

FOUNDATION™ FIELDBUS revolutionises operation and maintenance of field devices

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Introduction

FOUNDATION™ Fieldbus is an enabling technology with the potential to revolutionise operation and maintenance in the process industry and thereby to contribute significantly to reducing these costs, everyday of the lifetime of a plant. Specifically with regard to maintenance, FOUNDATION™ Fieldbus opens the way to proactive diagnostics and to virtually eliminating preventive maintenance and to avoiding shut-downs. The implication, however, is that proactive maintenance will require close collaboration of system engineers and instrument technicians with process engineers and operators to make fast and efficient use of the information communicated by means of FOUNDATION™ Fieldbus. The process and diagnostics information generated is used to make informed decisions which will alter the traditional role of maintenance profoundly and a knowledge workforce will be created.

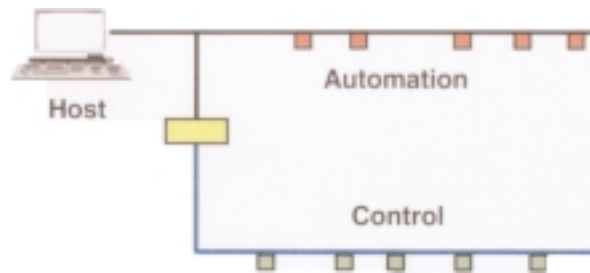
FOUNDATION™ Fieldbus

FOUNDATION™ Fieldbus integrates sensors and actuators with the traditional control system to create a single plant-wide integrated process automation system. In this automation system, sensors and actuators become information servers providing measurement values and essential information about the status of the field devices themselves and also the process. This diagnostic capability expands the view on the process and contributes significantly to reducing the total cost of ownership over the lifetime of a plant.

FOUNDATION™ Fieldbus is a fully digital replacement for the analogue 4-20 mA concept. The digital communication protocol enables multiple field devices to communicate via the same pair of wires. This means considerable savings in terms of hardware such as cabling, terminations and barriers. Not only from a physical point of view, but also from an engineering, commissioning and maintenance point of view. Digital communication enables field devices to communicate multiple measurement values, and also the status of the field device itself. The measurement values are validated immediately so guaranteeing the quality of the information communicated. This diagnostic information is important for efficient operation, and has far reaching consequences for maintenance and thus plant availability.

Furthermore, the integration enabled by FOUNDATION™ Fieldbus will have a major impact on maintenance management. Instrument technicians will need to develop system expertise in order to access and verify the status of field devices. System engineers will need to develop instrumentation expertise in order to understand how to use the diagnostic information communicated.

System engineers and instrument technicians will, therefore, need to collaborate with one another and with process engineers and operators to make optimal use of the information communicated.



A FOUNDATION™ Fieldbus system consists of:

** a low speed bus (FF-H1, referred to as the control bus integrating pressure transmitters, conductivity analysers, flowmeters and control valves*

** and a high speed bus (FF-HSE), referred to as the automation bus, integrating electric drive sub-systems, PLC's, weighing scales, gateways to sensor buses*

Interoperability

Another important advantage of the FOUNDATION™ Fieldbus technology is that the format for communicating device parameters has been standardised and thus host system device configuration tools give access to devices from different vendors. With FOUNDATION™ Fieldbus, plants are therefore not necessarily locked into field devices from one supplier. In fact, Yokogawa has taken the lead in stimulating and developing interoperability between devices and host systems of different vendors. The Fieldbus Foundation guarantees interoperability by means of a strict mandatory interoperability test regime. Interoperability creates competitiveness on both price and functionality and consequently, fosters innovation.

FOUNDATION™ Fieldbus provides the mechanism to unlock the multi-variable capability of newly developed field devices. The Yokogawa multivariable vortex flowmeter (dYF-MV), for example, measures volumetric flow and also process temperature via a detector embedded in the meter's shedder bar. This eliminates the need for an additional temperature transmitter and helps to reduce the number of process penetrations, so contributing to greater safety. Furthermore, an on-board flow computer calculates mass flow (saturated steam) from data on volumetric flow and density.

