Research on intelligent ultrasonic gas meter based on Lora communication technology

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Abstract
The existing membrane gas meter has the disadvantages of low measurement accuracy and difficult to realize remote monitoring. The new ultrasonic gas meter can solve these problems after adopting the new Lora communication technology. This paper describes the measurement principle of the ultrasonic gas meter and the components of the ultrasonic gas meter. The hardware composition block diagram of the gas meter and the design idea of low power consumption are described. The software design framework and main design flow chart of the gas meter are described. The detailed design of segment code liquid crystal is described. The design of Lora communication module is also described in detail. The flow measurement accuracy of the gas meter in the flow range of 0.16 m^3 / H ~ 6m^3 / h and the temperature adaptive flow measurement accuracy in the temperature range of - 10 ℃ ~ + 40 ℃ meet the measurement accuracy requirements of national standards, In the actual application scenario, the communication distance and communication performance of the gas meter also meet the requirements of customers. In the actual application scenario, the communication distance and communication performance of the gas meter also meet the requirements of customers. The gas meter has been used in many gas companies for a long time and in large quantities, and the results meet the use requirements. Finally, the conclusion is given and it is pointed out that the gas has reached our expected goal.

1. Introduction

Nowadays, most domestic and foreign residential users use membrane gas meters for gas consumption measurement. A flexible membrane is installed in the membrane gas meter. During operation, the inner membrane of the meter is driven by the gas pressure difference at the inlet and outlet of the gas meter, so as to measure the gas volume. Membrane gas meter is greatly affected by temperature, especially after long-time measurement, mechanical wear occurs, which seriously affects gas volume measurement.
Compared with membrane gas meter, ultrasonic gas meter based on ultrasonic measurement has the following advantages:
It is a pure electronic gas meter with no mechanical moving parts, low failure rate, no wear of measuring parts, good durability, and no deterioration of measuring accuracy in long-term use; It can accurately collect the cumulative flow; It is small in size and light in weight; It can carry out temperature compensation; It is convenient for remote measurement, and can realize step pricing, convenient for remote data transmission, etc.
The communication technology has also experienced many technical iterations, and the latest Lora communication technology based on spread spectrum communication technology is gradually applied in the remote communication technology of measuring instruments. Therefore, it is of great significance to develop an intelligent ultrasonic gas meter based on Lora communication technology.

2. Measurement principle and system composition

2.1 Measurement principle
The gas meter is a kind of velocity instrument which causes the time difference of ultrasonic forward and reverse flow propagation through the effect of gas flow on ultrasonic beam in a closed pipeline.
The actual propagation velocity of ultrasonic wave in the gas is composed of the propagation velocity of ultrasonic wave in the static state of the gas and the component of the axial flow velocity of the fluid in the ultrasonic propagation direction, Ultrasonic wave propagates fast in the downstream direction and slow in the upstream direction. Measure the propagation time in the forward and reverse flow directions, calculate the time difference, calculate the gas flow rate by using the relationship between the time difference of ultrasonic forward and reverse flow propagation and the propagation

distance, and then obtain the gas flow through the cross-sectional area of the sound channel of the gas meter.

The basic principle of ultrasonic gas meter with time difference method is shown in Figure 1.

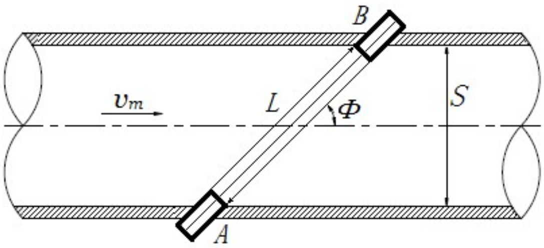

Figure 1 Basic principle diagram of time difference gas meter

The relationship between ultrasonic forward and reverse flow propagation time of gas meter and each quantity is as follows:

$$t_{down} = t_{AB} = \frac{L}{c_f + v_m \cos\phi}$$

$$t_{up} = t_{BA} = \frac{L}{c_f - v_m \cos\phi} \qquad (1)$$

Where:

t_{down} ——time of ultrasonic wave propagating downstream in fluid, s;

t_{up} ——time of ultrasonic wave propagating counter current in fluid, s;

L ——Length of sound channel, m;

c_f ——Speed of sound wave propagation in fluid, m/s;

v_m ——Average axial velocity of gas, m/s;

ϕ ——Channel angle, ° .

