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DEVICE CONDITION MANAGEMENT

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A key architectural component of FOUNDATION Fieldbus is the provision of access to diagnostic information about device behaviour, performance and condition. The wealth of information available is generally accessible rather than being published. This provides a basis for remote and automated diagnosis of problems to initiate rapid corrective action. This is considerably different to device self-diagnostics intended only to initiate alerts/alarms. To get full value from the indications available in FF devices, a methodology is needed to access and interpret the wide variety of indications in the context of the condition of the device and the potential impact on the production process.

Honeywell implements control solutions that utilise FF valves and instruments from a wide variety of vendors affording us some insight into what is standard and what is not in relation to the implementation of device diagnostics in function blocks. The nature of device diagnostic information available and how it can be accessed and utilised will be explored as will the use of diagnostic information to improve management of FF device condition.

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1. Introduction.

An often cited justification for selecting FOUNDATION Fieldbus is the availability of diagnostic alerts and alarms. FOUNDATION Fieldbus instruments typically provide a wide range of information that can add clarity to the diagnosis of device problems but also add significantly to the quantity of field data to be managed. For instance, a digital valve controller is likely to have more than twenty alerts / alarms and many more diagnostic parameters and calibration settings. Control system design can be used to manage the propagation of alerts/alarms and access to diagnostic information. This assists operations and maintenance personnel to effectively manage and utilise the available data.

FOUNDATION Fieldbus system architecture enables the specification of diagnostics where relevant for reporting through a specified FOUNDATION Fieldbus protocol alert reporting model. If users' want the capability to become aware of device indications remotely then it is necessary to understand how the associated diagnostics behave. It is also important to recognise the nature of information that will be available and how this might be used to recognise both device and process integrity issues.

1.1. Smart Device Condition Indication.

The FOUNDATION Fieldbus alert reporting model provides the capability to alert a device block state transition but can specific alerts be identified? Are alerts associated with reduced dependability of a device or a reduction in the certainty of its behaviour/indication recognisable? Whilst this information might be expected, it is seldom provided directly as an alarm/alert. Similarly, it would not be unreasonable to expect self diagnosis and reporting of conditions such as;

- No diagnostic warnings or failures
- Diagnostics disabled
- Loss of instrument air pressure
- Plugged impulse line
- Dirty sensor suspected
- Excessive actuator resistance detected
- Excessive communication errors detected
- Out of calibration at low range
- Out of calibration at high range

What is more often provided is the block name (if one was defined when the device was configured) as an alert to indicate that a diagnostic event (usually one of many possible) has occurred. On this occurrence, the vendor expectation is that someone will interrogate the device through the control system, an asset management application or with a handheld field tool to determine what has happened and what should be done about it. The interrogation reviews accessible diagnostic parameter values and compares these against troubleshooting tables to determine the appropriate response action. Where accurate records of findings are available this

may be appropriate for managing long term device integrity. However it is not good enough for managing the dependability of the function it is performing.

1.2. Device Self-Diagnostic Indications

Whilst the protocol clearly defines the mechanism by which alerts are reported there is little standard about the information provided in alerts. This allows device vendors to implement alert information they choose and construct the most appropriate diagnostics for the care of device integrity. However this needs to be clearly understood by users to ensure the potential is realised. It would be a mistake, for example, to assume that two temperature transducers from different vendors are suited for the same process purpose and would provide the same range of self-diagnostics and alert indications. Other than the general alert indications provided by the resource, transducer and function block BLOCK_ERR parameter and the transducer block XD_ERROR parameter there is no standard for the information that will be available or published as diagnostic alerts/alarms.

For many devices, the BLOCK_ERR and XD_ERROR parameters are the only diagnostic indications available so it is important to appreciate their behaviour. BLOCK_ERROR indicates the error status of hardware and software associated with each block type. Sixteen parameters in the form of a 16 bit string (0-15), are defined, any one or all of which (it is a multiple simultaneous parameter) can be present at any point in time (Table 1).