A limiting factor of the analogue 4-20 mA concept has always been power and a field device had to be fully functional when communicating at 3.5 mA. FOUNDATION™ Fieldbus allows a much higher power budget and unlocks advanced diagnostic capabilities. The vortex flowmeter, for example, can distinguish pulsating flow and pipe vibration from actual flow and generates a message when preset limits are exceeded.

Not only all process input and output functions have moved from the traditional DCS into the field devices, but also arithmetic, integrator and some of the (PID) control functions will reside in the field devices. The control scheme is fully distributed. While some vendors are focusing on "control in the field", Yokogawa has adopted the strategy of "control anywhere". Simple control in field devices and complex control schemes are implemented in safe redundant controllers, possibly with a back-up controller in the field to ensure controlled degradation in the unlikely event that the controller or its interface card fails or is cut off from the field devices. Eliminating virtually all input and output on the host side has a major impact on installed cost, also by reducing the automation system footprint.

Capital and Operational Expenditure

FOUNDATION™ Fieldbus can thus have a considerable impact on capital expenditure. The amount of savings, however, will depend on the type of installation, whether in an existing plant or a grassroots project; a general purpose or hazardous area site. In case of an intrinsic safe installation, savings of 75% on IS barriers can be made by connecting four devices to a segment.

However, by far the most significant savings are made in operation and maintenance. Because field devices not only communicate measurement values, but also information on the status of the field device, maintenance can be addressed before potential problems become a reality. This means that the number of unexpected and costly shutdowns can be reduced substantially and thus plant availability raised significantly. The same diagnostic information is used by the device itself to indicate that attention is required, so enabling timely "planned" maintenance to be implemented. Furthermore, a more reliable automation system and higher plant availability also contribute to higher overall safety.

As all information is available throughout the network, consideration can be given to centralising both operation and maintenance. This could even ultimately result in unmanned remote operation of installations. Cost savings, however, are not the only driving force for remote operations, another important consideration is minimising exposure of personnel to hazardous environments.

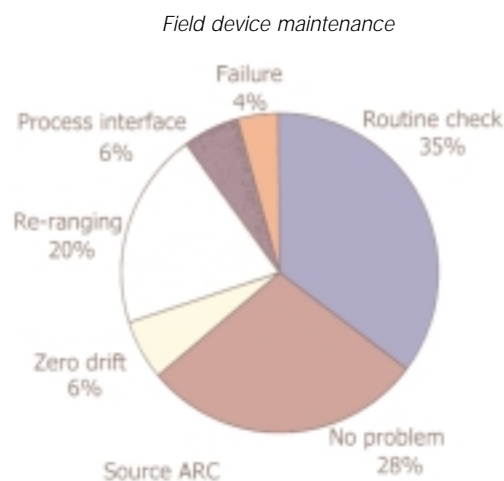
One such example is the Shell Brent Alpha project for which Yokogawa delivered the host system and field devices. By using the diagnostic capability of the field devices, technical staff are no longer required to reside permanently on the platform. Brent Alpha is now operated from Brent Bravo, reducing the manpower required to operate the Brent Alpha platform by 90%. Maintenance staff make planned visits to the platform armed with a maintenance agenda based on diagnostics provided by the capabilities of the Fieldbus automation system.

Maintenance Strategies

FOUNDATION™ Fieldbus will have a significant impact on maintenance strategies in the process industry, because it enables proactive maintenance. This will mean considerable cost savings both in terms of routine maintenance and also in preventing plant shutdowns. Like

equipment, such as domestic appliances and cars, field devices can fail unexpectedly. When field device failure may lead to a plant shut down, a strategy is needed to prevent unexpected failure and breakdowns.

The most common maintenance strategy in industry is to carry out preventive maintenance at regular intervals. Devices are inspected and their performance verified, whether or not there are indications that inspection is necessary. As a result, inspections are done too early or sometimes too late, leading to unnecessary replacements, failures and even shutdowns. A recent report prepared by ARC on the maintenance expenditure of a large petrochemical company showed that 19% of the total maintenance budget was spent on field devices (excluding valves), of which 35% went on routine checks. Often, a problem in the plant was attributed to a specific field device, and consequently, a high proportion of the budget (28%) was spent on "no problem found" work. FOUNDATION™ Fieldbus eliminates the need for re-ranging because devices communicate digitally, a saving of 20%.



