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# DELIVERING OPERATIONAL VALUE FROM FOUNDATION™ FIELDBUS FIELD DEVICES

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**A component of the justification for the use of FOUNDATION Fieldbus (FF) field devices has been the capability of those devices to provide comprehensive diagnostics. Delivering a useful result from these diagnostics has proven to require a structured approach to information collection, management and access. Raw device diagnostics must be processed to translate them into focussed, usable data that can be aligned to predefined maintenance actions and understood response urgencies. There is also benefit from the coupling of off-device assessments with on-device diagnostics to support functionally oriented process equipment performance assessment.**

**The application of FF field devices in minimally manned and unmanned plant increases the reliance on FF dependability and the performance of diagnostic assessment. Performance of the device function must be sustained and rare failure events must be recognised and acted on with appropriate urgency to prevent production impact. Managed appropriately, diagnostics can greatly assist in the timely detection of the need for planned intervention.**

**An approach for the management of device diagnostics for a range of FF device types, including transmitters and valve positioners, is discussed. This approach is currently used in the oil and gas industry in on-shore plants and off-shore processing facilities.**

**Keywords: performance, condition, behaviour, reliability, best practice**

## 1 Acronyms

| | |
|---|---|
| DD | Device Description |
| DVC | Digital Valve Controller |
| FF | FOUNDATION™ Fieldbus |
| FMECA | Failure Modes, Effects and Criticality Analysis |
| FPSO | Floating Production, Storage and Offloading |
| FVP | Fieldbus Valve Positioner |
| IO | Input / Output |

## 2 Introduction

Whilst not prescriptive with respect to diagnostic capabilities, the FOUNDATION Fieldbus (FF) protocol provides the capacity for device manufacturers to design equipment that provides a wide range of diagnostic data. This information potentially adds operational value beyond the primary function of the devices:

- satisfactory behaviour can be confirmed without venturing into the field
- questionable device behaviour can be identified before functionality is lost
- life-cycle performance can be monitored
- infrequent condition related events can be dealt with consistently
- baseline comparisons can be made and data trended

Releasing this potential requires an understanding of how to extract value from diagnostic information and planning for its utilisation.

Beyond individual diagnostic indications, many FF field devices provide optional advanced diagnostic assessment capabilities. These capabilities may require assessment with additional, proprietary software. Therefore their utilisation requires planning, training and additional cost. Also, in conjunction with manufacturer provided advice and an understanding of the operational application, the diagnostics on some FF field devices can be used to indicate condition on the process equipment to which they are attached. This typically requires off-device assessment to combine data from a variety of sources and should be planned for in the early stages of implementation.

Due to high variation in the range and nature of diagnostic capabilities between device types, careful selection is required to ensure the parameters required are available. However, the establishment of maintenance practices and condition monitoring requirements (Failure Modes, Effects and Criticality Analysis - FMECA) is typically performed after field device selections have been made. As this potentially limits the contribution device diagnostics can make to equipment condition management, careful consideration of the use to which FF device capabilities will be put is necessary when they are selected.

# 3 FF Device Condition Management

The primary purpose of FF device diagnostic indications is to provide device specific condition management. This capability fits well with the condition based equipment maintenance philosophy of just-in-time maintenance used by high performance process plants. The philosophy requires production critical equipment to be cared for by the assessment of dependable and timely condition indicators. The intended result is pro-active decision making on maintenance interventions to sustain the required rate of production at an acceptable risk of outage.

For condition based maintenance to work, the relationship between condition indicators and the root causes they are associated with must be understood. Single indications seldom uniquely identify a mode of failure. Some depth in equipment diagnostic detail is necessary to allow typical/critical faults to be identified. This is at the heart of the reliability centred approach to maintenance and is well server by the rich diagnostic detail provided by many FF field devices.

## Dealing with Rich Diagnostic Detail

In line with the reliability centred approach to maintenance, device condition indicators need to be carefully evaluated to select the data that can be used to initiate a response decision. Reviewing all diagnostic indicators for all devices is unlikely to be practical. Many indications will fall into the ‘information only’ category.

The most important indications may be infrequent, in many cases rare, and therefore be subject to highly variable assessment processes. This occurs due to operational personnel not being familiar with device diagnostics and their occurrence patterns. Most manufacturers provide diagnostic interpretation information in equipment manuals and this is often the only guide for response decision making. At the very least, these manuals should be kept directly accessible, preferably on-line, for ease of access to support timely decision making on the need to perform or defer a response. Device operational-use-guides as a component of datasheets would be useful as a primer to the greater detail that should be available in equipment technical manuals.

Summary alert indicators are often used to provide a general warning that a device is not behaving as intended. This is a practical approach to distilling the myriad of possible indications into general urgency of response indicators. One step better, and perhaps all that is warranted in most applications, is the combination and segregation of indicators into categories indicating the need for a specific type of response action.

## Look for what you need to know

Best practice for equipment care is to identify the possible range of response actions and streamline their initiation through condition monitoring logic. This aligns well with FF field instruments and valve positioners which, by their nature, have a limited range of operational response options and a wide range of diagnostics.

Plant maintenance controlled by planners is aided by providing for pre-estimated response actions with known labour, skill, test equipment and tool requirements. Doing this provides an improved capacity to respond to field device condition based events consistently and with urgency guided by the potential production impact should the device progress to failure.

