ADVANCED FIELD DIAGNOSIS TO ACHIEVE ASSET EXCELLENCE

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The aim of VigilantPlant AE (Asset Excellence) is to achieve high performance in plant operation. Improvement of the plant operation rate is a key to reliable and safe operation, as well as to reducing operation costs and improving efficiency. In addition to conventional periodic inspection and maintenance, advanced diagnostics contributes to the realization of reliable and safe operation by using intelligent sensors even during plant operation. Field instruments, such as differential transmitters and flow meters, are able to measure process values, calculate process variables, and send diagnostics information to the host system. This paper introduces diagnostics technology that provides great improvements in plant performance and system availability for less cost.

INTRODUCTION

Yokogawa Electric Corporation promotes the standardization of FOUNDATION™ fieldbus as the communication foundation supporting Asset Excellence for VigilantPlant, which is an approach aimed at the advancement of plant instruments and equipment. With the recent dramatic advancement of fieldbus technologies, information processing technologies, and network speed, it has become possible to process various kinds of information inside the field sensors and transmit the results to the distributed control system (DCS) and host computer. Plant Resource Manager (PRM) that is designed to manage online diagnostic information in an integrated manner has already been presented in other documents. It is, however, a group of individual diagnostic technologies that supports the substantial foundation of diagnosis. This paper presents the diagnostic technologies to be used for prognostic diagnosis, which employs multiple-sensor information that is available thanks to the recent advancement of field instruments (multiple functions, higher speed, and transition to digital).

CONFIGURATION OF DIAGNOSTIC FUNCTIONS FOR FIELD INSTRUMENT

FOUNDATION fieldbuses are applied to diagnostic technologies at plants. Figure 1 shows the configuration of diagnostic functions inside a field instrument. The diagnostic functions are implemented in the Sensor Transducer Block (STB) and the diagnostic results are passed as the status signal to the Analog Input Function Block (AIFB). In STB, diagnostic variables are obtained by a calculation based on the measured process values for flow rate, pressure, temperature, and the like, and logical operations are performed for diagnosis. The diagnostic results are transmitted as alarm signals to a host computer and used to support the overall maintenance plan.

Processing the diagnostic variables inside the field instrument allows for significantly reducing the volume and time of communication for transmitting the raw data to the host computer, thus shortening the diagnostic interval, and ultimately, increasing the speed and accuracy of diagnosis.

Since diagnostic programs are updated continuously,

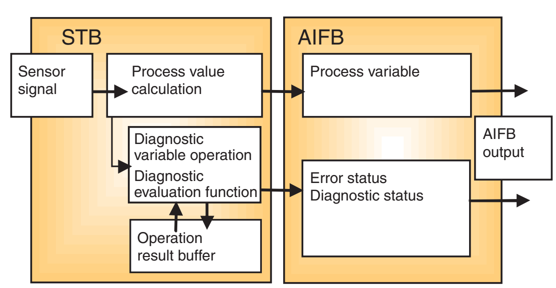

Figure 1 Configuration Example of Diagnostic Functions for a Field Instrument

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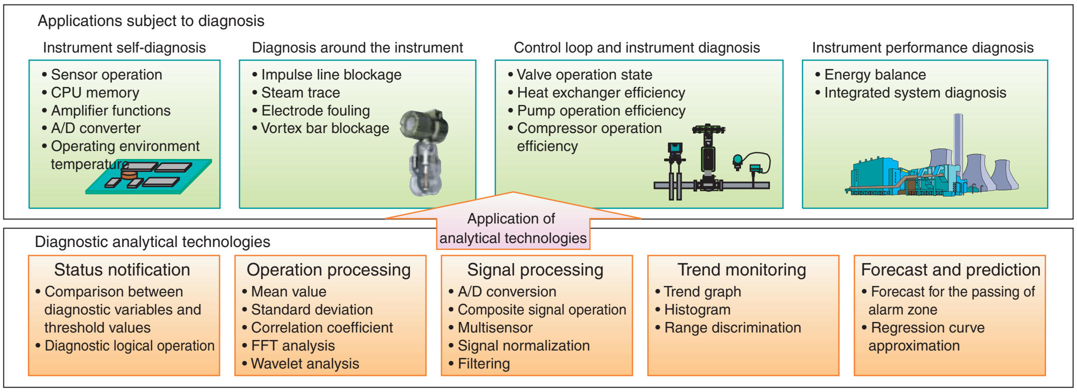


Figure 2 Diagnostic Analytical Technologies and Applications

downloading the software using digital communication allows for obtaining the latest diagnostic algorithms without replacing the printed circuit board.

