Intelligent monitoring and control system and control method of intelligent water meter

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***Abstract*—In order to improve the efficiency of household water consumption and reduce leakage, the intelligent water meter and monitoring and control system based on NB-IoT is designed and developed to monitor and analyze the abnormal instrument and equipment and domestic water consumption. Based on the statistics of conventional water consumption, the water consumption law is analyzed and the leakage and abnormal water consumption data is warned. For abnormal water (such as a large amount of water leakage or arrearage) automatic water control, reduce leakage, ensure water safety, improve the efficiency of domestic water and information, intelligent management level.**

***Keywords*—NB-IOT intelligent water meter,Internet of Things intelligent big data platform,Analysis of abnormal water use,Intelligent monitoring and control**

I. Introduction

With the continuous development of modern metering, Internet of things, big data and the new generation of communication technology, the long-distance water meter that integrates data collection, transmission, analysis and management is becoming more and more popular[1-5],Remote water meter transmits water meter information such as water meter user's water usage and water fee to management system platform through operator's network, which changes the working mode of traditional water meter, saves labor cost and improves work efficiency. The combination of remote water meter and management system platform not only improves the modern water management level of water supply companies, but also improves the efficiency of domestic water consumption and reduces leakage. At present, most remote water meters are equipped with useful water collection and reading systems, but they are mainly used for water consumption collection, transmission and visual presentation, and serve for water fee collection. Water consumption data analysis, information mining and related water consumption management are relatively weak[6,7].

In this paper, in order to improve the family life water use efficiency, to reduce the leakage for the purpose, designed and developed based on NB - IOT[8-10] intelligent water meter and monitoring and control system, on the basis of conventional water consumption statistics analysis, the instruments and equipment, an abnormal life water monitoring, analysis, construction of water control strategy, complete quick judgment of water leakage and abnormal data, Reduce leakage, control excessive water consumption, ensure water safety, improve the efficiency of domestic water consumption and information and intelligent management level.

II. Water meter control system based on Internet of Things intelligent instrument big data platform

Use of the Internet of things and cloud computing technology, based on the smart meters big data platform of water meter control system set state awareness, in the use of water control, abnormal analysis, equipment failures at an organic whole, to provide users with safe, reliable water service, provide water administrative department of the information analysis and decision-making service, promote water wisdom ability.

A. System architecture

The intelligent water meter control system constructed based on NB-IoT technology includes terminal layer, network layer, instrument big data platform and application layer. The system architecture is shown in Fig 1.

1) Terminal layer: Smart water meters with integrated NB-IoT modules are connected to the NB-IoT network of telecom operators. Information is uploaded to the IoT platform and control commands are received through the IoT platform.

2) Network layer: The NB-IOT network opened by communication operators can provide a reliable and efficient network for data collection, monitoring, control and abnormal alarm of intelligent water meter control system. The IOT management platform connects different terminals through unified protocols and interfaces and provides flexible and efficient data management such as data collection, classification, and structured storage.

3) Internet of Things intelligent big data platform: The intelligent instrument big data platform establishes a unified device management function, manages the operating data of hardware products in a unified manner, and conducts real-time monitoring and data analysis on equipment failures and other problems. Functions include system management, SMS platform and wechat platform, pipeline management, revenue management, equipment management, data copy, report center, production center, data analysis and management, etc.

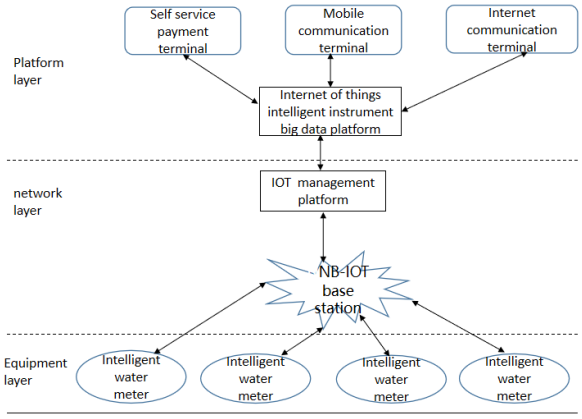

Fig. 1. Framework of intelligent water meter monitoring and control system.