Perhaps the single most important indication a device can provide is a positive indication of an unacceptable/failed state. Without this, it may be left to a secondary indicator to identify that process behaviour suggests a field device problem. If device monitoring does not focus on modes of failure, the result is labour effort consumed in diagnosing the situation and systematically ruling out all the possibilities until the fault is uncovered. Early warning of device faults is then missed allowing problems to progress to process impacts before they are able to be recognised.

## Remote Diagnostics Access

Readily accessible performance indications help confirmation of operational status. Anecdotal evidence of instrument technicians being requested to check performance of a field device with no fault found is commonplace. If nothing else, the FF protocol provides a rich source of device indications directly from the control room affording a rapid confidence check that apparent process issues are real. This should always be supplemented with periodic field inspections of general device condition to confirm housing/mounting integrity.

## The Diagnostics-fault Relationship

Just employing FF field devices does not readily provide direct recognition of developing problems, failed device sub-elements or the appropriate responses and urgencies. The diagnostic indicators in most devices require off-device processing to determine the nature and urgency of a developing problem. From an operational perspective, value comes from rapid, preferably automated, identification that a particular response, such as device replacement, is needed. The ability to diagnose in detail the specific issue that caused the device condition to be unacceptable has little meaning to a production manager. The ability to identify a fault before production is impacted and determine, that whilst replacement is warranted, it can be deferred for 72 hours does have value. Making such a determination is typically considered to be beyond the charter of on-device diagnostic assessment.

A joint operator/manufacturer approach to defining diagnostics that are useful contributors to the management of production risk would be beneficial. Diagnostic detail tends to be a manufacturer led domain and, as such, does not always provide detail structured to facilitate efficient and effective maintenance.

In the case of field transmitters, cost and replaceability typically results in their treatment as commodity items and therefore they are often not subject to repair action. Detailed diagnostics might be interesting to some but when the security of the production rate is what makes the money there is typically little justification for bench level analysis or device repair. In these instances, corporate management of device type life-cycle reliability information requires an off-device event history trapping capability to aggregate symptoms and failure mode information as the basis for detailed diagnosis and system design improvement.

### *3.1 Current Device Performance Assessment Approach*

The prevalent approach in industry at present is to manage field devices using process control practices. That is, devices are expected to be monitored in a manner analogous to the management of process alarms. This leads to an expectation that field devices provide good / suspect (alert) / bad (alarm) indications and that, therefore, some form of continuously monitored display (equivalent to an alarm summary display) is required.

This expectation doesn't appear to fit well with the small to medium size process plants in the Pacific region where there are seldom plant based instrument staff with a role to monitor diagnostic indicators. Control operators are focussed on process management and not generally amenable to responding to field device condition alerts.

Systems tend to be implemented to provide device current state information only which by definition requires continuous monitoring. As devices do not typically provide access to a history of diagnostic events they are then left to be managed reactively.

**Diagnostics Support Isolated Plants**

Process plants in the Pacific region have an increasing tendency to be built in remote and/or environmentally sensitive locations to optimise return on capital investment and production profitability with respect to proximity to primary resources, energy and export infrastructure. These factors are more likely to dominate construction decisions than the availability of skilled manpower. Focus is therefore being placed on minimising plant based manpower (for example Woodside's Nganhurra Floating Production, Storage and Offloading (FPSO) vessel and Chevron's Gorgon Gas Plant).

The result is a reduced ability to monitor and respond to equipment faults as they occur, therefore, introducing the need for a pro-active management process based on remotely assessed condition indicators.

To effectively support unmanned and isolated plants, asset managers have to utilise early warning indicators as the primary means by which to assess and predict the health of plant equipment. A wide range of dependable and accessible behaviour, performance and condition indicators are required for this assessment – a requirement well met by FF field devices.

To effectively monitor and diagnose the health of a facility remotely, the diagnostic data gathered must allow behaviour, performance and condition to be determined, assessed and correlated in relation to potential and actual fault conditions in a timely manner.

### *3.2 Best Practice Device Condition Management*

Best practice for equipment condition management, including FF field devices is, on the notified occurrence of an equipment issue (such as a diagnostic indication), for the device status and recent history to be reviewed.

Where practical, an automated identification of the nature of the fault that is likely should be provided aligned to the range of possible response actions. Additionally an indication of its typical relative urgency should be provided for confirmation through review of recent status / symptom history and current plant operational factors.

Implementation of such a system requires off-device assessment capabilities and management of device diagnostic indications beyond the access to current data which might be achieved through control system point detail displays. Structuring device assessment application contents, access and management are value generating tasks that are best carried out within the scope of an implementation project.

Fortunately most systems utilise a relatively small number of field device types allowing advantage to be taken from templating assessment practices and establishing typical device fault response urgencies. Customisation is then only required for the relatively few device tags that warrant lower or high response urgency due to their location and/or role in the production process.

### *3.3 Delivering Condition Based Value from Highly Reliable Devices*

FF field devices provide accurate, reliable and repeatable measurement of process variables. They are likely to perform without fault for many thousands of operating hours. Transmitter manufacturers will advise expected reliability for FF device electronics of the order of 0.5 failures per million operating hours. This equates to one failure per 250 years of accumulated device operation i.e. a population of 100 devices would be expected to yield one failure every 2.5 years for continuous operation within environmental limits.