DIAGNOSTIC ANALYTICAL TECHNOLOGIES AND APPLICATIONS

A field instrument is responsible for measuring the physical value and chemical composition of elements at a plant, such as temperature, pressure, flow rate, pH value, and concentration, and for providing the measurement information for the control system at the plant. A field instrument equipped with digital communication functions, such as a fieldbus, is required to provide many of the functions shown in Figure 2, in addition to measurement accuracy, measurement range, environmental resistance, or cost efficiency. Specifically, a field instrument is required by customers to provide information that supports maintenance and security for plant operations based on the results of the instrument self-diagnosis, the diagnosis of the field around the instrument, the control loop and equipment diagnosis, the instrument performance diagnosis, and the like. It is necessary to obtain diagnostic information based on multifunctional information of the existing fieldbus transmitters, instead of installing new sensors.

DIAGNOSTIC ALGORITHMS

As shown in Figure 3, in order to obtain diagnostic information, it is necessary to combine the process variables for the physical value and chemical composition with the diagnostic variables related to signal fluctuations, drifts and other variables, which were conventionally viewed as disturbances. In order to evaluate the diagnostic result, a proper diagnostic evaluation function needs to be defined by combining multiple diagnostic variables. A diagnostic variable includes an irregular disturbance than a process variable is, so the diagnostic variable is handled as a random variable. The diagnostic evaluation functions used combine the statistical processing operations such as the mean value and standard deviation for random variables, the differential and ratio operation for eliminating the disturbance, the compensation operation based on other measurement information, and the operation that performs comparison with the standard state, and the like. In addition, a Fast Fourier Transform (FFT) for transforming a time range variable to the frequency range variable, a Wavelet Transform for accumulating the result of multiplication of a nonstationary process variable by a properly assumed basis function, and the like can be used as a diagnostic evaluation function.

APPLICATION OF DIAGNOSTIC TECHNOLOGIES

The following shows specific diagnostic applications.

(1) Steam trace diagnosis of a Differential Pressure Transmitter EJX110

There is a case where an orifice flowmeter based on a differential pressure transmitter as shown in Figure 4 is used to prevent the fluid from solidifying by tracking steam trace and measuring the differential pressure while keeping the impulse line and flange warm. The following equation allows

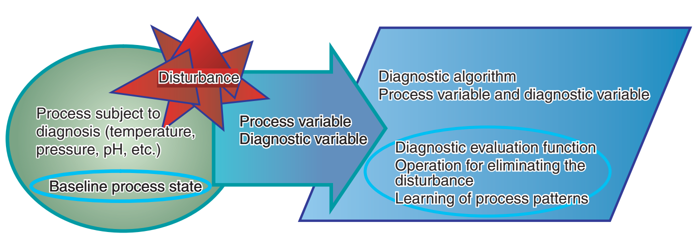


Figure 3 Configuration of Diagnostic Algorithms Using Diagnostic and Process Variables

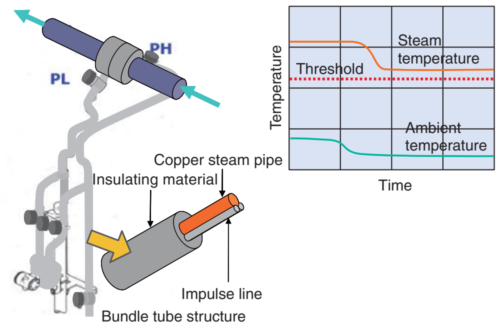


Figure 4 Example of Steam Trace Instrumentation

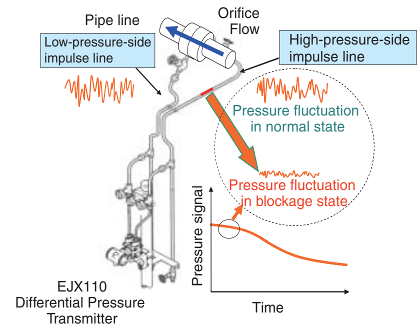


Figure 6 Impulse Line Pressure Instrumentation of a Differential Pressure Transmitter