4) Application layer: Implement water management related applications, including user management, billing management, abnormal alarm and so on.

B. Intelligent water meter function

Intelligent water meter is composed of main control module, flow volume measurement module, vibration interference monitoring module, clock module, pre-paid management module (with valve control), voltage monitoring module and remote upgrade module.The main control module stores and processes the data information of each water meter module, and sends the data to the cloud server through the NB-IOT communication module, receives the control instructions from the cloud server, and controls each module; Report alarm information in time.The NB-IOT communication module communicates with the cloud server, periodically reports data, timely reports abnormal situations, and receives clock synchronization, remote parameter setting, and various control commands sent by the cloud server.The flow volume measurement module collects water consumption data, accurately measures the current flow value, and sends it to the main control module, and then sends it to the cloud server through the NB-IOT module.The vibration interference monitoring module collects vibration data and sends it to the main control module, and then sends it to the cloud server through the NB-IOT module.The voltage monitoring module detects the battery voltage. When the battery undervoltage occurs, it records the undervoltage status and sends it to the main control module. Then, the NB-IOT module sends the alarm to the cloud server. At the same time, it also has power failure monitoring function to save measurement data in time to prevent accidental loss. The clock module integrates the real-time clock function. When the clock reports data, the module proactively corrects the clock with the cloud time to keep the clock consistent. Pre-payment management (with valve control), with cloud server platform can realize post-payment, pre-payment, mixed charging and other payment modes, when the main control module sends the valve to open or close the command, open or close the valve. All module programs support remote online upgrade. The remote upgrade module and the cloud server platform can realize the remote upgrade of the module without replacing, disassembling or approaching the meter.

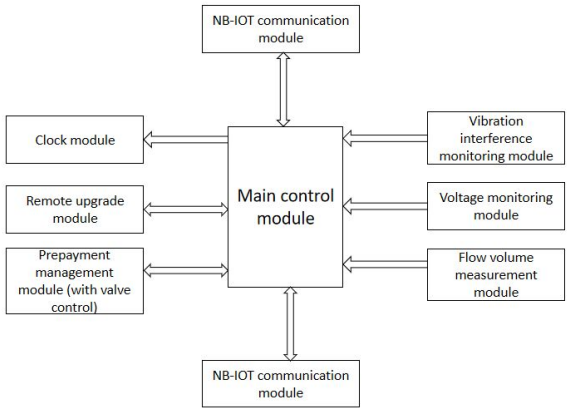

Fig. 2. Schematic diagram of smart water meter.

III. Analysis of Abnormal Water Use

Since the abnormal pattern includes the abnormal increase of water quantity at a specific moment, the feature of increasing water quantity change can be obtained by taking the absolute value of the difference between two adjacent flows. Finally, each sample vector is composed of two features of water consumption and water quantity change. These sample vectors constitute the sample set to identify outliers.

A. Analysis of water consumption characteristics of users

Daily data collection is a commonly used frequency of quantitative data collection. The algorithm in this paper is based on daily data collection for cluster analysis.

The steps to calculate the threshold of abnormal water use are as follows:

1) Data preprocessing: The i day of N users component vector r.

$$r_i = \begin{bmatrix} x_1 \\ x_2 \\ \dots \\ x_n \end{bmatrix} (i = 1, 2, ..., m) \tag{1}$$

Standardized:

$$Z = \frac{x - \overline{x}}{S} \tag{2}$$

Where, x is the sample value of each indicator, $\overline{x}$ is the sample mean, S is the sample standard deviation.

2) Classification of types: K-means clustering algorithm is adopted to analyze the water consumption rules of residential users and divide the user types (such as five types of users, such as nearly zero water users, small water users, normal water user, users with large water consumption and super large water users).