According to the two formulas of equation (1), the fluid velocity can be calculated as:

$$v_m = \frac{L}{2\cos\phi}\left(\frac{1}{t_{down}} - \frac{1}{t_{up}}\right) \qquad (2)$$

The instantaneous flow can be obtained by the relationship between v_m the average velocity of the gas in the closed pipe and S the cross-sectional area of the sound channel.

$$q = v_m \times S \qquad (3)$$

Where:

S ——Cross sectional area of sound channel, m^2;

q ——Instantaneous flow, m^3/h.

3. Design of ultrasonic gas meter

3.1 system design

The system schematic diagram is shown in Figure 2:

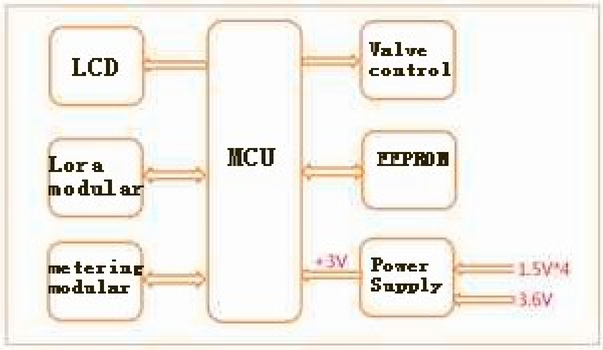

Figure 2 System principle block diagram

The circuit design should be as simple as possible and low power consumption design is required; The components must be low power consumption; Adaptive power control technology is adopted; At the same time, the dual battery power supply technology is adopted to supply power to the metering module separately to prevent the metering module from being unable to measure due to power shortage. In the example circuit, the measured power consumption is only (16.5-50) microwatts.

3.2 Measuring flow channel design

The design of the internal flow channel of domestic ultrasonic gas is very important. The flow channel directly affects the gas flow in domestic ultrasonic gas, which determines the accuracy of the ultrasonic measurement module. When designing the gas meter, we creatively used the CFX simulation software of ANSYS to carry out the gas hydrodynamics simulation research. Figure 3 shows some simulation results. The research results provide a certain theoretical basis for improving the internal gas channel structure design of ultrasonic gas meter, and also provide a certain guarantee for improving the stability and accuracy of ultrasonic gas measurement.

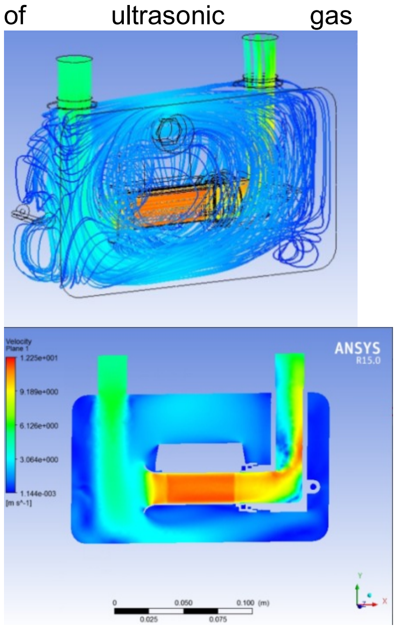

Figure 3 Simulation diagram of gas flow in internal structure of domestic ultrasonic gas meter

3.3 Detailed design of segment code liquid crystal

The LCD part adopts special customized LCD. The displayed contents include characters: instantaneous flow (x.xxx) L/s, cumulative flow (xxxxxx.xxx) m^3, battery replacement, valve opening and valve closing. The LCD is shown in the following figure 4: 21 character segments +17 digits, and 135 segments are displayed. The display is uniform and backlit. The display of cumulative flow and instantaneous flow will be refreshed once every 2 seconds. The display of "hour: minute" will be displayed normally. The display of "year" and "month + day" will be displayed once every minute. After 3 seconds each, the display of "hour: minute" will be restored.