Table 1: BLOCK_ERR Parameter Bit-string element meanings

BIT	MEANING
0	Other (Least Significant Bit)
1	Block Configuration Error
2	Link Configuration Error
3	Simulate Active
4	Local Override
5	Device Fault State Set
6	Device Needs Maintenance Soon
7	Sensor Failure detected by this block/process variable has a status of BAD, Sensor Failure
8	Output Failure detected by this block/back calculation input has a status of BAD, Device Failure
9	Memory Failure
10	Lost Static Data

BIT	MEANING
11	Lost NV Data
12	Readback Check Failed
13	Device Needs Maintenance Now
14	Power-up
15	Out-of-Service (Most Significant Bit)

Transducer blocks may contain the BLOCK_ERR parameter and/or may contain the XD_ERROR parameter. The standard bit meanings for XD_ERROR are identified in Table 2.

Table 2: XD_ERROR Parameter Meanings

VALUE	MEANING
16	Unspecified Error
17	General Error
18	Calibration Error
19	Configuration Error
20	Electronics Failure
21	Mechanical Failure
22	I/O Failure
23	Data Integrity Error
24	Software Error
25	Algorithm Error

For the purpose of device condition management, that is management of the integrity of devices and their continued capability to perform accurately;

- The transducer block provides diagnostic indications associated with sensors/actuators
- The resource block provides indications associated with device electronics

When a device detects the presence of a defined diagnostic indication, the BLOCK_ALM parameter is set. BLOCK_ALM is the associated alarm object that

generates a "Block Alarm" if one or more of the bits in BLOCK_ERR or XD_ERROR are set to 1. Bit #8 of the ALARM_SUM object corresponds to "Block Alarm".

In addition to these alarm parameters, individual device diagnostic detail parameters are accessible from the device but are not reported out individually as they occur. Where a history of parameter occurrence is not maintained within the device, this may limit the ability to track behaviour over time, thus impacting the ability to diagnose behaviour trends and tag related (physical installation point) recurrent problems.

1.3. Smart device reliability management

Field device maintenance can be a significant source of maintenance work. Anecdotal evidence suggests that historically, field device maintenance may be typified by:

- 65% of transmitter work orders are closed with no problem found; the problem is with some other equipment or with the process itself.
- 75% of control valves are pulled unnecessarily from the process line for maintenance.
- 50% of instrument technicians' time is spent filling out paperwork.

FOUNDATION Fieldbus device diagnostics provide a capability to address this wasted maintenance effort. The general idea is that the diagnostics available in smart field devices will prevent unnecessary maintenance through effectively reporting their condition. They enable rapid diagnosis of the existence of specific problems and hence contribute to the achievement of improved field device reliability management.

However, current device alerts/alarms do not provide clearly recognisable failure modes. If we expect to manage the condition of smart field devices through their diagnostic indications then it is necessary to be clear about exactly what is required to be managed and hence define what data is needed. Is the intent manage the integrity of the instrument/valve or the dependability of the function it provides? It is satisfactory for the answer to be "both" but, if this is the case we need to understand the fundamental difference between the two.

Device integrity management typically focuses on physical failure modes that are substantially similar regardless of the application. Functional performance management is more typically application specific.

Device Integrity Management.

Historically, device diagnostics have aimed to assist device level troubleshooting often with an in-the-field or bench-level analysis approach in mind. The integration of FOUNDATION Fieldbus devices within the control management domain changes the rationale for device management as they are now an embedded element of the control system. Management of their integrity can affect the execution of the process and so self-diagnostic outcomes and associated monitoring functions are more appropriately managed external to the device.

For FOUNDATION Fieldbus devices, remote monitoring, assessment and automated response action initiation is both appropriate and possible. In the case of control output devices such as valve positioners, condition indications can provide alerts to performance and physical condition degradation. These become essential initiators for pro-active maintenance.