Anecdotal evidence suggests most FF device issues stem from incomplete or incorrect device/IO configuration and/or poor installation practices exposing devices to extreme environmental conditions.

In a well implemented system, where then is the value from the wealth of diagnostic indications FF field devices typically provided? The answer is in the ability to efficiently handle infrequent faults and the capacity to provide information about the process equipment to which the devices are attached.

# 4 Management of Infrequent Failures

To effectively manage infrequent events requires efficient systems to guard against the occurrence of an event that may never occur and that if it does, could acceptably be allowed to proceed to failure without significant impact.

Managed by device class and focussed to align to readily applied response actions, FF device condition management can generally be justified. The analysis done to monitor critical devices is utilised on all devices of the same class, possibly with a range of response urgencies, at little or no additional labour, software or hardware cost. A significant benefit is the ability to standardise the manner in which infrequent diagnostic indications are assessed. A structure to allow learning of how best to deal with device problems is also required to incorporate operational experience.

Occurrence rates are so low that it is unlikely that any individual will see enough fault scenarios to remember the best practice approach to their diagnosis, the appropriate response and associated urgency. Without this structure, all faults tend to get dealt with as either emergency breakdowns or deferred until a shutdown/campaign maintenance interval as there is no maintenance framework to identify the relative importance to the process of each field device.

An example is FF temperature devices fitted with redundant thermocouple elements (dual/hot backup sensor). Failure of a thermocouple, subject to a benign environment, is a rare event and has no direct effect on the primary function of the device as the process variable continues to be reported from the secondary thermocouple. When a single thermocouple fails the risk of loss of the indication to the control system is significantly increased but the immediate performance is not affected.

The risk is efficiently managed by notifying maintenance that a thermocouple replacement failure has occurred as detected by device diagnostics and indicating a response urgency of ‘next available access’. What is perhaps less obvious is that determining the appropriate response urgency from the available diagnostics can quickly become a non-trivial exercise. Urgency is determined by the increased risk in relation to revenue and safety and, as this is production context specific, is variable.

The richness of the diagnostics clouds the appropriate urgency and again there is a tendency to either treat the situation as an emergency breakdown or defer it until access is convenient for maintenance. Planning is required to ensure diagnostics contribute value by assisting the development of a response decision that considers the current condition of equipment.

## *4.1 Example: Temperature Transmitter Fault*

Confronted with the occurrence of sensor related diagnostic indication from a pump output temperature transmitter, what action do you take?

In the case of a sensor failure (either open circuit or shorted) the appropriate response may be temperature element wiring assessment or sensor replacement. Both require access to the sensor.

From the perspective of instrument maintenance you might consider:

- how is the indication defined by the manufacturer?
- what does the manufacturer recommend as a response action?

Operationally there are two considerations:

- in what way does the fault jeopardise current production requirements and alter risk in terms of safety, environmental release, potential damage to capital.
- what kind of response is appropriate, how soon can it be implemented and at what cost?

Improving maintenance performance requires control over the initiation of maintenance based on condition indicators. The diagnostic indicators provided in FF field devices can be utilised to facilitate this practice.

Reviewing the sensor related indications available in the temperature transmitter (Table 1), it can be seen that the logic to determine the appropriate response urgency for a sensor failure is best structured to improve the ability to achieve uniform diagnosis and guide the appropriate response for the management of production risk.

Table 1: Example FF temperature fault assessment for a sensor fault

<table>
<tr><th>Temperature Sensor</th><th>Performance Impact</th><th colspan="3">LOGIC</th><th>SYMPTOM</th></tr>
<tr><td rowspan="4">sensor failure</td><td rowspan="4">Serious</td><td rowspan="4">AND</td><td rowspan="2" colspan="2">OR</td><td>sensor 1 open</td></tr>
<tr><td>sensor 1 shorted</td></tr>
<tr><td rowspan="2" colspan="2">OR</td><td>sensor 2 open</td></tr>
<tr><td>sensor 2 shorted</td></tr>
<tr><td rowspan="6">sensor fault</td><td rowspan="6">Significant</td><td rowspan="6">OR</td><td rowspan="4">XOR</td><td rowspan="2">XOR</td><td>sensor 1 open</td></tr>
<tr><td>sensor 2 open</td></tr>
<tr><td rowspan="2">XOR</td><td>sensor 1 shorted</td></tr>
<tr><td>sensor 2 shorted</td></tr>
<tr><td rowspan="2" colspan="2"></td><td>sensor 1 beyond operating limits</td></tr>
<tr><td>sensor 2 beyond operating limits</td></tr>
<tr><td rowspan="2">sensor alert</td><td rowspan="2">Tolerable</td><td rowspan="2" colspan="3">OR</td><td>sensor 1 out of operating range</td></tr>
<tr><td>sensor 2 out of operating range</td></tr>
<tr><td rowspan="2">sensor warning</td><td rowspan="2">Minor</td><td rowspan="2" colspan="3">OR</td><td>sensor 1 degraded</td></tr>
<tr><td>sensor 2 degraded</td></tr>
</table>

It is not reasonable to expect that operational personnel, confronted with a sensor fault indication, will automatically and uniformly recall the local best practice logic for assessing the response urgency.

