

Diagnosis Method of Vortex Flowmeter Based on IoT

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Abstract

Vortex flowmeter is widely used in various applications because it can measure a wide range of media. When the flowmeter fails, the traditional on-site trouble shooting method has the disadvantages of time-consuming and difficult to ascertain the cause due to the complexity of the field conditions. This paper presents a convenient diagnostic method based on the Internet of Things transmission technology, which consists of the hardware, server and website. The hardware is a vortex flowmeter itself, which is to respond to server-side requests and data feedback, the server-side is used for the information interaction between device-side and web-side and data processing, and the web-side is used for the interaction between human-computer. The server can automatically complete the abnormal checking of the flowmeter's settings. More importantly, it can perform the FFT transformation and feature analysis on the original signal of the vortex sensor. After trouble-shooting, a firmware package containing the corresponding solution can be selected to upgrade the firmware of the flow meter on site remotely. Before the flowmeter is delivered from the factory, all parameters will be saved in the cloud as backup. During the process of diagnosis, the original setting parameters are firstly found according to the serial number of the flowmeter, and then the server will one-to-one match the currently settings and the back up data. After matching, the discrepant parameters will be marked and the parameter modification commands will be sent automatically. After the parameter modification, the server will read the parameters again to ensure the correctness of the amendment. The server will push the info of successful amendment and the detailed information of the amendment to the web after the amendment is completed, and the web will show the specific reasons for the failure. If there is no problem with the parameter setting, the original signal of the vortex sensor is to be obtained, and the server will perform FFT transformation on the acquired time domain signal to obtain the amplitude spectrum, and completes the statistical analysis of the frequency variance and the high frequency component. The server will cross check the abnormal data template with the signal characteristics and the corresponding firmware package is automatically upgraded according to the matching result. After the diagnosis is completed, the field data is saved to improve and enrich the template data. The method presented in this paper offers a simple and

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intuitive human-computer interaction, and diagnose a vortex flow meter accurately and swiftly to reduce the maintenance cost of the flowmeter.

1. Introduction

When a non-linear bluff body planted vertically into a pipeline, as the fluid flows by the bluff body, the phenomenon of vortex separation occurs. There forms series of vortices on both left and right after the bluff body and they rotate reversely. Such vortices are known as Karman Vortex Street. Base on the theory above, vortex flow meter is invented ,which measure the flow rate according to the relationship between the frequency of the vortices leaves the bluff body and the flow rate.

When a vortex flowmeter fails, it is troublesome to find the cause of the problem due to its special structure, which means there is great disadvantage on the diagnosis of the vortex flowmeter. To solve the above problems, an IoT-based vortex flowmeter diagnosis method is proposed.

2. System Composition and Overview

The System consists of the hardware, server and website. The hardware is the vortex flowmeter itself, which is to respond to server-side requests and data feedback, the server-side is used for the information interaction between device-side and web-side and data processing, and the web-side is used for the interaction between human-computer.

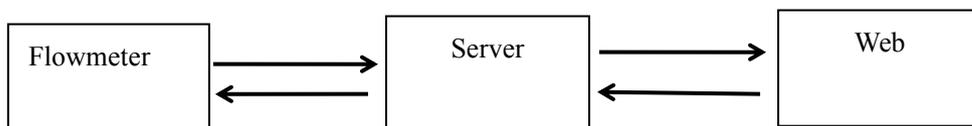


Figure 1: System Block

3. Diagnostic process

3.1 Parameter Settings Check

Website will firstly check if hardware is uploading any error code. If an error code is found, will cross check the parameters related to such error according to the error code. For instance, if find an error code of Err22, which means the max and min flow rate setting incorrect, the system will configure the hardware back to the setting which is preset in factory , according to the series number of the hardware and relevant data stored in database. If there find no error code, system will match and check all parameter and setting to find the abnormal one.

The detailed method for the match and check is as following: Say the acquired parameter is (attr, value), and the default setting of this parameter found in database is (attr', value'). When it is an int parameter, it will be judged as a match if value=value', otherwise a not match.

When it is an float parameter, it will be judged as a match if $\left| \frac{value - value'}{value'} \right| < 1e-5$,

otherwise a not match. After match checking , the parameters judged as not matching will be marked and corrected automatically. The system will also match check the hardware again after the correction to ensure all amendments have been processed and are correct. All amendment of all parameters will be saved in database as analyzing report for checking in the future.

