Improving the accuracy of valve diagnosis and facilitating more efficient operation through the provision of cloud services

Fumiaki Yamasaki

Mamoru Kagoura

Koichiro Hirao

Keywords

Valve, control valve, maintenance, diagnosis, condition-based maintenance, IoT, cloud, big data

Along with the digitalization of the process industry, technology for diagnosing the status of valves, which are critical equipment for production facilities, has been developed. We provide valve analysis and diagnosis services to prevent production problems from developing due valve failure. In addition, we have begun to provide the Valve Cloud Service, which assists plants by facilitating valve diagnosis work. Through the use of this service, we contribute to better equipment safety and stable operation of production facilities.

1. Introduction

Valves that control process quantities such as flow rate, pressure, temperature, liquid level, etc., in production facilities are indispensable for process control. Valves operate in various environments depending on the production facility, including high/low temperature and high/low pressure environments. If a valve causes a problem, there is a risk that production equipment will be stopped, quality will be degraded, or an accident will occur. Our customers do proactive valve inspections and maintenance to ensure stable operation of production facilities. However, even though the amount of needed maintenance may increase, maintenance personnel with superior skills are retiring, and it is becoming more difficult to secure sufficient staff. To compensate for these constraints, we are introducing diagnostic tools, accumulating know-how, and improving operation efficiency.

Generally, valve diagnostic tools consist of a smart valve positioner with functions that detect valve operation status while the valve is being adjusted, and a diagnostic system that collects and visualizes the operating data detected by the smart positioner. In a survey that we conducted, we found that even if after diagnostic tools were introduced, the valve operating data was not fully used. This may be because valve operating status in the production facility is not correctly detected by the smart positioners, or because personnel are not available to utilize the diagnostic tools. Also, know-how is required to understand the information made available by the diagnostic tools and to take countermeasures. Furthermore, with the worldwide spread of COVID-19, it has become more difficult to understand whether the condition of valves is sound, because maintenance personnel have restricted access to manufacturing sites to prevent infection, or are recommended to work remotely.

To contribute to the stable operation of valves in production facilities, Azbil provides 300 and 700 series smart positioners, the PLUG-IN Valstaff control valve maintenance support system, and a valve analysis and diagnosis service that evaluates the health of valves in depth by combining the large amount of valve operating data collected by Valstaff with our know-how. Also, in order to enable sustained use of our services, we began to provide our Valve Cloud Service as an SaaS (software as a service) solution.

In this paper, we report on efforts to correctly detect the condition of valves in production facilities, to appropriately evaluate the collected operating data, and to provide long-term support for stable operation of valves. In sections 2 to 4 we describe what we have been working on to utilize valve operating data, problems and solutions for utilizing valve diagnostic data, and future prospects for valve diagnosis.

2. Efforts to utilize valve operating data

Azbil has been focusing for some time on the introduction of smart positioners for new facilities and the replacement of aging positioners. Specifically, this applies to our 300 and 700 series smart positioners. Regardless of the shape of the valve, it can be controlled and its conditions monitored by installing a feedback lever within the accuracy-guaranteed angle of rotation range (±4° to ±20°). In particular, the 700 series is equipped with an air pressure sensor to detect abnormalities in the frictional force or air circuit, and can make use of more operating data than the 300 series, so the condition of the valve can be understood in greater detail.

Also, we provide Valstaff for the collection and visualization of the operating data detected by smart positioners. Valstaff operates on Azbil's InnovativeFIeld Organizer™ device management system or on Plant Resource Manager (PRM), a product of Yokogawa Electric Corporation. With Valstaff, valve condition can be understood using the operating data from the 300 or 700 series.

Below, we explain our efforts to detect effective operating data with these tools. Section 2.1 describes change from previous control current range, section 2.2 describes smart positioner and valve travel error, and section 2.3 describes how to handle valve operation data in irregular times.

2.1 Change from previous control current range

In many existing product facilities, a distributed control system (DCS) is used for operation control. Valves are controlled mainly by electric or pneumatic positioners (analog positioners) using a force-balancing method. Internally, an analog positioner is a collection of springs and sliding parts, so abrasion and deterioration occur due to vibration during plant operation or other environmental conditions. A resulting drawback is that the zero point for valve travel (PV) and the span position change, with the result that the valve may not fully close or fully open. To compensate for this, input signals (SP) from the DCS may be not only in the normal 4–20 mA range (0 to 100 %), but also 4 mA or less (0 % or less) or 20 mA or more (100 % or more), so that the analog positioner will fully close or fully open the valve even if the zero or span position of the analog positioner has changed (figure 1, top).