### *4.2 Variation in Diagnostic Indicators*

Process plants are seldom over-instrumented. There is typically no redundancy in process instrumentation and few transmitters that do not perform a function that either facilitates or optimises control and production efficiency. The unacceptable performance or loss of a field device will have some effect on the risk of adversely affecting productivity. Devices that facilitate the early recognition of a fault, regardless of how infrequently it might be expected, will provide a lower risk to productivity than those that require the impact of the fault to have occurred before their poor performance can be identified. Fieldbus technologies with on-line accessibility to on-device diagnostic assessment provide a high level of protection to device fault related production impact.

Cost effective management of field device diagnostics requires:

- selective use based on the range of fault types relevant to each plant
- pre-assigned urgency with which determined faults are to be addressed

As a competitive differentiator, device manufacturers provide the widest range of diagnostic indications that can be achieved commensurate with the device's cost, intended application and processing power. This should not be interpreted as meaning that all diagnostics are valuable for all users. The range of diagnostic indications on a particular device may exceed those needed for site support capabilities but, provided the data needed to recognise unacceptable behaviour is available, a sub-set of indications may satisfactorily aid management of equipment condition related production risk.

Just as the range of faults that are relevant is limited and possibly site specific, available response options are also typically limited. It is not uncommon for the capability of operational resources to practically limit response to:

- device configuration adjustment from the control room (such as device range or threshold level adjustment), or
- device replacement.

It is important to thoroughly understand the possible response actions as there is a wide variation in diagnostic detail between devices of the same type from different manufacturers. That is, diagnostic assessment effort must be outcome focused to avoid setting up device response assessment on a parameter by parameter basis. This is generally a much larger task than the value it generates. Outcome focussed assessment accommodates the variation between devices from different manufacturers for an identical application having little or no common detailed diagnostic indicators.

## 4.3 Comparison of Available Diagnostics

Table 2 provides a summary of FF device transducer block condition indicators provided by similar application temperature transmitters from two leading manufacturers.

Table 2: Example Temperature Transmitter Condition Indicators from Different Manufacturers

| TEMPERATURE TRANSMIITER 1 | | | TEMPERATURE TRANSMITTER 2 | | |
|---|---|---|---|---|---|
| Symptom | Source | Data Type | Symptom | Source | Data Type |
| other error | BLOCK_ERR:0 | bit pattern | other error | BLOCK_ERR:0 | bit pattern |
| device needs maintenance soon | BLOCK_ERR:6 | bit pattern | device needs maintenance soon | BLOCK_ERR:6 | bit pattern |
| input failure | BLOCK_ERR:7 | bit pattern | input failure | BLOCK_ERR:7 | bit pattern |
| lost NV data | BLOCK_ERR:11 | bit pattern | lost NV data | BLOCK_ERR:11 | bit pattern |
| device needs maintenance now | BLOCK_ERR:13 | bit pattern | device needs maintenance now | BLOCK_ERR:13 | bit pattern |
| power-up | BLOCK_ERR:14 | bit pattern | power-up | BLOCK_ERR:14 | bit pattern |
| out-of-service | BLOCK_ERR:15 | bit pattern | out-of-service | BLOCK_ERR:15 | bit pattern |
| general error | XD_ERROR: 17 | numeric | general error | XD_ERROR: 17 | numeric |
| calibration XD_ERROR | XD_ERROR: 18 | numeric | calibration XD_ERROR | XD_ERROR: 18 | numeric |
| configuration error | XD_ERROR: 19 | numeric | configuration error | XD_ERROR: 19 | numeric |
| electronics failure | XD_ERROR: 20 | numeric | electronics failure | XD_ERROR: 20 | numeric |
| mechanical failure | XD_ERROR: 21 | numeric | mechanical failure | XD_ERROR: 21 | numeric |
| I-O failure | XD_ERROR: 22 | numeric | I-O failure | XD_ERROR: 22 | numeric |
| data integrity error | XD_ERROR: 23 | numeric | data integrity error | XD_ERROR: 23 | numeric |
| software error | XD_ERROR: 24 | numeric | software error | XD_ERROR: 24 | numeric |
| algorithm error | XD_ERROR: 25 | numeric | algorithm error | XD_ERROR: 25 | numeric |
| invalid configuration | sensr_detailed_status:0 | bit pattern | input open | STT35F_XD.XD_diagnostics:1 | numeric |
| ASIC RCV error | sensr_detailed_status:1 | bit pattern | sensor drift red mode | STT35F_XD.XD_diagnostics:2 | numeric |
| ASIC TX error | sensr_detailed_status:2 | bit pattern | primary sensor failed | STT35F_XD.XD_diagnostics:3 | numeric |
| ASIC interrupt error | sensr_detailed_status:3 | bit pattern | sensor drift | STT35F_XD.XD_diagnostics:4 | numeric |
| reference error | sensr_detailed_status:4 | bit pattern | config alarm | STT35F_XD.XD_diagnostics:5 | numeric |
| ASIC config error | sensr_detailed_status:5 | bit pattern | zero out of range | STT35F_XD.XD_diagnostics:6 | numeric |
| sensor 1 open | sensr_detailed_status:6 | bit pattern | temp out of range | STT35F_XD.XD_diagnostics:7 | numeric |
| sensor 1 shorted | sensr_detailed_status:7 | bit pattern | bad cold junction | STT35F_XD.XD_diagnostics:8 | numeric |
| terminal temp failure | sensr_detailed_status:8 | bit pattern | input out of spec | STT35F_XD.XD_diagnostics:9 | numeric |
| sensor 1 out of range | sensr_detailed_status:9 | bit pattern | bad sensor type-config combo | STT35F_XD.XD_diagnostics:10 | numeric |
| sensor 1 beyond limits | sensr_detailed_status:10 | bit pattern | bad units selected | STT35F_XD.XD_diagnostics:11 | numeric |
| terminal temp out of range | sensr_detailed_status:11 | bit pattern | sensor brk detect off | STT35F_XD.XD_diagnostics:12 | numeric |
| terminal temp beyond limits | sensr_detailed_status:12 | bit pattern | CJ val too low | STT35F_XD.XD_diagnostics:13 | numeric |
| sensor 1 degraded | sensr_detailed_status:13 | bit pattern | hardware failure | STT35F_XD.XD_diagnostics:14 | numeric |
| calibration error | sensr_detailed_status:14 | bit pattern | | | |
| sensor 2 open | sensr_detailed_status:15 | bit pattern | | | |
| sensor 2 shorted | sensr_detailed_status:16 | bit pattern | | | |
| sensor 2 out of range | sensr_detailed_status:17 | bit pattern | | | |
| sensor 2 beyond limits | sensr_detailed_status:18 | bit pattern | | | |
| sensor 2 degraded | sensr_detailed_status:19 | bit pattern | | | |
| sensor drift alert | sensr_detailed_status:20 | bit pattern | | | |
| hot backup active | sensr_detailed_status:21 | bit pattern | | | |

