Foundation Fieldbus Control in Field - Benefits

By:
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Emerson Process Management
Middle East & Africa
Agenda

- Industry Challenges
- A Short Introduction to the Foundation
- The Technology and it’s Features
- The Opportunity + Benefits
  - 30% Tighter Control
  - 3 X Reliability
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FFMEMC is thankful to the following organizations, who have jointly supported this workshop by providing all technical contents and have authorized use of their logos, product and system images, arranged speakers, managed logistics and of course, commercially sponsored the workshop.
Process Industry Challenge

The global process industry loses $20 billion, or five percent of annual production, due to unscheduled downtime and poor quality. ARC estimates that almost 80 percent of these losses are preventable, with 40 percent largely due to operator error.

Source ARC Insight June 10 2010
Process Industry Challenges

Benchmark Results Indicate Room for Improvement

**20-40%** of control loops in manual control

**80%** of control loops demonstrate excessive process variability

Many potential Advanced Process Control (APC) benefits are being missed

**Unplanned downtime** is the largest single source of lost revenue

**86%** of maintenance is reactive (too late) or preventive (unnecessary)

- Best practice is 40% with predictive/proactive

**Most Petrochemical companies are not making returns greater than their cost of capital**
Fieldbus Foundation – Organization

- International not for profit organization promoting an open and interoperable fieldbus solution
- Worldwide support by manufacturers and users
- Foundation owns underlying intellectual property
- No single company controls the technology
- Technology enables interoperable products and systems; eliminates proprietary protocols
- Technology enables innovation by manufacturers
- Technology provides freedom for users to choose products regardless of manufacturer
- Technology designed to meet the information needs of all segments of the automation industry
Fieldbus Foundation - Organization

Fieldbus Foundation = Not for Profit Organization

FOUNDATION™ Fieldbus = the bus itself
The Opportunity

- Improved plant stability and reliability
- Improved asset utilization
- Reduced operating and maintenance fixed cost
- Improved Variable Cost
The Opportunity

Improved Asset Utilization (typical petrochemical complex)

- 1 % improvement on Asset Utilization

  \[ \text{= €2m /Year} \]

Process Availability is the big OPEX prize
The Opportunity

Cost savings in design and engineering

**CAPEX** capital expenditure
- reduced wiring
- reduced control room space
- reduced engineering and documentation
- easier configuration
- faster commissioning

Cost savings in operation and maintenance

**OPEX** operational expenditure
- increased process data
- reliable digital transmission technology
- flexible and easy expansions
- reduced down time (availability)
- improved diagnostics and maintenance
“Unneeded” Trips To The Field - Avoided Through Remote Diagnostics

Source: Dow Chemical Company
Measurement accuracy

4-20mA

PV = 392.8mb

Field JB + marshalling
12.83mA

IS Interface
12.86mA

I/O card
12.87mA

PV = 393.1mb

Leakage + noise

Conversion error

Conversion error

Fieldbus

PV = 392.8mb

Field JB + marshalling
PV = 392.8mb

IS Interface
PV = 392.8mb

H1 I/O card
PV = 392.8mb

PV = 392.8mb

*Source Ian Verhappen 2010
Control in the Field: Analysis of Performance Benefits

Dr Andy Clegg, ISC Ltd
ISC Background

Industrial Systems and Control Ltd.

- Founded 1987, Strathclyde University spin out
- Control Engineering Consultancy and Training
- Initially marine & metals Industries
- Now process, power, utilities and automotive

Applied Control Technology Consortium

- Started in 1990 with (3 yrs.) DTI funding
- Large end-users of control – BP, Shell, RWE, British Energy, Scottish Power, BAE Systems
Objectives

Many Foundation Fieldbus installations worldwide

Control in the Field (CIF) technology exists within FF, where control functions execute in Field devices

CIF can provide many potential benefits over control in the DCS

Here potential improvements in control performance are reported

- Compared to Control in DCS within FF scheme
- Understand what kind of processes would benefit
- Identify potential industrial applications
A CIF installation with Fieldbus

Fieldbus Macrocycle Scheduled
Controller synchronised

Control Cycle synchronized*

Fieldbus Macrocyle Scheduled
Typical installation with fieldbus

*Not Synchronized with Macro cycle and subject to jitter
CIF Benefits

There are many reviews of what benefits CIF can provide:

- Improved Control Loop Performance
- Increased reliability and availability
- Improved loop integrity
- Reduced loading on DCS / PLC and network
- Lower capital and installation costs
- Reduced Operating costs
CIF Control Performance Benefits

Improvements in control loop performance for CIF arise from:

- Faster sample times
- Shorter latency (delays) in the read-execute-write cycle
- Guaranteed determinism

For control in the DCS, sample time and latency are typically longer

- Also, DCS and FF segment updates can be asynchronous leading to significantly longer and potentially variable latencies

Delays in a control loop limit the performance .... but how much?
CIF: Latencies and Sample Rates

For CIF, latency and sample rate are determined by:

- How many loops are being controlled
- Where the control is executed (sensor, H1 card, actuator)
- The number of scheduled data transfers (depends on where executed), and the need to maintain < 50% loading for these
- The speed of the FF devices
- The complexity of the control logic

These define the “macrocycle” – the update rate for the FF segment
CIF: Latencies and Sample Rates

A fast, but realistic, single loop control loop is considered where the PID is executed in the actuator

- Flowmeter : AI execution – 20msec
- Data transfer AI to PID – 30msec
- Valve Positioner : PID execution – 30msec
- Valve Positioner : AO execution – 25msec

This fits in a typically supported fast macrocycle of 150msec

- Sample rate = 150msec, latency = 105msec ("Case 1: CIF")
Control in DCS: Latencies and Sample Rates

For control in the DCS, the latency and sample rate are defined by:

- The macrocycle of the FF segment – which is changed due to the extra data transfers but faster block execution times
- The scan time of the DCS control block
- If the DCS and FF segment are synchronous or asynchronous

The loop sample rate is the largest of the FF macrocycle length and the DCS block scan time
Control in DCS: Latencies and Sample Rates

A fast, but representative single loop control loop is considered (using the same field devices as assumed for CIF)

- AI execution – 20msec
- Data transfers AI to PID and PID to AO – 2 × 30msec
- DCS: PID execution – 20msec (max.)
- AO execution – 25msec

The latency is 125msec. The sample rate is taken to be 500msec as typical for a typically fast scan time in a DCS (“Case 2: Control in DCS (sync.)”)

When the FF segment and DCS are asynchronous, the latency is increased to 625msec (“Case 3: Control in DCS (async.)”)

- The latency can be higher than this and variable, but such cases are not considered here
Assessment of Performance

The three aforementioned cases were considered

- Case 1: Ideal CIF
- Case 2: Fast Control in DCS (synchronous with FF macrocycle)
- Case 3: Fast Control in DCS (asynchronous with FF macrocycle)

Assessment was made in simulation:

- A simple continuous process model, coupled to a discrete PI controller
- IMPORTANT - controllers tuned to same stability to allow comparison
- Speed of response to SP change and disturbance rejection assessed
- Repeated for different process dynamics
Results: Fastest Possible Process

Dynamics to match an ideal flow process

- 40m, 2" pipe, no dynamics for sensor / valve. Deadtime = 0.06sec, Time constant = 0.22sec

Speed of Response

Disturbance Rejection
## Results: Different Processes

*(Case 3 as baseline)*

Settling times (in seconds, to within +/- 1%) to Setpoint step

<table>
<thead>
<tr>
<th>Process Speed</th>
<th>Case 1: CIF</th>
<th>Case 2: Control in DCS</th>
<th>Case 3: Control in DCS out of sync</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Settling Time</td>
<td>c.f. Case 3</td>
<td>Settling Time</td>
</tr>
<tr>
<td>&quot;Fastest&quot;</td>
<td>2.59</td>
<td>68% better</td>
<td>3.65</td>
</tr>
<tr>
<td>Very Fast</td>
<td>4.57</td>
<td>66% better</td>
<td>6.1</td>
</tr>
<tr>
<td>Fast</td>
<td>4.49</td>
<td>55% better</td>
<td>6.05</td>
</tr>
<tr>
<td>Medium</td>
<td>11.1</td>
<td>39% better</td>
<td>12.65</td>
</tr>
<tr>
<td>Slow</td>
<td>up to 15% better</td>
<td>up to 10% better</td>
<td></td>
</tr>
<tr>
<td>Deadtime</td>
<td>Negligible</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Results: Different Processes

(Case 3 as baseline)

Standard Deviation (in %) in presence of disturbance:

- Note frequency content of disturbance changed for “Fast”, “Medium”

<table>
<thead>
<tr>
<th>Process Speed</th>
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<th>Case 3: Control in DCS out of sync</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dist std dev</td>
<td>c.f. Case 3</td>
<td>Dist std dev</td>
</tr>
<tr>
<td>“Fastest”</td>
<td>0.642</td>
<td>65% better</td>
<td>0.834</td>
</tr>
<tr>
<td>Very Fast</td>
<td>1.058</td>
<td>50% better</td>
<td>1.252</td>
</tr>
<tr>
<td>Fast</td>
<td>0.231</td>
<td>55% better</td>
<td>0.291</td>
</tr>
<tr>
<td>Medium</td>
<td>0.53</td>
<td>35% better</td>
<td>0.58</td>
</tr>
<tr>
<td>Slow</td>
<td></td>
<td>up to 15% better</td>
<td></td>
</tr>
<tr>
<td>Deadtime</td>
<td>Negligible</td>
<td></td>
<td>Negligible</td>
</tr>
</tbody>
</table>
Observations

For typical fast process loops (e.g. flow, pressure), CIF will provide up to a 40-60% faster settling time, and up to 30-50% better rejection of disturbances

- The faster the process, the larger are the benefits
- Assuming baseline case of asynchronous Control in the DCS – which is typical

For slower processes (e.g. > than 40 secs settling time) and processes with any significant deadtime (e.g. > than 5 secs) the benefits become small