When smart positioners are introduced, the amount of control current must be corrected. Smart positioners are equipped with an internal CPU and have a required drive current minimum. If a smart positioner is introduced without changing the typical control current, the current will be inadequate and the CPU (computational circuits) will stop, preventing the collection of the required operating data.

Azbil's 300/700 series smart positioners have forced fully open and fully closed functions, and the output air pressure from the smart positioner can be forcibly controlled with respect to the input signal (%). Regardless of changes in the zero point or span, which were previously problematic, Azbil's positioners operate toward the fail-safe direction. Therefore, the input signal from the DCS is changed so that it remains equal to or more than the minimum drive current. As a result, valid operating data can be collected (figure 1, bottom).

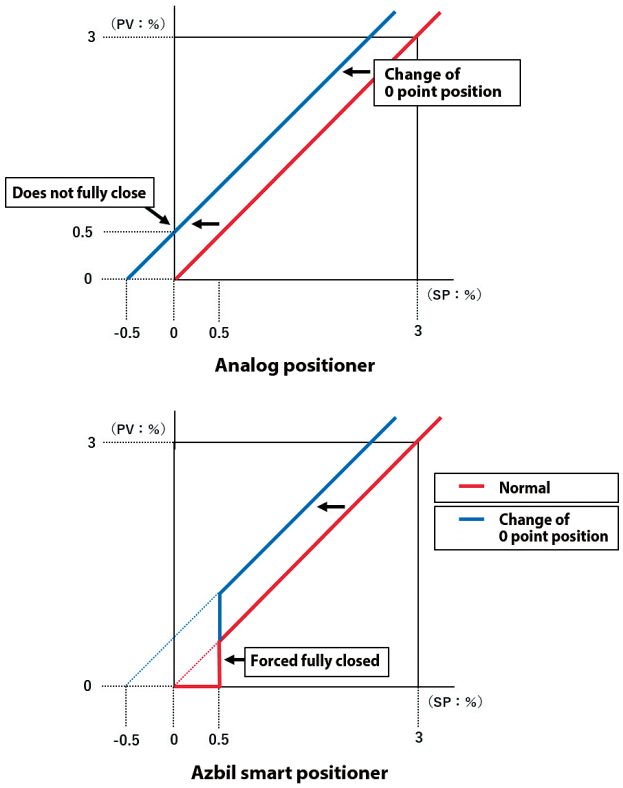

Fig. 1. Difference in zero point change

2.2 Smart positioners and valve travel error

Azbil smart positioners use an angle sensor to detect valve travel by means of an electrical signal from the feedback lever. As a result, valve travel (PV) value can be checked against the input signal (SP). In contrast, adjustment of valve travel is typically done based only on the valve scale plate, and sometimes the valve travel (PV) detected inside the smart positioners is not recognized by maintenance staff. As a result, there can be a gap between the actual valve travel and the valve travel (PV) detected by the smart positioner, which makes correct detection of the valve's condition impossible.

For example, as shown in figure 2, even if the valve travel is 0 % (fully closed), the positioner's travel value may be −5 %. In this case, the positioner detects a minus value for valve travel from the beginning, and that operating data may bring about the correct conclusion that there is internal valve damage. To collect effective operating data, when a smart positioner is installed on a valve, the input signal (SP), valve travel (PV), and valve scale must match.

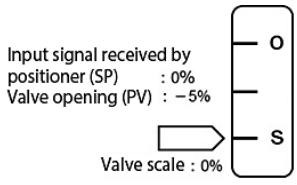

Fig. 2. Example of incorrect valve travel in positioner

2.3 How to handle valve operating data from irregular operation

The valves in production facilities operate in a variety of ways depending on their operational environment. Therefore, operating data includes not only immediately valid data but also data collected during irregular operation such as manual control. If this data from irregular times is included, normal and abnormal valve status cannot be distinguished, and it becomes difficult to understand the condition of valves. Taking this into consideration, Azbil has developed new analysis and diagnosis methods. In this section, one such method is described.