Similarities are evident in the nature of indications provided largely due to BLOCK_ERR and XD_ERROR parameters having standard meanings in the FF specification. However, there is a low correlation of parameters for the detailed diagnostic elements.

### *4.4 Implementing Response Oriented Assessment*

Regardless of the availability of highly knowledgeable instrument technicians/engineers who are thoroughly versed in the intricacies of specific device types, operational support practices are likely to limit the range of efficient response actions that can be provided and the range of urgency options. An example response policy is provided in Table 3.

Table 3: Example FF device constrained diagnostic indication response action and urgency.

| **Nature of Event** | | **Facility Type** | | |
|---|---|---|---|---|
| | | **Manned** | **Minimally Manned** | **Not Normally Manned** |
| **Severity** | **Effect** | Gas Plant | FPSO | Unmanned Platform |
| | | **Response** | | |
| **BREAK DOWN** | production affected | Replace device within this shift | Replace device within 48 hours | Intervention visit to replace device |
| | no immediate effect on process | Replace device within 48 hours | Replace device within 72 hours | Replace on next available access |
| **FAULT** | device primary function impaired | Adjust or replace device within 72 hours | Adjust within 72 hours or replace at next campaign maintenance | Adjust within 72 hours or replace at next campaign maintenance |
| | information diagnostic not requiring immediate response | Monitor | Monitor | Monitor |

The value of monitoring the integrity of field devices is relatively high where the detection of symptoms, notification of technical staff and identification of typical response action and urgency is automated. Achieving this value requires:

- selection of field devices that provide the range of diagnostic indications required to determine the presence of faults warranting the type of maintenance responses capable of being implemented.
- configuration of off-device applications to monitor fault symptom history, provide initial diagnostic recommendation and indicate typical response urgency

- training of operational support personnel in the use and management of the device management application.

# 5 Process Equipment Performance Assessment and FF Device Diagnostics

Beyond the acceptable performance of the FF device, the computational capacity and the transducer block element of the device architecture can be used by manufacturers to make assessments of the behaviour, performance and condition of the process assets to which the devices are connected. This is most frequently the case for intimately coupled devices such as valve positioners. FF valve positioners commonly monitor valve functions including performance associated with the supply air, actuator and valve body.

## *5.1 Fieldbus Valve Positioner – Detection of valve leakage in the closed position*

Device diagnostics can be coupled with off-device indications to make a rudimentary assessment of the presence of equipment failure modes such as leakage in the closed position for a valve assembly. This could be achieved by coupling a routine assessment of a valve closed position indication with an off-device assessment such as downstream flow sensor value. A time period over which the condition must remain true would normally be required to stabilise the reporting of a definite fault. Example logic for the Dresser FVP (Dresser, February 2004) is in Table 4.

Table 4: Example FVP FF device fault logic for leakage in the closed position.

| **Valve Leakage in Closed Position Fault** | | | |
|---|---|---|---|
| AND | FVP_TRANSDUCER.FINAL_POSITION_VALUE.VALUE | less than | 1.1 |
| | FLOWSENSORTAG.PV | greater than | 0 |

Tolerance for leakage in respect of process management cannot be relied on by maintenance so as to wait for a process alarm to trigger maintenance initiation. For maintenance to retain control of critical equipment condition and plan for the restoration of faults before production is impacted, condition indicators need to be monitored, managed and responded to pro-actively.

## *5.2 Fieldbus Valve Positioner - Detection of Actuator fault*

A valve positioner might also be utilised to assess the state of a valve actuator by using a travel feedback linkage for elements of valve movement assessment. It also monitors travel deviation to a range of alert parameters and provides a general ‘travel deviation’ alert where any of the travel high or low limit thresholds have been passed. These diagnostic parameters can be combined to provide a simple identification of an actuator fault (Table 5).