3) Abnormal water usage threshold setting: According to the results of cluster analysis, Classification and extraction of a class of maximum daily water consumption $x^i_{max}(x = 1, 2, ..., m)$, of the vector $r_{max} = [x^1_{max}, x^2_{max}, ..., x^m_{max}]$, calculate vector mean $\overline{X}$.

$$x_i = z_i(\max_{1\le j\le n}\{x_j\} - \min_{1\le j\le n}\{x_j\}) + \min_{1\le j\le n}\{x_j\} \quad (3)$$

Take $\overline{X}$ as the abnormal threshold of water consumption of this kind of water users.

4) : Repeat the above steps to obtain the abnormal water consumption threshold of various water users.

B. Experimental analysis

Analysis of daily water consumption data of 630 households in a community from January 2020 to December 2021.

Taking the daily water quantity of each household as the parameter, k-means clustering algorithm is adopted to analyze the water consumption rule of users in the community and divide the user types into four categories: small water users, normal water user, users with large water consumption and super large water users. The calculated and determined water consumption abnormal threshold is shown in Table 1. When the user's water consumption exceeds the threshold, the system reminds the user to check whether water leakage occurs.

IV. Control Strategy

A. Abnormal control strategy of instrument and equipment

Data analysis management Provides data analysis functions such as enterprise production and operation, user analysis, and device fault diagnosis.

1) Anomaly analysis and control strategy based on monitoring data.: The cloud server analyzes the data reported by the water volume measurement module and vibration module on a daily basis, finds abnormal phenomena, takes corresponding control strategies according to preset thresholds, communicates with users or controls valve closing,shown in Table 2.

B. Abnormal control strategy for water use

According to the cluster analysis results and the calculated daily water consumption abnormal threshold, different water consumption abnormal control strategies can be formulated for different types of users. When the water consumption of users exceeds the abnormal threshold, the system will remind users to check whether water leakage occurs, so as to reduce the occurrence of water leakage events and reduce the leakage rate. When the threshold is abnormally large, close the valve directly to avoid the occurrence of water leakage and greater loss caused by no one at home.

C. Arrears control strategy

For users whose arrears exceed the preset threshold, different response control operations will be adopted according to the user's historical payment situation.

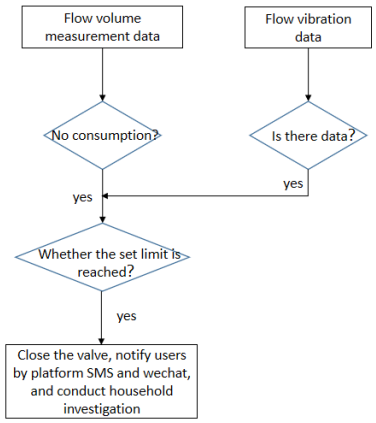

Fig. 3. Abnormal situation of water flow vibration without consumption for a long time.

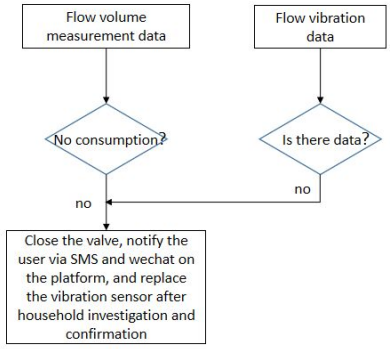

Fig. 4. Abnormal situation of consumption without water flow vibration.

1) : Users with no record of arrears will be notified by SMS/wechat on the cloud platform to pay and keep water supply.

2) : Users with arrears exceeding the preset threshold (historical water consumption is normal) will be notified by SMS/wechat of cloud platform to pay and water will be cut off. Water supply will be restored within half an hour after payment.

3) : The cloud platform will notify users with overdue fees exceeding the preset threshold if there is abnormal heavy water consumption in the past, and the data reporting frequency will be changed to daily reporting. The water supply will be restored within half an hour after the payment, and the data reporting frequency will be changed to normal,shown in Fig.5.