■ Max travel speed diagnosis

Max travel speed diagnosis is an analytical algorithm that obtains the maximum valve stem speed in the opening and closing directions every day. By analyzing characteristics like abnormal speed and changes in speed, the algorithm determines the state of sliding parts such as the gland packing. Previously one difficulty was that, depending on the operating conditions, the maximum travel speed varied, so that a valve that was normal was judged to be abnormal. For that reason, an algorithm that considered operating conditions had been sought.

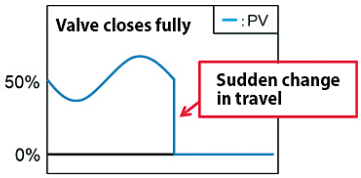

Fig. 3. Example of change to fully closed status

Drawing upon the knowledge of our service engineers and on the results of analyzing accumulated operating data, we found that variation in the maximum travel speed was caused by step changes that occurred in operation to/from a fully closed position. Based on this result, data was divided according to whether there was operation to/from a fully closed position, different thresholds were set for each type of data, and the algorithm was improved to reduce overly sensitive detection (figure 3).

Figures 4 and 5 show an example of data division according to whether a fully closed valve is involved. Even though there is no problem with the valve, its speed exceeds the threshold for abnormal speed, so it would have been erroneously judged to be abnormal in the past. When the data is divided according to fully closed operation time, as shown in figure 5, the fully closed time is gray and the other time is blue and red. Now, it can be seen that the occurrence of abnormal speed is caused not by a valve abnormality but by the sudden change in travel due to operation to/from a fully closed position. Overly sensitive detection of an abnormality can be suppressed by setting different thresholds for abnormal speed (red and blue dashed lines) according to the category of the divided data.

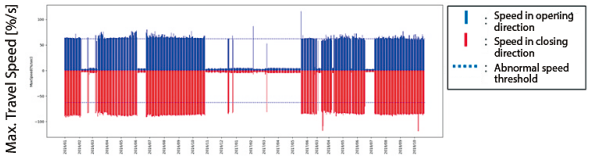

Fig. 4. Example of maximum operating speed leading to erroneous judgment

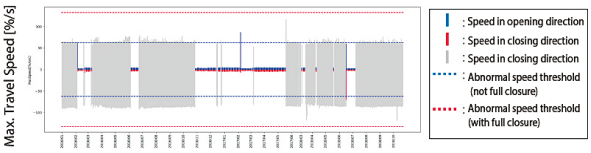

Fig. 5. Maximum operating speed data divided according to fully closed operating time

3. Problems in using valve diagnostic data and their solutions

In addition to valves, various devices must be maintained and managed to achieve stable operation of production equipment. Therefore, it is not possible to carry out operations solely by focusing on valves, evaluating information on valves obtained by diagnostic tools, understanding the condition of valves in a timely manner, and accumulating valve know-how. Due to the recent labor shortage and reduction in manpower caused by automation, the scope of work that one maintenance worker is responsible for is expanding, so the situation may be the same when tools for diagnosis of equipment other than valves is introduced.

Previously, we have provided valve analysis and diagnosis services to assist customers in the task of evaluating valve diagnostic information (figure. 6). This service provides customers with the result of evaluation of the soundness of valves by combining the enormous amount of valve operating data collected by Valstaff with Azbil's know-how in order to produce in-depth analyses and diagnoses.

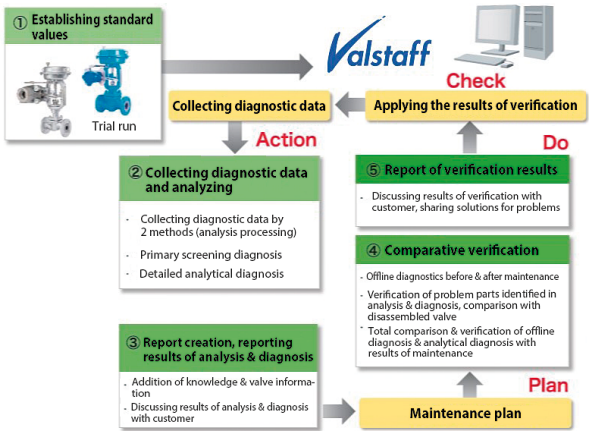

Fig. 6. A typical cycle for a valve analysis diagnostic service

Two levels of service are provided. The first is the primary screening diagnosis, which lists the diagnostic data for all the targeted valves. The second is the detailed analytical diagnosis, which gives in-depth diagnostic data for each valve. When we launched the valve analysis and diagnosis service, these two types of service levels were provided, as requested by customers.