Table 5: Example FVP FF device fault logic for actuator faults.

| DVC6000 Valve Actuator Fault | | | |
|---|---|---|---|
| OR | AND | valve stuck low or arm damage | Bit 10 of ValveTag.transducer.PD_DETAIL1_ACTIVE' is on |
| | | travel deviation | Bit 0 of ' ValveTag.transducer.TRAVEL_ACTIVE' is on |
| | AND | valve stuck high or arm damage | Bit 11 of ' ValveTag.transducer.PD_DETAIL1_ACTIVE' is on |
| | | travel deviation | Bit 0 of ' ValveTag.transducer.TRAVEL_ACTIVE' is on |

### *5.3 Fieldbus Valve Positioner - Detection of Air Supply Fault*

Definitively determining the presence of a valve system fault such as with the air supply can present a more difficult challenge. After a detailed review of the device operation manual and consultation with the vendor it was determined that four parameters could be utilised to definitively identify a fault with the valve supply air:

- FVP_TRANSDUCER.SERVO_OUTPUT_SIGNAL
- FVP_TRANSDUCER.OUTPUT_PRESSURE
- FVP_TRANSDUCER.MEAS_SPRING_RANGE
- FVP_RESOURCE.DEVICE_STATUS_3

Clearly, the combination of transducer block parameters that will identify the fault is not directly evident even when you know which specific parameters are related to the fault.

Over and above recognising how to interpret the parameters these diagnostic indicators provide, inhibiting logic is necessary to account for the range of device configurations to ensure applicability of the fault model regardless of the application.

Table 6 shows the fault logic that would determine the presence of an air supply fault. It must be recognised that the specific parameters that are used to make this assessment may not be available from all FF positioners. They may also be in different forms that require fault models of greater of lesser complexity to resolve into the definitive identification of an air supply fault.

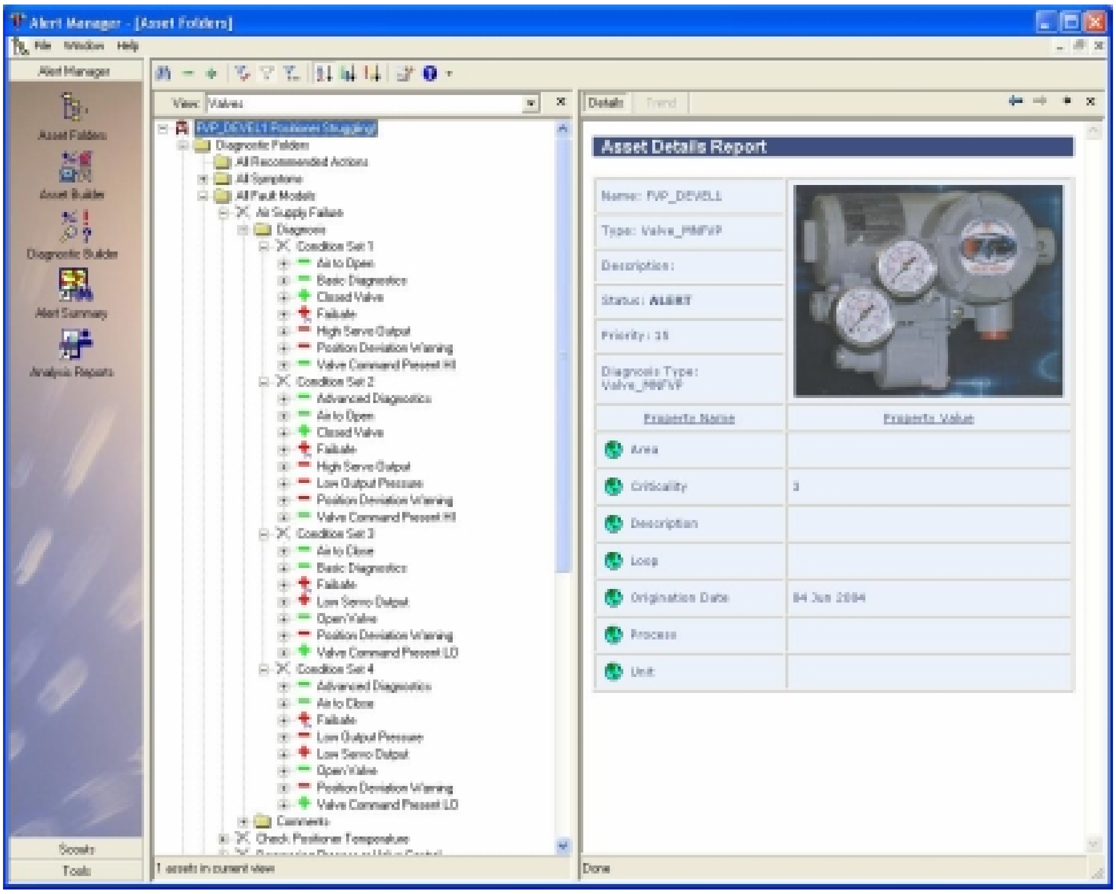
Table 6: Example FVP FF device fault logic Air Supply Fault.