for estimating the flange temperature (FLANG_TEMP) which represents steam temperature for keeping the impulse line warm by using the capsule temperature (CAP_TEMP) and the amplifier temperature (AMP_TEMP) of the Differential Pressure Transmitter EJX110.

FLANG_TEMP = (1 + K) * CAP_TEMP –
K * AMP_TEMP

The flange temperature can be calculated by the optimization of the K value in the above equation, and the soundness of steam can be diagnosed.

(2) Electrode fouling diagnosis using a Magnetic Flowmeter AXF

A Magnetic Flowmeter AXF is employed to diagnose the level of fouling by measuring resistance values based on the Ohm's law by allowing a flow of a very small amount of square current through the earth ring from the electrode as shown in Figure 5. The square wave frequency is set so that it does not have any influence on the flow rate signal operation. As a result, the flow rate signal is masked so that it is not reflected in the signal during the time of signal processing for the diagnosis of the dirt contamination of the electrode.

(3) Impulse line blocking diagnosis using a Differential Pressure Transmitter EJX 100

If an impulse line for the orifice differential pressure meter is blocked, a problem occurs on the flowmeter side, which then leads to a problem for the plant control as shown in Figure 6.

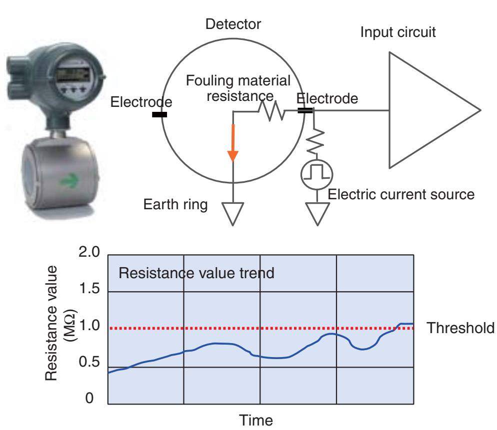


Figure 5 AFX Resistance Value Trend of Electrode Fouling Material

The impulse line blocking diagnosis is performed based on changes caused by the fluctuations of a pressure signal that can be measured in the flow of the pipe line during normal operation. A diagnostic function F called “Blockage Factor,” which is obtained by combining the fluctuation correlation coefficients of differential pressure, high-pressure-side pressure, and low-pressure-side pressure, is employed to identify which impulse line is blocked.

Figure 7 shows the difference in the fluctuation correlation coefficient *CorL* for the differential pressure and the low-pressure-side pressure between the normal state and the high-pressure-side impulse line blockage state. When the low-pressure-side pressure fluctuation and the differential pressure fluctuation are plotted as 2 random variables in the 2-dimensional diagram, the *CorL* value for the high-pressure-

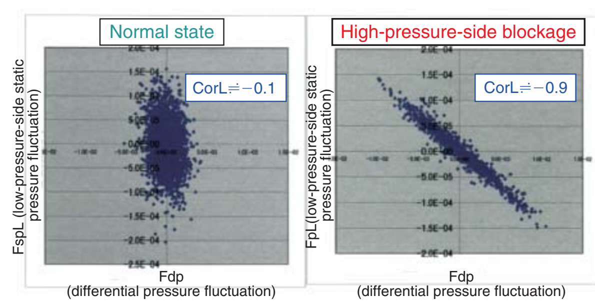


Figure 7 Correlation between Low-pressure-side StaticPressure Fluctuation and Differential Pressure Fluctuation in the case of high-pressure-Side blockage

$$F = \left(1 - \frac{1 + CorL}{1 - CorH}\right) \Big/ \left(1 + \frac{1 + CorL}{1 - CorH}\right)$$

where the high-pressure-side blockage is expressed by 1+ CorL≒ 0, therefore, the Blockage Factor is expressed by F≒+1.