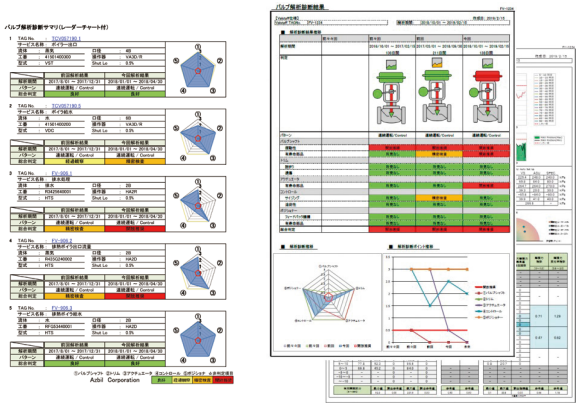

Fig. 7. Primary screening diagnosis (left)
Detailed analytical diagnosis (right)

The customers use the diagnostic data to establish a valve maintenance plan and to understand the condition of the valves, but we have found that the diagnostic data provided to customers is not fully utilized. Azbil then began to provide the Valve Cloud Service as an SaaS (software as a service) solution for the long term.

This section describes some problems with diagnostic data and their solutions. Sections 3.1 to 3.3 describe respectively customers' difficulties in utilizing diagnostic data, the Valve Cloud Service, and how difficulties in using diagnostic data can be solved with the Valve Cloud Service.

3.1 Difficulties in utilizing diagnostic data

In our efforts to encourage the continuing use of diagnostic data, we have identified the following two difficulties experienced by our customers. The Valve Cloud Service can solve these problems and assist customers' operations. The two problems are as follows.

(1) Operation load

Many tasks are required to maintain the stability of production facilities. The maintenance and management of valves is one of the most important. Valstaff and our valve analysis and diagnosis services were introduced to provide an understanding of the soundness of valves, stabilize production facilities, and optimize maintenance. However, since it is difficult for our customers to secure time to utilize and evaluate the results from Valstaff or the valve analysis diagnostic service, the results are not fully used. Also, in some cases the use of the services was discontinued due to personnel changes or retirement.

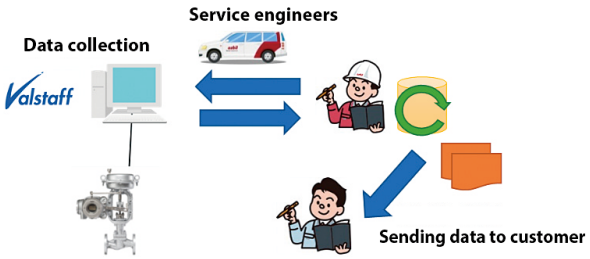

Fig. 8. Workflow of previous valve analysis and diagnosis service

(2) Timing of diagnostic data

For our valve analysis and diagnosis service, analysis using the latest operating data was difficult. In this service, our engineering staff manually collects the operating data accumulated by Valstaff every six months or every year. We analyze the collected operation data and provide the customer with diagnostic data. After the collection of operating data, 3 to 6 weeks is required until the diagnostic data can be submitted to the customer, and as a result it was difficult for the customer to quickly obtain diagnostic data to prepare a maintenance plan or to check on the condition of valves (figure 8).

3.2 Valve Cloud Service

The Valve Cloud Service, which was developed to solve customers' difficulties in utilizing diagnostic data, is an SaaS solution for understanding the soundness of valves in a cloud environment. Valve operating data is automatically transmitted to the cloud, and diagnostic data there can be checked by customers when needed, how needed, and where needed. In the past, in order to check on valve health on a daily basis, it was necessary for customers to check and evaluate the operating data accumulated in Valstaff every day. With the Valve Cloud Service, they can find valve abnormalities at an early stage and check the expected progression of abnormalities without checking or evaluating operating data. In this way the service contributes to the stabilization of production equipment and better maintenance (figure 9).