| Fault Conditions | | Diagnostic Indicator | Comdined Diagnostic Indication | | | | | Device Parameter | Assessment Type | Operator | Value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Air Spply Fault | | | | | | | | | | | |
| OR | OR | Air to Open | | | | | | FVP_TRANSDUCER.ACT_FAIL_ACTION | numeric | equals | 1 |
| | | Basic Diagnostics | | | | | | FVP_TRANSDUCER.PRESS_SENS_INSTALLED | numeric | equals | 1 |
| | | Closed Valve | | | | | | FVP_TRANSDUCER.FINAL_POSITION_VALUE.VALUE | range | less than | 1.1 |
| | | Failsafe | NOT | failsafe | combination | OR | failsafe1 | RESOURCE.DEVICE_STATUS_3 | Bitstring | equals | 0001000000000000 |
| | | | | | | | failsafe2 | RESOURCE.DEVICE_STATUS_3 | Bitstring | equals | 0010000000000000 |
| | | | | | | | failsafe3 | RESOURCE.DEVICE_STATUS_3 | Bitstring | equals | 0100000000000000 |
| | | High Servo Output | | | | | | FVP_TRANSDUCER.SERVO_OUTPUT_SIGNAL | range | greater than | 98 |
| | | Position Deviation Warning | | | | | | RESOURCE.DEVICE_STATUS_3 | bitstring | equals | 0000000100000000 |
| | | Valve Command Present High | | valve command present high | combination | OR | valve command present high 1 | FVP_TRANSDUCER.FINAL_VALUE.VALUE | range | greater than | 0 |
| | | | | | | | valve command present high 2 | FVP_TRANSDUCER.FINAL_VALUE.VALUE | range | greater than | FVP_TRANSDUCER.FINAL_VALUE_CUTTOFF_LO |
| | OR | Advanced Diagnostics | | | | | | FVP_TRANSDUCER.PRESS_SENS_INSTALLED | numeric | equals | 2 |
| | | Air to Open | | | | | | FVP_TRANSDUCER.ACT_FAIL_ACTION | numeric | equals | 1 |
| | | Closed Valve | | | | | | FVP_TRANSDUCER.FINAL_POSITION_VALUE.VALUE | range | less than | 1.1 |
| | | Failsafe | NOT | failsafe | combination | OR | failsafe1 | RESOURCE.DEVICE_STATUS_3 | Bitstring | equals | 0001000000000000 |
| | | | | | | | failsafe2 | RESOURCE.DEVICE_STATUS_3 | Bitstring | equals | 0010000000000000 |
| | | | | | | | failsafe3 | RESOURCE.DEVICE_STATUS_3 | Bitstring | equals | 0100000000000000 |
| | | High Servo Output | | | | | | FVP_TRANSDUCER.SERVO_OUTPUT_SIGNAL | range | greater than | 98 |
| | | Low Output Pressure | | | | | | FVP_TRANSDUCER.OUT_PRESSURE | range | less than | FVP_TRANSDUCER.MEAS_SPRING_RANGE[2] |
| | | Position Deviation Warning | | | | | | RESOURCE.DEVICE_STATUS_3 | bitstring | equals | 0000000100000000 |
| | OR | Valve Command Present High | | valve command present high | combination | OR | valve command present high 1 | FVP_TRANSDUCER.FINAL_VALUE.VALUE | range | greater than | 0 |
| | | | | | | | valve command present high 2 | FVP_TRANSDUCER.FINAL_VALUE.VALUE | range | greater than | FVP_TRANSDUCER.FINAL_VALUE_CUTTOFF_LO |
| | | Air to Close | | | | | | FVP_TRANSDUCER.ACT_FAIL_ACTION | numeric | equals | 2 |
| | | Basic Diagnostics | | | | | | FVP_TRANSDUCER.PRESS_SENS_INSTALLED | numeric | equals | 1 |
| | | Failsafe | NOT | failsafe | combination | OR | failsafe1 | RESOURCE.DEVICE_STATUS_3 | Bitstring | equals | 0001000000000000 |
| | | | | | | | failsafe2 | RESOURCE.DEVICE_STATUS_3 | Bitstring | equals | 0010000000000000 |
| | | | | | | | failsafe3 | RESOURCE.DEVICE_STATUS_3 | Bitstring | equals | 0100000000000000 |
| | | Low Servo Output | | | | | | FVP_TRANSDUCER.SERVO_OUTPUT_SIGNAL | range | less than | 2 |
| | | Open Valve | | | | | | FVP_TRANSDUCER.FINAL_POSITION_VALUE.VALUE | range | greater than | 98 |
| | | Position Deviation Warning | | | | | | RESOURCE.DEVICE_STATUS_3 | bitstring | equals | 0000000100000000 |
| | | Valve Command Present Low | | valve command present low | combination | OR | valve command present low 1 | FVP_TRANSDUCER.FINAL_POSITION_VALUE.VALUE | range | less than | 95 |
| | | | | | | | valve command present low 2 | FVP_TRANSDUCER.FINAL_POSITION_VALUE.VALUE | range | less than | FVP_TRANSDUCER.FINAL_VALUE_CUTTOFF_HI |
| | OR | Advanced Diagnostics | | | | | | FVP_TRANSDUCER.PRESS_SENS_INSTALLED | numeric | equals | 2 |
| | | Air to Close | | | | | | FVP_TRANSDUCER.ACT_FAIL_ACTION | numeric | equals | 2 |
| | | Failsafe | NOT | failsafe | combination | OR | failsafe1 | RESOURCE.DEVICE_STATUS_3 | Bitstring | equals | 0001000000000000 |
| | | | | | | | failsafe2 | RESOURCE.DEVICE_STATUS_3 | Bitstring | equals | 0010000000000000 |
| | | | | | | | failsafe3 | RESOURCE.DEVICE_STATUS_3 | Bitstring | equals | 0100000000000000 |
| | | Low Output Pressure | | | | | | FVP_TRANSDUCER.OUT_PRESSURE | range | less than | FVP_TRANSDUCER.MEAS_SPRING_RANGE[2] |
| | | Low Servo Output | | | | | | FVP_TRANSDUCER.SERVO_OUTPUT_SIGNAL | range | less than | 2 |
| | | Open Valve | | | | | | FVP_TRANSDUCER.FINAL_POSITION_VALUE.VALUE | range | greater than | 98 |
| | | Position Deviation Warning | | | | | | RESOURCE.DEVICE_STATUS_3 | bitstring | equals | 0000000100000000 |
| | | Valve Command Present Low | | valve command present low | combination | OR | valve command present low 1 | FVP_TRANSDUCER.FINAL_POSITION_VALUE.VALUE | range | less than | 95 |
| | | | | | | | valve command present low 2 | FVP_TRANSDUCER.FINAL_POSITION_VALUE.VALUE | range | less than | FVP_TRANSDUCER.FINAL_VALUE_CUTTOFF_HI |