An ARC study reveals that 19% of the total maintenance budget was spent on field devices and an other 8% on valves.

Further, ARC also found that dealing with process interface problems, such as clogging of impulse lines took 6% of the budget and failures 4%. The latter may seem low, but is realistic because most field devices today (except valves) are solid-state devices with no moving parts and an MTBF of 400 years indicating their reliability. Essentially, 60% of the maintenance budget spent on field devices (12% of the total) went to routine checking and unnecessary inspections.

To address the cost of routine checking, a predictive maintenance strategy is adopted directed at optimising the time interval between checks on the basis of statistical data and models. However, device behaviour differs with application and geographical location. In relation to predictive maintenance, often Reliability Centred Maintenance is applied taking into account issues such as whether the correct measurement technology has been selected (when a magnetic flowmeter has to be taken out every two weeks to clean the electrodes, it is not suitable for the application). Or, when the quality of the device is in question or the quality and uptime of the automation system. This is referred to as Condition-Based Maintenance, a term borrowed from rotating equipment condition based monitoring systems. It is essentially inappropriate for field devices because the condition is predicted on the basis of statistical data and models.

FOUNDATION™ Fieldbus helps to address the issue of routine checking and unnecessary inspections because build-in diagnostics (Maintenance Indicators) alert maintenance staff before failure occurs. Maintenance becomes proactive.

Proactive Maintenance Indicators generated from on-board diagnostics are activated when the device is powered up and continuously monitor the need for maintenance. FOUNDATION™ Fieldbus allows the device to communicate its measurement value(s), its status and consequently, the validity of the measurement. Furthermore, it may well be possible in future to quantify the validity of measurements. A field device will communicate its measurement and the accuracy probability of the measurement on the basis of embedded expert rules. A temperature transmitter, for example, may give a temperature reading of 38.2° C and the accuracy probability is 98.8%.

If a device fails, maintenance indicators will help to diagnose the cause of failure, for example, over-pressure or over-heating, provided, of course, the electronics are still functioning.

Proactive Maintenance and Diagnostics

The key to a proactive maintenance strategy is diagnostics. The Netherlands-based International Instrumentation Users Association (WIB) proposed a concept for classifying categories of diagnostics.

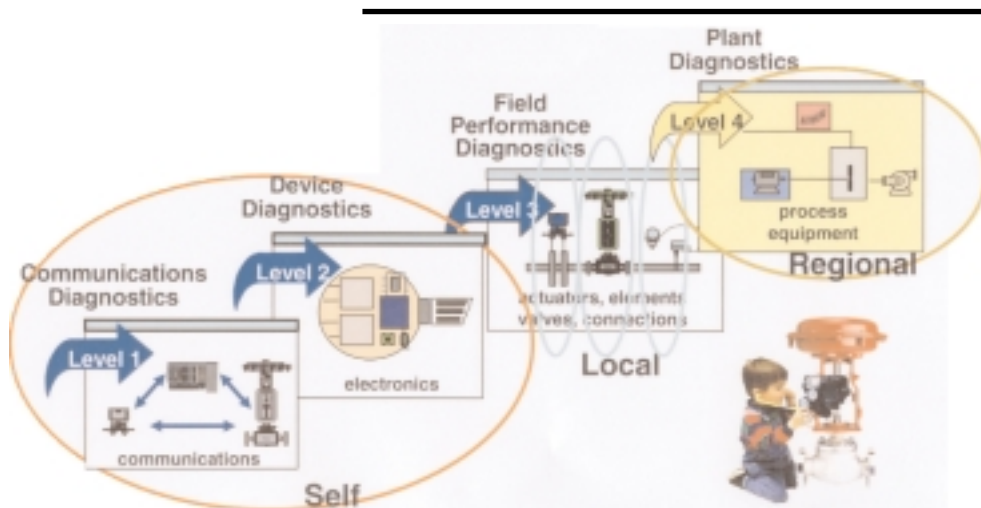
The basis for on-line diagnostics is analysis of the raw sensor signal. In the 4-20 mA analogue concept, manufacturers within the limited power budget have applied extensive filtering and dampening of the raw sensor signal to achieve a stable measurement signal. This can sometimes lead to sluggish responses and limited rangeability. Furthermore, valuable secondary information is filtered out. The higher power budget with FOUNDATION™ Fieldbus, however, enables analysis of a raw sensor signal and use the noise information to observe and describe secondary effects on the basis of empirical data, engineers expertise, models and/or experiments.