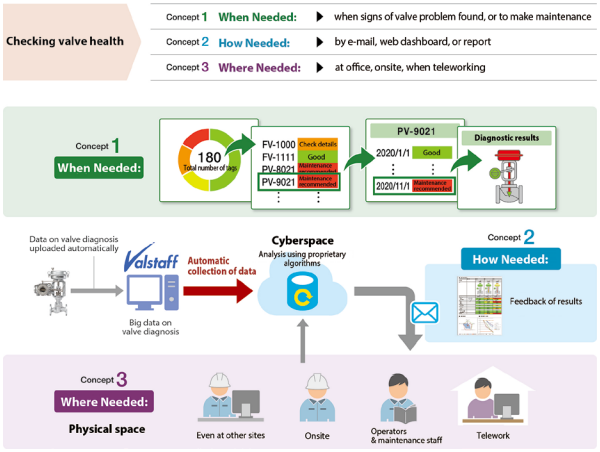

Fig. 9. Provision of the Valve Cloud Service

(1) Security

Ensuring security is one of the challenges for plant IoTs. With the Valve Cloud Service, three security features are combined to protect the control network from unauthorized external access (figure. 10). The first is the use of a one-way communication device that prevents unauthorized access and virus intrusion from the outside. Due to the structure of the device, data can be physically transmitted (on internal wiring) in only one direction. The second feature is the use a closed network (dedicated line) provided by the telecommunications carrier to prevent unauthorized access through the telecommunications environment. As a result, a sealed area is established between the site and the cloud network, so diagnostic data can be transmitted directly into the cloud. Third, in order to prevent unauthorized login and unauthorized access to Web applications, in addition to management by ID and password, access is possible only from within the customer's environment.

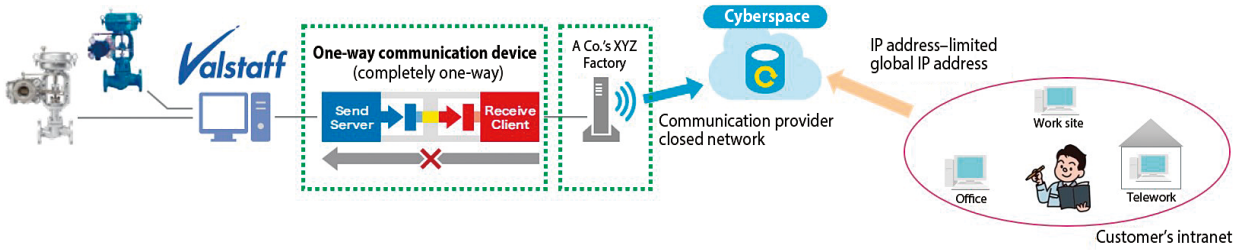

Fig. 10. Security configuration

(2) Operation monitoring

In recent years, the IoT has advanced in the factory process market as well, where the threats include ransomware and targeted attacks by continually evolving viruses. Our Valve Cloud Service is operated and monitored by a specially created Cloud Operation Center, which has acquired international standard ISMS*1 certification to ensure that we can provide a cloud service with highly reliable information security. In this way the customer's assets are protected from threats such as ransomware and targeted attacks by viruses. The Center also sets service level objectives (SLOs) to ensure quality in cloud services.

CLOUD 722670
IS 722669

Fig. 11. ISMS certification marks (international standard)

3.3 Problems solved by the Valve Cloud Service

(1) Operation load

The Valve Cloud Service aims to monitor valve health for its customers. Valve operating data is automatically analyzed and diagnosed in the cloud, and the resulting diagnostic data is published by a web application on the Internet. An overall view of the diagnostic data (distributions and trends in diagnoses) can be seen on the dashboard screen of the application, and if there is concern regarding a valve, a report can be downloaded for more detailed information. As a result, the time needed for customers to check and evaluate valve health has been significantly reduced. Also, even if the customer's personnel change, the diagnostic data is maintained in the cloud, and past results can be easily understood (figure 12).