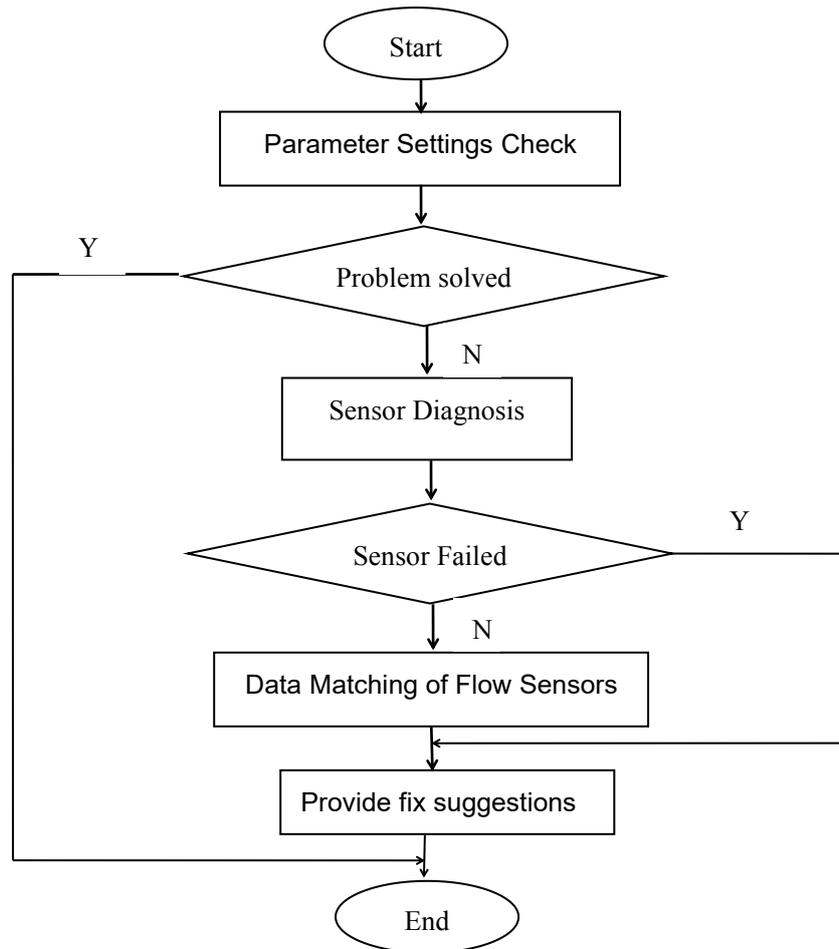


Figure 2: Diagnosis flow chart

3.2 Sensor Checking

The original data of flow sensor is acquired through Website, if the original data curve of flow sensor is straight when there is of flow in pipeline, the system will judge as flow sensor failure. In this case, the server will notify the maintenance engineer to replace the flow sensor on site or return the flow meter back to the factory for repairing.

3.3 Application condition checking

Perform similarity calculations between the origin sensor data with known standard data to decide the cause of abnormal measurement.

The detailed procedure of the similarity calculation are as following: Say Y0 is standard database of normal measurement, and Y1, Y2,~~~Y8 are database of abnormal caused by flow rate too small, flow rate too big, vibration too strong, improper installation, bluff body blocked, mixed-phase fluid, electromagnetic interference and leakage of pipeline. Figure 3 and figure 4 shows different signal curve sample of normal measurement and abnormal measurement caused by bluff body blockage.

