GPRS/CDMA chip, antenna socket, SIM card socket and its circuit, controllable power supply circuit, and peripheral circuit.

3.6 Pressure detection unit
The pressure detection module mainly includes pressure sensors, amplifying circuits, AD acquisition, and controllable peripheral circuits of power supply boxes. The pressure sensor is the core component of the module, which directly affects the accuracy, reliability, and stability of the acquisition. The model of pressure sensors is shown in Fig. 3.

3.7 Gas leakage detection unit
The gas leakage detection module consists of CH₄ and CO gas detectors, communication units, and alarm devices. The gas detector is the core component of the module, which directly affects the reliability and stability of the detection. The model of the gas leakage detection module is shown in Fig. 4.

3.8 Control unit
The control unit realises reading conversion, valve control, fault diagnosis and alarm, and human–machine interaction. The schematic diagram is shown in Fig. 5.

3.8.1 Fault detection and alarm: The control unit has the ability to diagnose all kinds of fault conditions, can alarm with the valve and display, and can feed all the fault information to the management system. The specific functions include
(a) Valve fault detection
(b) Direct reading anomaly detection
(c) Battery undervoltage detection
(d) Pressure sensor fault detection
(e) CO and CH₄ gas probe fault detection
All fault flags are recorded in the terminal status byte and can be fed back to the management system.

3.8.2 Human–computer interaction:

(a) Button: the terminal sets the valve opening/inquiry button. This button has both the start valve and the display switching function.
(b) Display content: accumulated readings, valve status, pressure alarm status, CO gas alarm status, CH₄ gas alarm status, battery-level indication, battery change prompt, and fault code prompt

3.8.3 Valve control: The control unit can effectively and reliably control the valve switch according to the control commands of the management system and the power supply voltage, and accurately feed back the valve state.

3.9 Power estimation and power supply scheme

The terminal power consumption mainly includes the following aspects:

(a) The terminal standby power consumption: due to the use of low power series chip, the chip has power saving mode – sleep mode, and considering other peripherals, standby current is calculated at 20 μA.
(b) GPRS module communication power consumption: according to sending and receiving text messages every day, it takes 10 s for each online configuration, and it takes ~5 s to send and receive information once. The online power consumption of the terminal is ~68–138 mA. After the terminal is online, the power consumption current is ~11.33–13.96 mA when it is waiting to receive the message.
(c) Power consumption of the pressure sensor: power is supplied by a constant current source and the current is ~1 mA. Each acquisition time is 10 ms. To save power, the constant current source supply is turned off when the acquisition is completed. The pressure sensor is collected once every interval.
(d) Gas leakage detector power consumption: As a stand-alone detector is used, the detector itself is powered by the mains and communicates with the terminal control via RS485. There is only the terminal serial communication and RS485 interface current, and the RS485 interface chip standby current is ~175 μA, and send and receive operating current is 12 mA. Assuming that the baud rate is 9600 bps, 20 bytes requires ~0.2 s, plus delay waiting, then each acquisition time is ~0.3 s and the current is 12 mA. To save power, the RS485 interface uses a controllable power supply to shut off the power supply when the acquisition is complete. However, in order to detect the probe fault status, it is determined that the query will be performed every 10 min.

(see (1))

The pressure sensor is collected once every 1 min, the gas sensor is collected once every 10 min, and the SMS is sent and received once a day: (see (2)) . Assuming that the terminal performs the on–off valve action once a month, the required capacity of the on–off valve for 10 years is

\[ (80 \times 3 + 80 \times 0.2) \times 12 \times 10 / 3600 = 8.53 \text{(mAh)} \]  \hspace{1cm} (3)

For 10 years of work, the maximum required capacity is

\[ 42.95 \times 24 \times 365 \times 10 + 8.53 = 3770.95 \text{(mAh)} \] \hspace{1cm} (4)

Average current = quiescent current + pressure sensor operating current
+ gas detector communication operating current
+ GPRS communication current

Average current = \(20 + 1000 \times 10/60 + 12000 \times 0.3/(10 \times 60)\)
\[+ (138000 \times 10 + 13960 \times 5)/(24 \times 3600) = 42.95 \mu A\]  \hspace{1cm} (2)

Fig. 5 Schematic diagram of control unit

Fig. 6 Developed product

If four alkaline batteries are used, the effective capacity is generally 2 AH. Alkaline batteries have a self-discharge rate of 15% in a standard environment (60% RH and 20°C):

\[2 \text{ years effective capacity} = 2 \times (1 - 0.15^4) = 1.4 \text{ (Ah)} \] \hspace{1cm} (5)

Based on the above theoretical calculation and analysis of power consumption, alkaline battery power supply can guarantee two years of use.

If the external power supply is supported, since the existing gas detectors directly supply power through the mains, the gas detectors may provide the DC power supply, and the terminal internally supports the alkaline battery backup power supply.

4 Product and practical application effect

The developed product is shown in Fig. 6.

The main components of the realised product are as follows: four-wire motor valve, mechanical character wheel/optical reading head, wireless communication unit, control unit, pressure detector, and CO and CH₄ gas monitor.

At present, the product has been tested and operated by large gas companies such as Guangzhou Gas Group, Fuzhou China Resources Gas, Kunming China Resources Gas, and Chengdu City Gas. All performance indicators have met the design requirements. The success rate of metre readings and the monthly metre reading success rate are up to 100%, improve the user's gas security, realise the management centre's real-time monitoring and centralised management of terminal billing information, gas security, avoid a...
lot of security accidents, get customers' wide praise, and prepare for mass use.

5 Conclusion
This paper describes a household gas safety information terminal, describes the system components of the terminal and the functions, performance, and technical indicators of each part. Finally, the actual application effects of the terminal are introduced. The terminal achieves the following innovations:

(a) By installing a household safety information terminal with pressure detection and flammable gas detection in the home, when an abnormal situation occurs, the terminal can close the built-in valve of the terminal and send an alarm message to the monitoring centre of the gas company. According to the alarm information, the monitoring centre promptly directs the management system to close the corresponding valve and arrange emergency repair personnel.

(b) The implementation of the terminal depends on the realisation of various types of sensors. The pressure sensor can detect the gas pressure and alarm the gas company's monitoring centre through the wireless network under overpressure or low pressure. External gas leak detectors can detect indoor gas leaks and alert the monitoring centre through the wireless network.

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