V. Conclusion

As the most promising new generation technology, NB-IoT improves the security and reliability of network transmission compared to other LPWA technologies. This paper designs and develops an intelligent monitoring and control system based on the NB-IoT water meter. The system consists of a terminal and an intelligent big data platform for the Internet of Things. Based on instrument monitoring data and control strategy,

Table I

water user type	households	average daily water consumption(m3/day.household)			
		range	mean value	median value	abnormal threshold of water consumption
small water users	245	(0,0.12]	0.08	0.07	0.36
normal water user	233	(0.12,0.4]	0.27	0.24	0.54
large water users	144	(0.4,0.5]	0.43	0.40	0.65
extra large water users	8	(0.5,0.7]	0.55	0.56	0.90

Table II

serial number	input information	control information	control strategy
1	long term no consumption and water flow	close the valve	close the valve,the platform communicates with customers through SMS or wechat, arrange household investigation immediately,verify whether the measuring sensor is faulty or there is an unmeasured leakage near the upstream of the water meter, Take measures according to the verification
2	consumption without water flow	close the valve	close the valve, the platform communicates with customers through SMS and wechat, i mmediately arrange household investigation to verify whether the vibration sensor fails, and take maintenance measures after verification

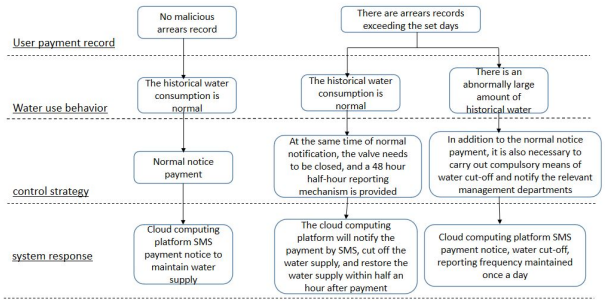

Fig. 5. Arrears control response strategy.

analyze instrument and equipment abnormalities, analyze user water consumption abnormalities with big data, effectively control water consumption abnormalities, reduce the occurrence of water leakage events, reduce leakage rate, and protect the interests of users and water supply companies. The closed-loop control of iot water meters lays a good foundation for water supply enterprises to realize fine management and improve performance management.

VI. Acknowledgment

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References

[1] Zhao Zhihong Explore the design of remote intelligent water meter centralized reading system [J] Computer products and circulation, 2019 (7): 179.

[2] Zhou haiguang, Lu Ning, Zhang Chunyang Preliminary study on the establishment of Intelligent Cloud control intelligent water meter system in the central urban area of Ordos [J] Inner Mongolia water conservancy, 2019 (10): 71-72.

[3] Guo Rongxiang, Lei Gaoyang. Design of remote monitoring water supply system based on PLC and GPRS [J] Computer measurement and control, 2013,21 (10): 2694-2696.

[4] Chen Xu Analysis of smart water meter in urban smart water [J]. Anhui architecture, 2019, (9): 167-169.

[5] Wang Yimin, Qian Haohan, Wang Peijun, Ma Jun Application of intelligent water meter and analysis of industrial development status [J] Measurement and testing technology, 2022,49 (03): 102-105 + 108 DOI:10.15988/j.cnki. 1004-6941.2022.3.029.

[6] Wang Lin, Zhang Liying, Jia Ling, et al Research and application of refined management of household domestic water [J]. Research on water conservancy development, 2021,21 (08): 7-14.

[7] Huang Chen, Li Wenting, Zhang Xu, et al Pattern recognition of abnormal water use in urban water supply network area [J] Journal of Yunnan University (NATURAL SCIENCE EDITION), 2018,40 (05): 879-885.

[8] Wang Anna, sun Shuo, Li Mengyang, et al Research on influencing factors and application of Nb IOT intelligent water meter [J] Water supply and drainage, 2020,56 (09): 109-112118.

[9] Wang Wenqing, Wang Yuchen, Kang Hongbo Design of intelligent water meter collector based on nb-iot [J] Modern electronic technology. 2019,42 (22): 39-43.

[10] Liu Shengli, Guan Baodong, Zhang Yonghui, et al Design and application of Nb IOT Internet of things water meter [J] Water supply and drainage, 2019,55 (S1): 290-293.