When control is executed through FOUNDATION Fieldbus devices the intent is not to wait for a production impact to determine if it is necessary to send someone into the field to find the problem. With FOUNDATION Fieldbus, the earliest indications can be identified by the device and made accessible in the control domain for recognition, analysis and response initiation.

The controlling element should provide advice of its degradation through an alert/alarm mechanism thus allowing diagnosis and response at a system level. FOUNDATION Fieldbus protocol handles this well and allows all assessed parameters to be monitored remotely. Alerts however will require diagnostic detail review through parameter value assessment before the type and severity of the problem can be identified. Where there are many devices and/or the impact of degradation may be significant to the process, it may be impractical to undertake this task manually. To make sense of the task of monitoring the wide range of fault parameters from all the devices employed, an automated, exception detecting system is required. This should recognise alerts and manage the current values along with the history of the range of diagnostic indications as components of the failure mode types they represent.

Used in this way, FOUNDATION Fieldbus protocol allows for operators to be advised via control system alarm functionality and for instrument technicians to be advised of degradation through a device condition management interface. The ability to remotely monitor all condition assessment parameters facilitates remote assessment of the type of problem present. This facilitates definition of the response required before personnel are sent into the field. When coordinated with other process indications, the extent of the impact and the appropriate response urgency can also be assessed. Alerts allow operators to be advised of the nature of the problem and hence so they can manage the issue appropriately for the particular process. Where device diagnostics assessment identifies the need for a response, then an appropriately specific corrective action work order can be initiated. The extra detail provided by the assessment of the diagnostics and the type of failure mode identified allows for work order scheduling which is consistent with the type of fault identified and the impact on the process. FOUNDATION Fieldbus protocol greatly assists this workflow process.

For FOUNDATION Fieldbus protocol devices, vendors normally establish alarmed parameters as summary indicators. This minimises the device generated communication traffic associated with events that indicate a change in status/condition. It also recognises the fact that there isn't anyone available to monitor device diagnostic indications as they occur. The result is that the initial indication of an issue is general in nature and usually requires some form of assessment prior to initiating a response action.

As an example, consider the case of a temperature transmitter. Transmitter diagnostics provide data that assists understanding of the particular performance/behaviour problems a transmitter might be experiencing. This can guide the operator/maintainer to determine the type of issue present, assisting

recognition of the appropriate response action and level of urgency. However, it is unlikely that there will be anyone in the plant with time to monitor diagnostics as they occur. Therefore a summary indicator (alarm) can be used to advise the operator that a problem has been identified. Then immediate action can be taken to address the fact that the associated temperature indication may no longer be dependable. To actually resolve the problem, an instrument technician needs to be made aware that a problem exists, track it down and deal with it.

Available diagnostics provide useful indicators to the specifics of the device's condition that are relevant to repair/replacement decisions but do not necessarily directly advise what action is appropriate. Whilst the life cycle management of the transmitter is important (ie what failure mode has occurred and what is the implication of that for all assets of a similar type), the primary concern is to ensure the ability of the process to operate efficiently. This requires dependable transmitter indications and it requires to be determined if the problem is degradation or total failure. Then one can assess if the response action is device replacement, in-situ repair or calibration. It would be desirable for device self-diagnostics to provide this advice but they are usually not that conclusive. By some mechanism, the instrument technician needs to make this determination and FOUNDATION Fieldbus makes provision for device diagnostics to assist with that assessment.

Accessibility of device diagnostic indications via FOUNDATION Fieldbus protocol allows the technician to remotely review the current indications – all that remains is to establish a standardised review framework to assist with determining the appropriate response action. Largely this troubleshooting logic is provided by the device vendor's prepared maintenance documentation which is necessarily generic and limited in its coverage.