Managing logical combinations of device diagnostics as well as combining off-device indicators is typically handled in an asset effectiveness management system such as is show in Figure 1. These systems provide two key features:

- combinatorial assessment of behaviour, performance and condition indicators based on assessing diagnostic parameter values
- history of the occurrence of individual events, device faults and device type reliability

Figure 1: An Asset Effectiveness Management Application Monitoring a Detailed Valve Fault.




## 6 Advanced Diagnostic Performance Assessment

In addition to generally accessible diagnostics, several manufacturers utilise the computational power of FF field devices to provide advanced proprietary functionality. It is typical for the value from this functionality to require additional proprietary software for full configuration and utilisation. Some of the additional capabilities relate to advanced device configuration and some provide high performance diagnostic applications.

Level gauges occasionally utilise additional software applications for configuration and many valve positioners have a proprietary high performance diagnostic software application.

Utilising these applications to release operational value typically requires planning to ensure communication infrastructures provide access to devices from a central location rather than restricting connection to devices on individual FF segments and the associated need to travel into the field to perform advanced diagnostics.

## 7 Delivering Value Takes Planning

It is unreasonable to expect that access to a wide range of detailed diagnostics as is available with FF field devices will, of itself, make the recognition of faults self-evident. It is necessary to focus on the required outcomes (fault identification) that diagnostics can support and their alignment to the possible range of operational maintenance responses. Achieving this result will require some effort; the reward is low variability response to changes in device condition and routine assessment behaviour as if your most experience personnel were available regardless of who is present when a device condition change occurs.

Deriving value from FF device diagnostics is a non-trivial exercise but one that offers high rewards due to the proliferation of instances of relatively few types of devices. Sites with thousands of devices of less than twenty types are common. This provides a wide capacity for payback on the investment to determine the appropriate utilisation of FF device diagnostic information as a facilitator to the initiation of appropriate maintenance responses.

As the use of device diagnostics matures it is expected that manufacturers will take increased advantage of the FF transducer block architecture element and device computational capability to provide a larger range of operational support oriented fault indications.

There will always be a place for site and application specific tuning of generic fault identification. It would be inefficient to attempt to manage such generic capability modification on a device-by-device basis so it is expected that off-device, system wide asset effectiveness management applications will grow in importance in standardising site equipment management. Their ability to template customised fault models and manage fault sets on a device type template basis provides a more powerful and customisable approach than can be achieved by individual device content management. They also have the additional ability of being able to manage replacement of devices with versions having different DD revisions without having to modify the generic diagnostics setup of the new device.

Utilising off-device indications to provide assessment of related system behaviour, performance and condition can also be expected to emerge as a user requirement. The FF protocol, providing controller capabilities and being able to operate in conjunction with other devices provides the structure necessary to deliver system performance management outcomes. These outcomes are likely to be susceptible to both process variation and equipment condition. As the combinatorial assessment requirements are the same for each there is no barrier to including condition assessment as a system performance assessment factor.

Utilising this potential value demands planning for incremental capability development and implementation of asset effectiveness management applications at sites. Application content requirements can be expected to grow in sophistication as use identifies what is valuable for the range of device utilisation at each site. It would therefore be wise to overlay a strategy and chronological roadmap for FF diagnostic assessment capability utilisation.

On the manufacturer side more options in respect of flexible function blocks can be expected and strategies for managing segment bandwidth will be required as the use of diagnostic detail expands.

## 8 Summary

Delivering operational value from FF field devices is frequently overlooked at the project implementation stage. To provide higher value, implementation effort needs to be extended to establish what the devices need to achieve to deliver operational value. This is a well practiced methodology in maintenance (reliability centred maintenance) and there is an increasing trend for field device capabilities to be included in the project phase maintenance requirements analysis.

There is additional operational value to be gained through the active use of device diagnostic capabilities for minimally manned and unmanned facilities which require advanced warning of maintenance requirements.

To gain value from the diagnostic assessment capabilities of FF field devices requires a strategy, planning and effort. The outcome, based on device type diagnostic assessment, provides a solution that can be leveraged efficiently across all FF field devices at a site and used as a guide for corporate asset effectiveness management best practice for multi-site organisations.

## 9 References

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