Three diagnostic levels are distinguished as follows:

- * *Self* diagnostics monitors the health of the device itself. At this level, sensor failures can be identified such as rupture of the pressure transmitter diaphragm due to corrosion.

- * *Local* diagnostics monitor the *in-situ* health of an installed device including its process interface (connections). A classical example is the detection of impulse line blocking in d/p-based flowmeters using orifice plates or venturies. In this case, *local* diagnostics is a device diagnostics. The dYF vortex flowmeter can identify abnormal vibration and flow pulsations. Neither of these anomalies is created by the vortex flowmeter, which is just observing the events created elsewhere, for example, by a malfunctioning pump; a process diagnostics.
- * *Regional* diagnostics monitor the health of a process unit or plant and combines a number of *self* and *local* diagnostics with expert rules and maybe soft sensors in assessing the health of the unit.

It is envisioned that with one or more iterations, *Self* and *Local* diagnostics will be implemented in the devices. *Regional* diagnostics will be implemented in the host using Expert Packages. Advanced diagnostics are not limited to the regional level because the detection of thermocouple aging and diaphragm rupture due to progressive corrosion, currently being researched, are perceived to be highly advanced.



Field based "information servers"

Implementing Proactive Maintenance

Proactive Maintenance Indicators are generated at all three diagnostic levels discussed. Field devices have become information servers within the integrated Plant Automation System (PAS) communicating measurement and status information. The operator is assured that a measurement value presented on his screen is correct unless otherwise indicated.

Proactive maintenance strategies can be implemented with Plant Resource Manager (PRM), Yokogawa's asset management software. This powerful software gives easy access to the diagnostics information provided by FOUNDATION™ Fieldbus enabling Proactive Maintenance strategies to be implemented. PRM is totally embedded (integrated) in the Plant Automation System and sits on top of a database (the field device maintenance server) by on-line collection of information from field devices. PRM enables multiple users in the automation system network to access all information as required.

PRM vertically interfaces with Plant or Enterprise Asset Management systems (often referred to as Computerised Maintenance Management Systems) such as Maximo or SAP.

To visualise the various diagnostics concepts discussed above, several “plug-ins” are available such as Device Viewers for *Self* and *Local* diagnostics and Helper packages for *Regional* diagnostics. Furthermore, valve and calibration management software packages can also be integrated in PRM.

Advanced Diagnostics

PRM provides the platform to manage all field devices within the Plant Automation System's network providing various navigation methods. The user has access to configuration details, both current and historical. Changes made are registered using an Audit Trail mechanism (www = who did what, when and why) for future review. This applies to both field device maintenance and operational alarms. Further, menu driven guidance for calibration and tuning is included as well as links to on-line documentation such as up-to-date user manuals and parts lists. When used without interface with a higher level Plant Asset Management system, it provides maintenance scheduling functions.

PRM is at the heart of efficient Field Device Maintenance Management. For the first time ever a Computerised Maintenance Management System (CMMS) such as Maximo can issue work orders triggered by real Maintenance Indicators initiated by continuously running diagnostics in the field devices.

FOUNDATION™ Fieldbus provides a wealth of information from the field about both the devices and the process. This information flow must be well managed to prevent users being flooded with excessive numbers of alerts and alarms. PRM using plug-ins enables the right information to reach the right people. The diagnostic capability changes the role of the instrument technician, system (maintenance) engineer, plant engineer and operator. Instead of routinely checking on device health and performing calibrations, the instrument technician will collaborate with the system engineer, plant engineer and operator, monitoring the process in a central control room. The process and diagnostic information will be used to make informed decisions and to act on them. The traditional monitoring role is left behind as a “Knowledge Workforce” is created.