The extent to which the correct action is identified and initiated is directly related to how effective and efficient the maintenance task becomes. Correct response task identification and urgency translates to minimised production impact. This enables the achievement of optimised maintenance (perhaps defined as the least that can be done to ensure the desired level of dependability, timed to be completed with the minimum production impact). For production critical applications, it is appropriate for standardised response logic, enhanced with site and application specific knowledge, to be captured to assist with uniform event analysis.

Considering the example of a temperature transmitter further, it may fail (require maintenance intervention) due a range of issues which might be summarised as;

- Electronics board and memory faults
- Sensor faults
- Measurement faults
- Calibration faults
- Configuration faults

These are device integrity or 'physical' modes of failure.

From a functional perspective, the failure modes might be summarised as:

- Total Failure

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- Output >100%
- Frozen output
- No output
- Degraded Operation
 - High output
 - Low output
 - Output slow to respond
 - Output too fast
 - Output erratic

These parameters are required for the functional purpose of the control system.

Failure modes of these types are indicated by various diagnostics indications from FOUNDATION Fieldbus devices but seldom are any of them defined explicitly in these terms. As a result it is normally left to the instrument technician to work out what type of failure is present and consistently record similar failures to provide data for long term reliability analysis. This seldom happens.

Functional Performance Management.

Managing self-diagnosed field device indications can be a different task to pro-actively managing field device reliability. To manage field device functional dependability the mechanics of reliability engineering need to be understood. To monitor the achievement of an expected level of reliability, there is a requirement to accumulate data that allows for the assessment of the rate at which defined modes of failure occur. This facilitates recognition of;

- Overall failure frequency
- Failure mode frequency
- Failure rate distribution characteristics

From this information it is usually an aim to assess performance against expectation and then identify focus areas for improvement. This usually involves analysis for factors indicating abnormal failure frequency / rate causes warranting specific types of response. Usually evidence of infant mortality or lifecycle degradation is assessed.. Typically this information is supplemented with time to repair and repair cost / lost production value data to allow overall system availability and effectiveness to be assessed.

To make these assessments with statistically significant outcomes the data used needs to be grouped. This requires a hierarchical structure for assessing device, sub-system and system data and a standardised definition of what will be termed a failure. Specific device process application effects must be allowed for where there is significant variation in application of the same device type. Reliability assessment is usually based on functional performance but a mixture of functional and physical failure modes is not uncommon.

To uniformly identify the presence of equipment failure modes requires consistent practices for the review of condition indicating factors. Efforts to uniformly address FOUNDATION Fieldbus device diagnostics, typically through off-device performance assessment functionality, provides the input data needed to make valid performance assessments for device types used in similar conditions.

1.4. Practical Use of Field Device Diagnostics

It is one thing to recognise the capabilities of the FOUNDATION Fieldbus protocol in the area of device diagnostics, it is perhaps another to extract their potential. To ensure device condition is managed pro-actively to maintain any functional dependability requires off-device performance assessment. This also facilitates device type lifecycle management should accommodate any variation in application. An approach to effective utilisation of device diagnostics is to capture the experience and/or knowledge of device vendors and process specialists as fault models within the control environment. Device built-in diagnostics are then used as fault symptom information at the system level to recognise the presence of failure modes that can be made specific to the device application. This allows the status of both device integrity and function dependability to be analysed, reported and managed.

FOUNDATION Fieldbus devices for which off-device fault models have been prepared in an asset condition management system are automatically detected and diagnostics are actively monitored for the presence of faults. Fault categories typical to the management of control instruments monitored include;

1. Network Communications
2. Electronic Board
3. Memory and Database
4. Sensor
5. Calibration and Configuration
6. Process or Environment Related

An additional category entitled “Application Status” is used to support fault models for application diagnostics that are device specific. Examples include “entrained air alert” for Coriolis mass flowmeters and “level at Tank bottom” for radar level gauges. Honeywell’s asset condition management system recognises an ever growing list of FOUNDATION Fieldbus devices for off-device performance assessment. The list of vendors currently includes manufacturers such as Dresser-Masoneilan, Endress+Hauser, Flowserve, KROHNE, Yokogawa and Honeywell.