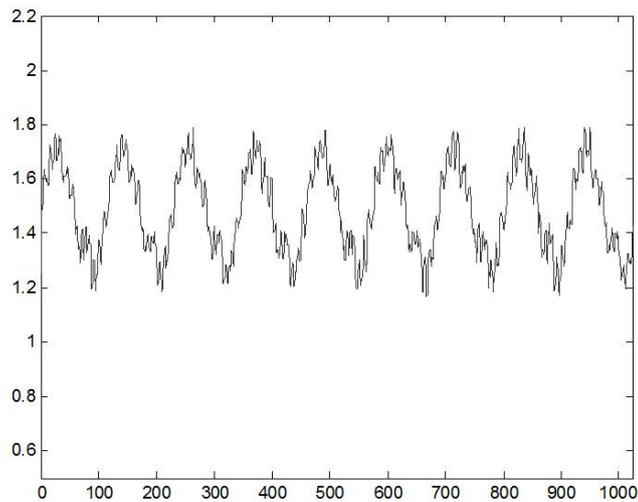


Figure 3: Normal measurement

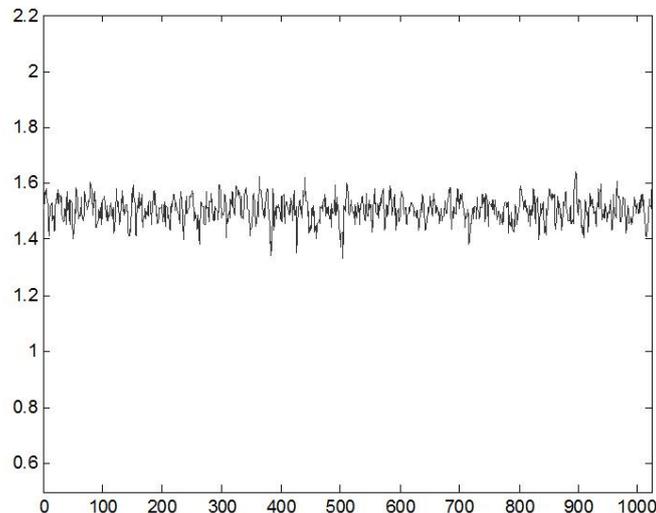


Figure 4: Abnormal measurement caused by bluff body blockage

Say X is origin data from field, C is the nominal size of the flow meter, M is the fluid, T is process temperature and P is process pressure.

Check the standard database and every database of abnormal measurement according to C 、 M 、 $[T-T_0, T+T_0]$ 、 $[P-P_0, P+P_0]$ parameters. T_0 、 P_0 are preset values for

the temperature and pressure range to check. Acquire 20 sets of data samples which is more similar to application condition, say they are $Y0'$, $Y1'$, $Y2'$, ... $Y8'$.

Perform similarity calculation between X the origin data array X and $Y0'$, with the method of Algorithm of Pearson correlation coefficient (Equation 1)

$$\rho_{xy} = \frac{Cov(X,Y)}{\sqrt{D(X)}\sqrt{D(Y)}} = \frac{E\{[X - E(X)][Y - E(Y)]\}}{\sqrt{D(X)}\sqrt{D(Y)}} \quad (1)$$

In the equation above, X is the origin data from field, Y is data sample from database. $\sqrt{D(X)}$, $\sqrt{D(Y)}$ are the standard deviation of X and Y. $E\{[X - E(X)][Y - E(Y)]\}$ is the covariance of X and Y as Cov(X,Y). The quotient of the standard deviation and the covariance of X and Y are so called the correlation coefficient of X and Y (ρ_{xy}).

Compare the average correlation of origin data and standard database against preset threshold. If average correlation is larger than threshold value, the origin data will be judged as normal. This judgement can be a proof of the correctness of the measurement in field and eliminate user's doubt on the measurement. If the average correlation is smaller than threshold, will proceed as following

Calculate the correlation of X and $Y1'$, $Y2'$... $Y8'$ one by one.

Get the the average correlation of each and every array, $\bar{\rho} = \frac{\sum_{i=1}^n \rho_i}{n}$.

Calculate the max value of the average correlation of each array.

Compare the correlation with preset threshold. If correlation is larger than threshold, we can judge that the relevant cause is the cause of the abnormal measurement. We can also recommend relevant signal processing method or advise on application condition improving. In case the signal processing method need to be improved, system will adopt the method provided by Chinese Invention Patent (Publication No. 106775588A) to update the program. If the correlations are smaller than thresholds, engineers shall pay a field visit for trouble shooting locally, system will store the abnormal data in the abnormal database after the judgement. So make the database more resourceful and improve the completeness of future diagnose and improve the efficiency of troubleshooting.

4. Conclusion

To solve the disadvantage of inconvenient of traditional troubleshooting method of vortex flow meter, this paper proposes a new online diagnosis method based on the Internet of FLOMEKO 2019, Lisbon, Portugal

Things technology. The human-computer interaction is intuitive and simple. The method provide an accurately and quickly diagnose on vortex flowmeter and reduce the maintenance cost of flow meter efficiently.

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