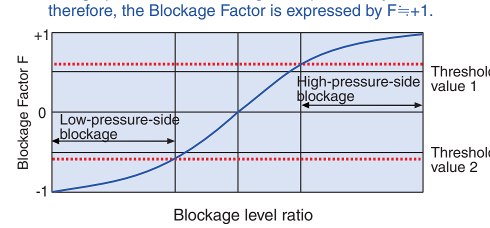
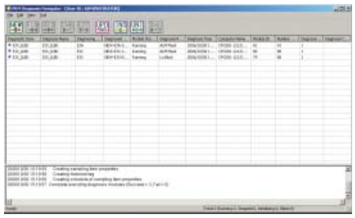
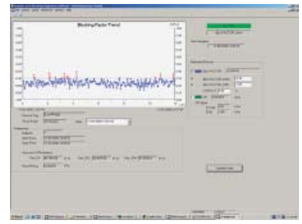


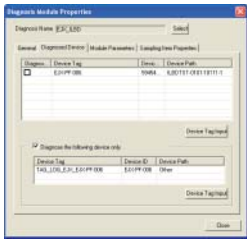
Figure 8 Relation between One-side Blockage Factor F and Blockage



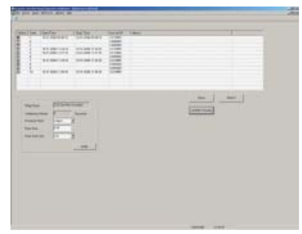
A: PRM diagnostic menu screen



C: Diagnostic trend and threshold setting screen



B: ILBD instrument registration screen



D: Diagnostic reference data registration screen

Figure 9 ILBD Diagnostic Screen for PRM

side blockage state is close to –1. On the other hand, although not shown in the figure, the correlation coefficient *CorH* value for the random variables for the high-pressure-side pressure fluctuation and the differential pressure fluctuation on the low pressure side is close to +1. The diagnostic function F, which is obtained by combining the *CorL* and *CorH* values based on the principle equation in Figure 8, and which is normalized to ±1, is used for impulse line blocking diagnosis. When this function is close to +1, the high-pressure-side impulse line is diagnosed as being blocked, and when the value is close to –1, the low-pressure-side impulse line is diagnosed as being blocked.

IMPULSE LINE BLOCKING DIAGNOSIS FOR PRM SYSTEM

A field instrument equipped with digital communication functions such as a fieldbus is able to perform diagnosis on its own. However, when performing advanced diagnosis, such as trend diagnosis based on a trend graph, or multivariable range diagnosis, it is necessary to understand the results visually by combining a Plant Resource Manager (PRM) system and fieldbus instruments. Furthermore, in many cases of actual diagnostic practices, the standard characteristics of diagnostic variables are established as reference data in a normal state and then compared with the variables of diagnosis that is performed each time. In some cases, a lot of reference data is prepared in advance for future changes in the plant operation conditions. When using diagnostic results, for example, setting a proper threshold value based on the trend graph, or revising a maintenance plan before a problem occurs, dedicated diagnostic packaged software installed in the PRM system is required to perform advanced diagnosis.

Figure 9 shows the screens of the Impulse Line Blocking Diagnosis (ILBD) software, which enable the registration of instruments for impulse line blocking diagnosis (B), the observation of the diagnostic result trend and the setting of thresholds for the blocking level (C), or the registration of reference data for diagnosis (D).

CONCLUSION

The diagnostic technologies presented in this paper allow for always monitoring the process state onsite using intelligent sensors, for analyzing the trend in changes, and for providing information for preventive maintenance at earlier stages. It is necessary to further improve the practical issues; for example, the application range of diagnostic technologies and the method to evaluate the diagnostic accuracy.

It is also expected that the variation of input signals such as ultrasonic and optical signals will be increased, and faster diagnosis based on the measured values in the high-frequency range will be developed. The existing diagnosis will ultimately progress from the localized diagnosis to the more advanced diagnosis that is based on the 2-dimensional and 3-dimensional information obtained by sensors at multiple points. ◆

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