This approach allows the monitoring and response to;

- (a) The physical integrity of individual devices
- (b) The functional integrity of the role the device performs as it affects the associated process.

Historical behaviour and performance are retained and fault symptom and failure mode data is captured in a uniform manner hence supporting lifecycle management decisions.

2. Beyond the Field Device: Process-centric Asset Management

An approach to the management of the behaviour/condition/performance of production assets, including control and instrumentation hardware, is to provide embedded management of diagnostic messages and assessment of available condition indications. By continually monitoring the status, events, and operating conditions around all field devices and the control system hardware, an efficient approach to ensuring instrumentation, control and production asset reliability is realised.

1.5. Process-Centric versus Asset-Centric

In the control domain, most asset management offerings are instrument centric, focusing only on field devices and not on the impact of these and other assets to overall operational or process effectiveness. Delivering a useful solution for dealing with control hardware and field device diagnostics is, however, part of a bigger asset condition management picture that utilises the same control system data distribution infrastructure. The near real-time management of equipment diagnostic data offers the potential to get immediate feedback on the current condition of equipment and its affect on production performance. This closes the loop on asset management strategy implementation by reporting the presence of equipment modes of failure as they occur. The feature is just as relevant to production assets such as pumps, compressors, heat exchangers as it is to the life-cycle management of smart field devices.

Consider a definition of reliability-centred maintenance (RCM):

“A process used to determine what must be done to ensure that any physical asset continues to do what its users want it to do in its present operating context”.

Traditionally the science of reliability centred maintenance was focused on rotating equipment as these assets had assessable degradation parameters, high capital value and expensive repair processes. However anecdotally, most of the dollars lost from unreliability come from fixed equipment like piping, vessels, and heaters where the losses are associated with lost plant production and restricted capacity. This leads to the view that a focus on reliability and availability in the control domain should allow for the inclusion of assessment of the equipment and processes being monitored/controlled as well as the control/instrumentation infrastructure itself.

Work practices to improve reliability necessarily extend past the maintenance department and are now recognised as best practice in operations. With access to non-instrumented data input, the synergy between maintenance and operations for improved operations and equipment dependability can be captured. This is the basis of a process-centric asset condition management solution and the means by which it is achieved is via the control domain. This is necessary because it is the only plant infrastructure that continually monitors and reports equipment condition/behaviour/performance data as it happens and as it affects production.

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Honeywell's approach to realising near-real-time RCM results reporting was originally conceived with the idea of a Reliability Engineering focussed "DCS for Maintenance" in mind. It is designed to share domain expertise with frontline personnel, thus aiding troubleshooting of off-normal equipment functions in near real-time. The result is an advanced decision support application that provides actionable notifications. The application collects and organises data from a variety of sources, analyses the data, identifies process and equipment symptoms and faults, and notifies personnel of potential failures so that action can be taken before problems develop. In order to facilitate this, the package is a repository of captured site and manufacturer expertise. It also continuously applies this knowledge to live plant data to monitor asset and device performance on a 24/7 basis.