The performance benefits will be reduced if:

- Slew rate and saturation of the actuators limit the available performance
- If it is desired to use a de-tuned controller
- FF devices with slower block execution times, if the FF segment is heavily loaded, if the control functionality is complex or if the design of the CIF is not good
Potential Industrial Applications

The findings show that CIF will provide significant performance benefits for loops with certain dynamics

- Typically flow and pressure and some temperature loops

Applications where such improved performance may be beneficial include:

- Paper Manufacturing, Power Generation, Combustion Control, Continuous Food Manufacturing and Compressor Control

- CIF could be important for controllers that respond to spurious events
  - i.e. that try to maintain operations, before safety protection systems are engaged
  - e.g. pressure control of fuel gas for a gas turbines in a power generating plant
  - when one GT trips the controller has to act quickly to stop the other GT tripping on a high fuel gas pressure
Impact of Tighter Loop Control
Summary

It has been shown that CIF can provide significantly better control for fast process loops

- In terms of speed and ability to reject disturbances

For some process loops (e.g. slow dynamics and where there is significant deadtime) no improvement in control will be realisable

- Or if there are constraints within the CIF implementation
End user Recommendation

Shell Global Solutions International (SGSI) has performed extensive evaluation of control in the field. A statement by the company indicated, “Control in the field using FOUNDATION fieldbus technology is recommended by SGSI for simple and cascading loops, not for complex loops. Major benefits identified by SGSI are reduced process controller loading, reduced network traffic enabling more loops per segment, as well as very fast loop response.”
CIF = Increased Availability

Use methodologies of the safety community
Use MTTF data from the safety community

Apply the method and data to a typical control loop to compare traditional analogue with FF
In today's systems, control functions all reside in central controllers.

Fieldbus can be used in the same way, but fieldbus also enables control and I/O functions to be distributed to field instruments.
## Reliability Analysis

<table>
<thead>
<tr>
<th>Control in the DCS</th>
<th>Control in the Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Transmitter</td>
<td>1. Transmitter</td>
</tr>
<tr>
<td>2. Valve</td>
<td>2. Valve</td>
</tr>
<tr>
<td>3. Cables</td>
<td>3. Cable</td>
</tr>
<tr>
<td>4. Terminations</td>
<td>4. Terminations (&lt;half)</td>
</tr>
<tr>
<td>5. Power Supply</td>
<td>5. Fieldbus Power Supply</td>
</tr>
<tr>
<td>6. AI Card</td>
<td></td>
</tr>
<tr>
<td>7. AO Card</td>
<td></td>
</tr>
<tr>
<td>8. Backplane</td>
<td></td>
</tr>
<tr>
<td>9. Controller</td>
<td></td>
</tr>
<tr>
<td>10. Controller Power Supply</td>
<td></td>
</tr>
</tbody>
</table>

MTBF = X

MTBF = Y

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Analogue Fault Tree

Sensor Subsystem Failure

Logic Solver Subsystem Failure

Final Element Subsystem Failure

Sensor Transmitter Failure (including Primary Element)

Logic Solver Fault and Shield Mode Fails to Function

VF Transducer Fails

Valve/Actuator Fails

EVENT1

EVENT19

EVENT2

EVENT3

Contact Loop Failure - Conventional Analog

7.18E-8 failures per hour yields MTTF = 15.9 years

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FF Fault Tree

Control Loop Failure - Fieldbus Segment

TOP2

Sensor Subsystem Failure

GATE4

Logic Solver Subsystem Failure

GATE5

Final Element Subsystem Failure

GATE6

2.37E-6 Failures per Hour yields
MTTF = 48.2 years

Sensor Transmitter Fails (including Primary Element)

Detect Failure and Shed Mode Fails to Function

Fieldbus Segment Device Coupler Common Failure

Writing, Termination, Connection Failures

Positioner Fails

Valve/Actuator Fails

EVENT9

EVENT18

EVENT15

EVENT20

EVENT10

EVENT11

ROSEMOUNT 3051C

w=4.18e-007
w=4.180e-7

w=0
w=0.000

P+F 3051 COUPLER

w=2.17e-007
w=2.170e-7

FISHER DVC000

w=1.173e-006
w=1.173e-6

FISHER GX

w=9.39e-007
w=9.390e-7

Results

Bottom line, FF is significantly better:
MTTF of 48.2 versus MTTF of 15.9.

Now all you have to do is put some Dollar/Euro values on the cost of a nuisance trip, and you can start generating $/€ savings for switching to FF.
"Foundation Fieldbus CIF with inherent backup capability prevented 2 incorrect plant shutdowns, which would have resulted from communication interruptions"

Shin-Etsu
Summary

- Control in the Field has higher Availability
- Control in the Field has lower Variability
- Devices with more function blocks offer more flexibility for Control in the Field
- Most of the regulatory control can be done in the field
  - Devices involved in a control strategy should be in the same segment or bridging is required
- Advanced Control, Optimization should be done in the DCS. This type of control can always send setpoints for the regulatory control
Thank you!