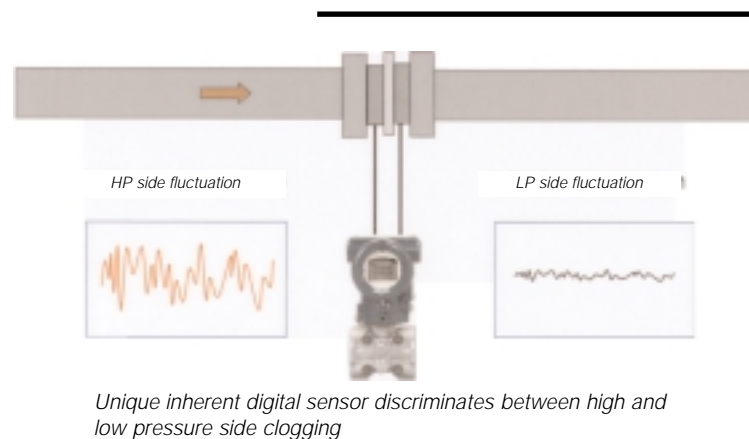
Fault Detection

A classical example to demonstrate on-line diagnostics and fault detection is the differential pressure transmitter based square law flowmeter (in this example, an orifice plate). Although not often used now in new built plants, there is a large installed base of square law flowmeters (orifice, averaging pitot tube, etc.) in industry. In many revamps, instrumentation is generally

renewed, but not the pipework. Consequently, the orifice plate is not replaced, only the differential pressure transmitter.

Most square law flowmeters use impulse lines between the primary element and differential pressure transmitter. These are maintenance intensive. For gas flow measurement, no condensate must be collected in either the d/p transmitter or impulse lines. When metering liquids, however, the impulse lines must be full with the product (or filling fluid) and for steam with condensate. Often, the impulse lines also provide a cooling function. It is likely that at some time during the lifetime of a plant, impulse lines will clog because of dirt accumulation or solidification, or freeze in winter. As a result, the measurement fails and in the case of freezing, the differential pressure transmitter is damaged.

By analysing the differential pressure noise level, pattern and trend, the differential pressure transmitter can identify impulse line clogging (or freezing) and alert maintenance before measurement fails. The Yokogawa pressure transmitter portfolio features a unique inherent digital multi-sensing sensor, which simultaneously measures differential pressure and static pressure. This multi-sensing capability enables the transmitter to discriminate between high and low pressure side clogging. Impulse line blocking is detected as a fault in the device *in-situ* (process interface) and consequently, a local, proactive device diagnostics is initiated.



As well as primary differential and static pressure measurements, the transmitter has an on-board temperature sensor, measuring the temperature of the transmitter capsule's fill fluid. The latter is used to correct for expansion and contraction of the fill fluid and to minimise the effect of ambient temperature on the device's performance. This temperature measurement provides an alarm to prevent over-heating or freezing, if the transmitter steam (or electrical) tracing fails. The transmitter is often located at a dead end, remote from the actual process.

Fault Correction

Diagnostics are not limited to fault detection. Within certain limits, secondary effects on the primary measurement can sometimes be corrected. Take for example, the Yokogawa digital YEWFO vortex flowmeter, which has a dual piezo-electric crystal sensing mechanism. Based on empirical data, experiments and modelling, the raw sensor signals are continuously analysed, discriminating the flow signal from noise. As this process is continuous, it automatically adapts to changing noise conditions. Spectral adaptive filtering is then applied to enhance the vortex shedding frequency. This results in a stable flow signal even in low flow conditions (where the vortex signal is relatively weak in relation to the flow noise).

The spectral filtering mechanism then discriminates between low and high frequency noise. Low frequency noise is an indication of pulsating flow caused, for example, by a malfunctioning pump or valve, which is observed by the vortex meter. When a certain threshold is exceeded, a diagnostic message is initiated long before the pulsation begins to affect the primary flow signal of the vortex flowmeter.