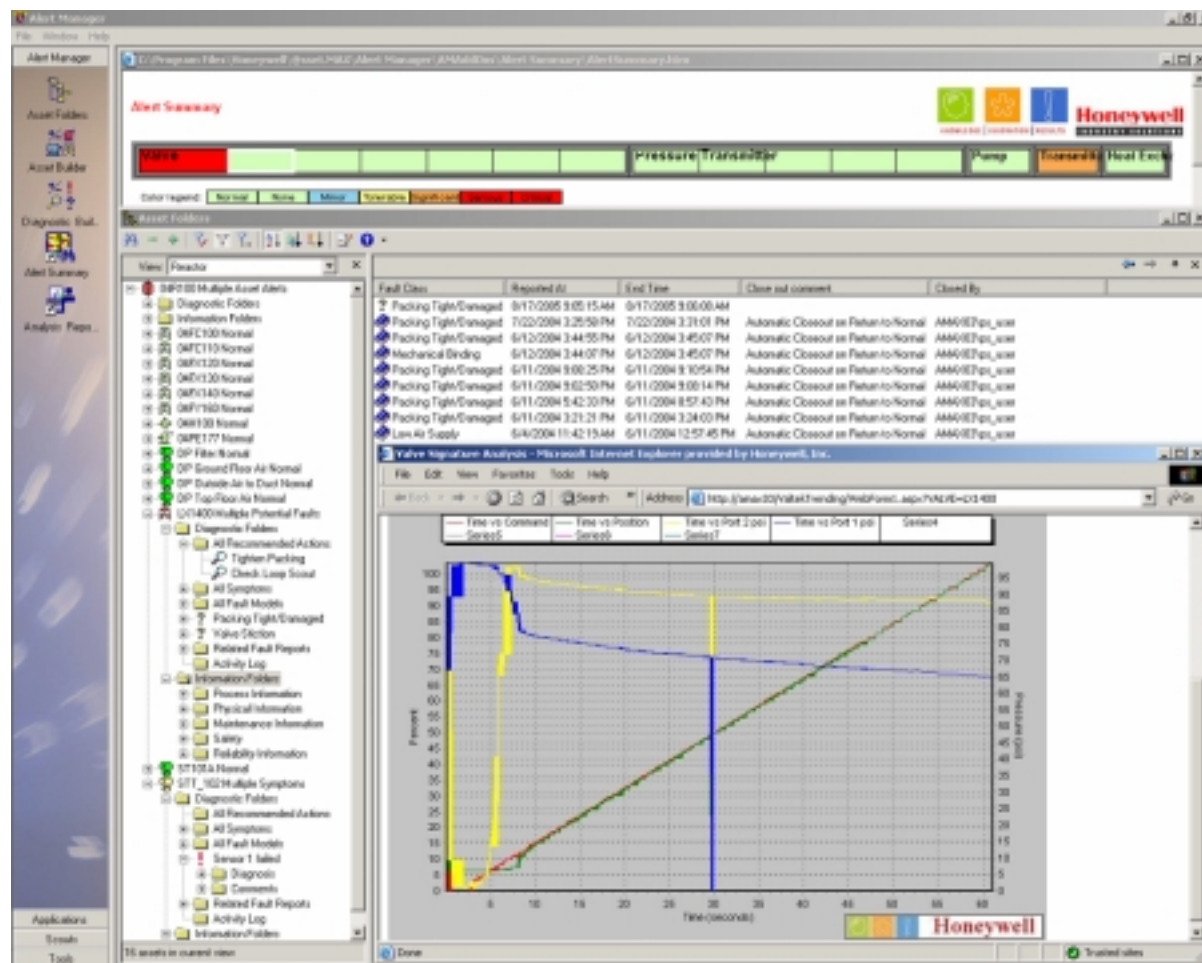


Fig 1. Equipment behaviour indications are managed as fault symptom sets, supported with information relevant to fault diagnosis and history management tools are provided..

3. Summary

To fully embrace the diagnostics potential available in FOUNDATION Fieldbus devices requires mechanisms to access and assess the available diagnostic indications. This allows degradation to be recognised and responded to with the appropriate urgency. To not do this may jeopardise the ability to return part of the benefit on which the protocol may have been justified

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FOUNDATION Fieldbus protocol advances the potential for device diagnostics to provide highly effective physical integrity management and application function dependability. Achieving this potential requires external assessment of device indications in the context of the process in which they are being used. This is consistent with plant equipment reliability management practices and allows FOUNDATION Fieldbus devices to be managed in a manner consistent with other process critical assets.

4. References

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