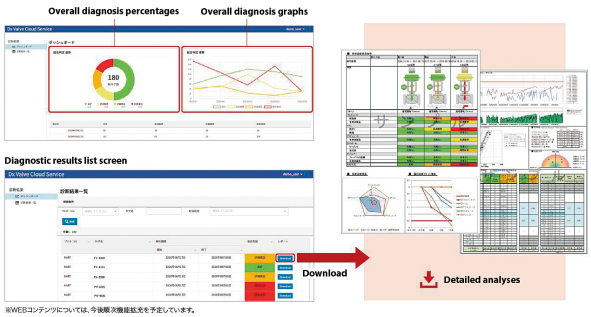

Fig. 12. Web application screen sample

(2) Timeliness of diagnostic data

With the Valve Cloud Service, valve operating data is automatically transferred from Valstaff to the cloud. This completely eliminates the work of our service staff in visiting customer sites to manually collect operating data. Since the latest operating data constantly accumulates in the cloud, the analysis and diagnosis processing can be automatically executed as desired by a scheduling function. Customers can access the cloud from the Internet and check the latest diagnostic data in the Web application when needed. In addition, the primary screening diagnosis and detailed analytical diagnosis, which were previously provided as separate levels of service, are now provided at the same time. Furthermore,the Web application in the cloud can be used from anywhere, in whatever situation it is needed. In maintenance offices, on work sites, and even at home while working remotely because of the current coronavirus epidemic, diagnostic data can be checked and understood.

4. Future outlook

We are collecting and analyzing the operating data of valves operating in various production facilities to construct a big-data database with data differentiated by the usage environment. We believe that this will enable us to understand valve status in greater detail, to prevent problems, and predict the remaining life of valve parts subject to wear. We also aim to utilize the cloud environment to connect diagnostic data with valve information (maintenance history, problems, etc.) and take on a greater role in the customer's business cycle. In so doing, we will reduce the work load of customers while providing stable valve operation through advanced valve diagnostic technology. In addition, we would like to connect the Valstaff systems operating overseas with the cloud environment so that the status of valves operating in domestic "mother plants" and overseas "daughter plants" can be compared, analyzed, and evaluated from Japan. This would establish the environment for plants overseas to receive flexible assistance and allow us to provide our valve diagnostic technology to customers regardless of whether they are in Japan, helping to enhance the safety and security of overseas production facilities.

*1 ISMS certification is granted to information security management systems that comply with ISO/IEC 27001:2013 (JIS Q 27001:2014) and ISO/IEC 27017:2015 (JIS Q 27017:2016). It ensures that companies provide comprehensive information security through the use of risk assessments against threats like targeted attacks and ransomware in order to protect the IT systems and networks that form the indispensable infrastructure of society.

5. Conclusion

In this paper, we have reported on our efforts to correctly detect the condition of valves in production facilities and to enable the sustainable use of operating data by our customers. In recent years, with the worldwide spread of COVID-19, the practice of maintenance has changed significantly, and we believe that it will not resume as it was before COVID-19. With the Valve Cloud Service, we are able to respond to the changing shape of maintenance and to achieve sustainable efforts together with our customers. Based on our corporate philosophy of "human-centered automation," we strive to prevent problems arising in valves and to contribute to the improved safety and security of our customers' production facilities.

References

1. Nippon Keidanren [Japan Business Federation]. "Digital Transformation (DX): Opening Up the Future through Co-creation of Values" (in Japanese with separate English summary). Available from http://www.keidanren.or.jp.
2. Japan Institute of Plant Maintenance. "Summary of 2019 Maintenance Survey Report" (in Japanese). Available at https://www.jipm.or.jp/company/report/.
3. T. Ishihara, et al. "Valve Analysis and Diagnosis Services for Increased Safety of Plant Operations." *Technical Review*, April 2017, pp. 20–26 (in Japanese).
4. M. Fukuda, et al. "Development of New Smart Valve Positioners for Enhanced Safety of Plant Operations." *Technical Review*, April 2014, pp. 54–61 (in Japanese; Engl. transl. available online).
5. Y. Iida et al. "Diagnostic Software Supporting Condition-Based Maintenance of Control Valves." *Technical Review*, April 2015, pp. 3–10 (in Japanese; Engl. transl. available online)

Author affiliation

Fumiaki Yamasaki IAP Marketing Department
Advanced Automation Company
Azbil Corporation

Mamoru Kagoura IAS Development Department
Advanced Automation Company
Azbil Corporation

Koichiro Hirao AI Solution Department
Azbil Corporation