Figure 4 Liquid crystal display panel

1）Instantaneous flow

Instantaneous flow shows the real-time flow value. The flow measurement range of the ultrasonic measurement module is G1.6～G4. The maximum flow range is (2.5~6)m^3/h. The maximum instantaneous flow is (0.694~1.666) L/s. The minimum flow range is (0.016~0.04) m^3 /h, and the minimum flow is (4.44~11.11) mL/s.

Instantaneous flow display: the instantaneous flow display data range is between the maximum flow and the minimum flow range. At the same time, the flow is calculated in L, so the display is in L, accurate to 0.001,i.e. 1.0mL, i.e. the display flow range is (0.000~1.666) L/s.

Under the normal working mode, the flow value is collected once every 2S, the instantaneous flow value and cumulative quantity are calculated, and the display part is also updated once every 2S.

2） Cumulative flow

The cumulative flow is based on the instantaneous flow detection, and the sampling frequency is 2S. Therefore, for the collected flow data, the cumulative flow is calculated in 2S, and the flow value within 2S is the instantaneous flow multiplied by the cross-sectional area of the inner channel. Add up the 2S flow value with the original flow, that is, the new cumulative flow value. The cumulative flow is displayed in m^3.

3.4 Lora communication design

The indoor equipment adopts wireless communication between the domestic ultrasonic gas meter based on spread spectrum communication technology and the concentrator. The user networking diagram is shown in Figure 5. The household ultrasonic gas meter based on spread spectrum technology adopts Lora wireless communication technology to upload the user's gas consumption information to the concentrator, which then transmits the information to the community management machine, which then transmits it to the management center, which further processes the information. As a terminal device, domestic ultrasonic gas meter can not only realize remote meter reading, but also close the built-in valve when detecting gas leakage or overcurrent or arrearage, and cut off the gas source to ensure safety and normal metering consumption.

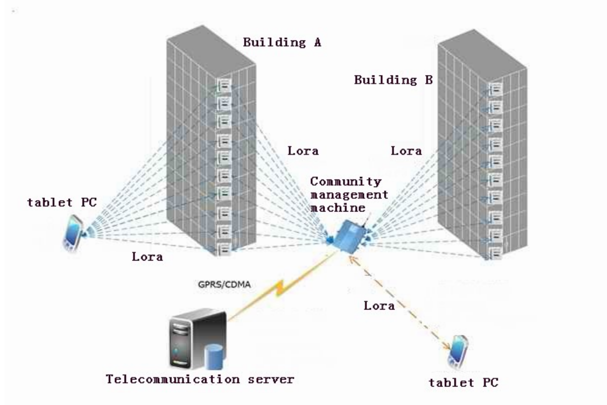

Figure 5 User networking diagram

4. Developed products and test results

4.1 Ultrasonic gas meter developed

The ultrasonic gas meter developed is shown in Figure 6:

Figure 6 Ultrasonic gas meter

4.2 Normal temperature flow accuracy test

Table 1 shows the test results of normal temperature (20 ℃) flow accuracy of several ultrasonic gas meters of G2.5 specification:

Table 1: Normal temperature (20 ℃) flow accuracy test results of G2.5 specification.

Test flow point	Experimental results（%）			
	First gas meter	Second gas meter	Third gas meter	Fourth gas meter

q_{max}	-0.32	0.17	-0.73	-0.44
$0.7q_{max}$	-0.16	0.45	0.22	-0.21
$0.4q_{max}$	-0.15	0.33	0.08	2.86
$0.2q_{max}$	-0.45	-0.02	0.73	-0.65
$0.2q_{max}$	0.72	-0.09	-0.24	-0.81
$0.1q_{max}$	-0.01	0.22	0.26	-0.11
$3q_{min}$	-0.41	-0.59	-0.35	-0.52
q_{min}	-007	-0.19	-0.06	-0.59

It can be seen that the measurement accuracy meets the requirements of level 1.5 meter

4.3 Temperature adaptive flow accuracy test

The test results of temperature adaptability flow accuracy of two meters of G2.5 specification are shown in Table 2:

Table 2: Test results of temperature adaptability and flow accuracy of two meters of G2.5 specification:

Test items	Temperature of tested meter	Test flow point	Experimental results（%）	
			First gas meter	Second gas meter
Temperature adaptability	-15℃	q_{max}	1.20	0.41
		$0.2q_{max}$	1.06	0.22
		q_{min}	1.87	2.86
	-5℃	q_{max}	0.73	-0.02
		$0.2q_{max}$	0.72	-0.07
		q_{min}	2.17	2.64
	20℃	q_{max}	-0.27	0.09
		$0.2q_{max}$	0.33	0.22
		q_{min}	0.93	0.62
	35℃	q_{max}	-0.27	0.55
		$0.2q_{max}$	0.32	0.34
		q_{min}	0.23	-0.47
	45℃	q_{max}	-0.51	0.09
		$0.2q_{max}$	0.35	0.40
		q_{min}	0.23	-0.52
	60℃	q_{max}	-0.55	0.31
		$0.2q_{max}$	0.46	0.59
		q_{min}	0.71	-0.89

It can be seen that the measurement accuracy meets the requirements of level 1.5 meter

5. Long term use effect

At present, the gas meter has been applied in batches in a large number of customers for a long time, and some test.

5.1 Flow accuracy test

The long-term operation results of 22 ultrasonic gas meters in 3 years are shown in Table 3

Table 3: Retest of 22 gas meters in 2020:

22 gas met-ers	Delivered in 2017		Retest in 2020			Changes	
Flow point	Root mean square of indica-tion error	Mean value of indica-tion error	Extre-me value of indica-tion error	Root mean square of indica-tion error	Mean value of indica-tion error	Root mean squ--are cha-nge	Mean chan-ge
Q_{max}	0.274	-0.35	Max: 0.56 Min: -0.78	0.282	0.04	0.008	0.39
$0.7Q_{max}$	/	/	Max: 0.58 Min: -0.78	0.295	0.05	/	/
$0.4Q_{max}$	/	/	Max: 0.40 Min: -0.82	0.289	-0.21	/	/
$0.2Q_{max}$	0.334	-0.52	Max: 0.52 Min: -0.63	0.312	-0.13	0.022	0.39
$0.1Q_{max}$	/	/	Max: 0.64 Min: -0.76	0.409	-0.26	/	/
$3Q_{min}$	/	/	Max: 0.68 Min: -0.82	0.501	-0.21	/	/
Q_{min}	0.182	-0.09	Max: 1.14 Min: -2.36	0.906	-0.55	0.724	-0.46

5.2 Communication test

The long-term meter reading success rate based on Lora communication technology is shown in Table 4

Table 4: Long term communication test

Operation volume (PCs.)	587486
Meter reading (Times)	5326263
Number of successful meter reading (Times)	5139626
Success rate of over meter (%)	96.5%

According to the three-year operation data:

a. After three years of operation, the indication errors of seven flow points q_{min}~q_{max} are all within the factory range of the new meter (large and medium flow ± 1.5%, small flow ± 3%), which is much higher than the accuracy range required by the in-service verification of the gas meter (large and medium flow ± 3%, small flow ± 6%).

b. After three years of operation, the mean value of indication error of large and medium flow points deviates to the positive direction, which is faster than that of the factory as a whole, and the mean value of indication error of small flow points deviates to the negative direction, which is slower than that of the factory as a whole.

c. After three years of operation, the root mean square error of large and medium flow has no obvious change, and the indication error data is relatively centralized with good consistency. The root mean square error of small flow is obviously larger, and the data discreteness is worse, indicating that the indication error of small flow is obviously affected by the running time.

6. Conclusion

a. The ultrasonic gas meter has the advantages of high precision and small volume in the normal temperature (20 ℃) and temperature adaptability range (-15 ℃ ~60 ℃).

b. The ultrasonic gas meter with Lora communication function has the advantages of long communication distance and high meter reading success rate.

c. After long-term (3 years) actual operation test, the ultrasonic gas meter can reach the accuracy of level 1.5 meter and meet the needs of gas measurement.

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