High frequency noise is caused by pipe vibration and may increase with time, perhaps due to bearing wear in nearby rotating equipment (pump). Again, when a certain threshold is exceeded, a diagnostic message is generated before the primary measurement is affected. The detection of flow pulsation and/or excessive pipe vibration observed by the vortex flowmeter then initiates a local, proactive process diagnostics.

Valve Management

The control valve is the last mechanical component in the control loop; it controls the process and is subject to wear and tear, which degrades performance over time. Although a Device Viewer is available in PRM to monitor the diagnostics performed by the valve positioner, the functionality of both valve and positioner can be visualised by plug-in dedicated valve management software.

The positioner continuously monitors the number of times the valve has changed direction of movement (total cycle count) as well as the total accumulated travel. It also observes the time the valve has been open, closed or nearly closed. The latter is an important parameter because when the nearly closed interval is high in relation to the total open interval, this may indicate that the valve is wrongly sized. When the valve is nearly closed, the fluid has an eroding effect on the valve trim and wear of the seat and plug is high. When pre-set limits are exceeded, an alarm alerts maintenance staff and in case of the total cycle count or total travel, valve stroking is scheduled for the first convenient opportunity. Valve stroking makes the valve travel from closed to open and back, so this is an off-line procedure.

The result of the stroking process is a valve signature plotting the applied pressure versus travel. By comparing the resulting signature with a previous signature, packing box problems can be detected (a change in hysteresis may indicate loosening of the packing resulting in fugitive emissions), seat problems (sticking or erosion causing the valve not to close properly), or deterioration of the actuator spring (causing the valve not to open fully). When the valve plus positioner are considered as one device, the diagnostic functionality initiates self, proactive device diagnostics.

Preservation of Investment

Most of the diagnostic functionality discussed is available now or will be shortly. The functionality of field devices will continue to evolve because FOUNDATION™ Fieldbus has build-in capabilities to foster ongoing innovation. Advanced Function Blocks will be implemented in field devices, for example, performing arithmetic functions such as mass flow computation in volumetric flowmeters. As signal-processing capabilities advance, the diagnostic functionality will also increase. It is envisioned that it will be possible to identify ageing of thermocouples (initiating replacement before failure), orifice wear, on-line valve friction and corrosion of pressure transmitter diaphragms.

When field devices are equipped with Flash Memory (EEPROM), new firmware can be downloaded into the device memory. The FOUNDATION™ Fieldbus specifications are such that a check is performed to ensure that the download process has been performed correctly. Rather than replacing field devices, Flash Memory will enable firmware updates and upgrades and thus add new diagnostic functionality and additional Function Blocks. This will consequently preserve the initial investment in a FOUNDATION™ Fieldbus automation system.

Conclusion

FOUNDATION™ Fieldbus is an enabling technology for integrating sensors and actuators with a traditional control system to become information servers providing measurement values and information on the status of the field devices and the process. This capability opens the way to proactive diagnostics with the potential to eliminate preventive maintenance and to contribute to reducing Total Cost of Ownership over the lifetime of a plant.

Capital expenditure can be reduced because less wiring and smaller footprint (less marshalling and input/output cabinets) are required in system installation and commissioning. The most significant savings to be made, however, are in operation and maintenance. FOUNDATION™ Fieldbus is not in itself the cost-saver, but the enabler of a new level of effectiveness in asset management. By empowering plant personnel with diagnostic information, informed decisions can be made that contribute to raising the quality of the manufactured product, the environment and plant performance.

With FOUNDATION™ Fieldbus, the status and condition of field devices is no longer monitored on the basis of predictions but on the basis of real-time diagnostics. Proactive Maintenance Indicators enable more efficient field device maintenance with potential savings on the total maintenance budget of up to 10-15%. Further, device firmware upgrades enable new innovative functionality to be implemented without the need for hardware replacements, provided of course functionality upgrades do not require new hardware.

Yokogawa is fully committed to take FOUNDATION™ Fieldbus further by expanding and innovating our product portfolio. Yokogawa is also collaborating with users, consultants and other vendors to enhance the technology with "Functional Safety", to be applied in Safety Instrumented Systems (SIS). By taking a lead in enhancing interoperability, Yokogawa is contributing to enabling users to buy "Best-in-Class" products.

