Fieldbus Testing with Online Physical Layer Diagnostics

The significant benefits realized by the latest fully automated fieldbus construction & pre-commissioning hardware, software and test methodology. Installation and wiring work currently requires tedious and typically incomplete methods for checkout and validation. New online advanced physical layer diagnostic systems automate construction and pre-commission test and report generation, up to the point of loop check-out.

This paper describes a newly revised, significantly shortened and vastly simplified test procedure applicable to fieldbus systems. Additional guidelines for troubleshooting described herein further enhance commissioning and testing work.

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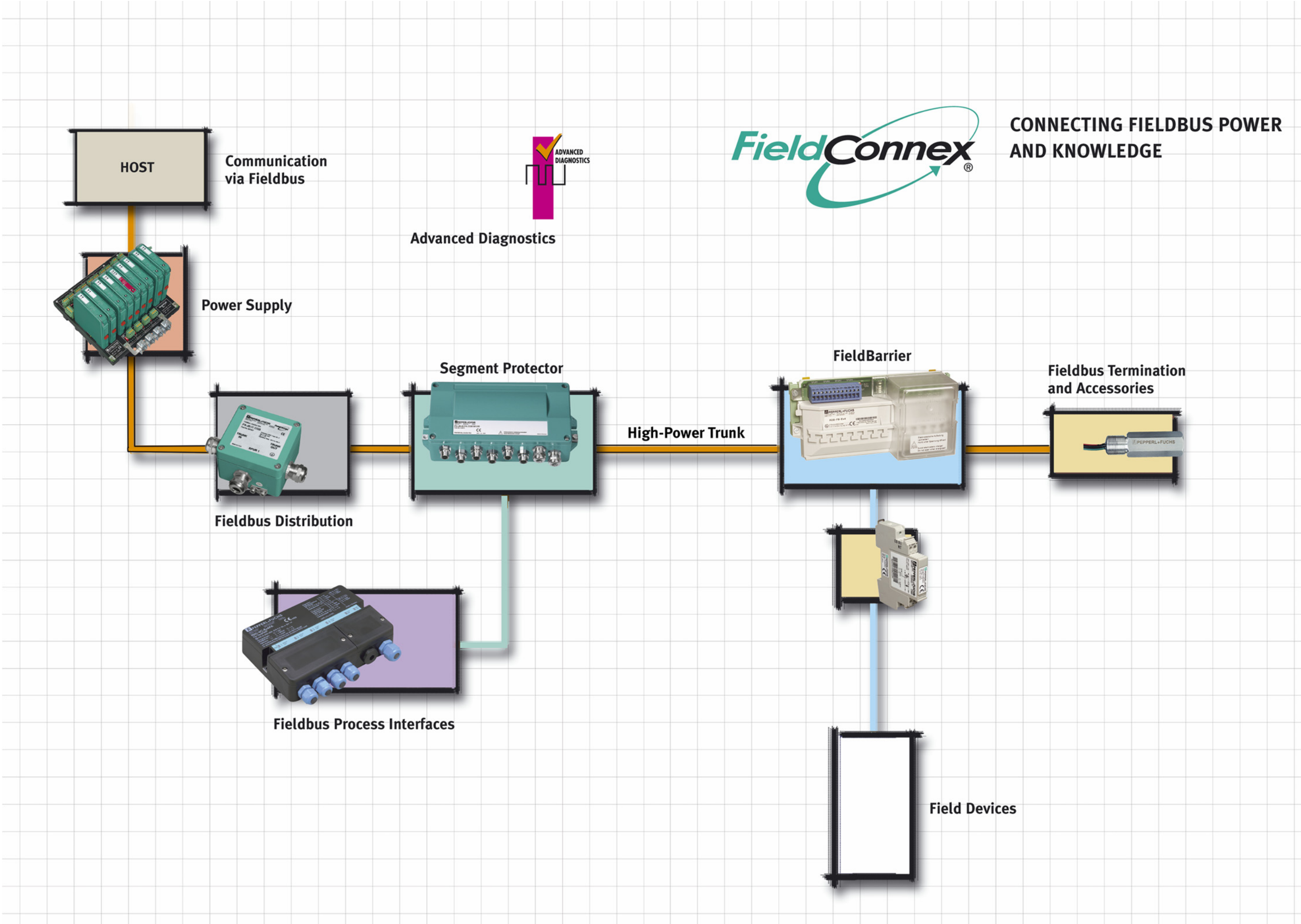

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1 Introduction

Fieldbus has fully matured following its cautious introduction back in the late 1990s: Many of the major projects are now using digital fieldbus technology as the preferred platform for control and instrumentation. Most of the lessons learned from the early projects have been implemented successfully for the current projects, and there is no doubt that the companies responsible for commissioning are seeing a marked improvement in the commissioning times with a resulting reduction in CAPEX.

With the introduction of online Advanced Physical Layer Diagnostic equipment, the transition to a fully automated network test and reporting program reduces the time and cost for construction and commissioning even further by optimizing the test process and report generation. The new Advanced Physical Layer diagnostic equipment will of course need a revised, yet vastly simplified construction and commissioning procedure requiring minimal technical expertise.

This paper will provide an insight into fieldbus commissioning and how it is achieved today, with an overview of how significant savings can be made using advanced physical layer diagnostics for high-speed automated construction as well as commissioning testing with automated test report generation and documentation. Advanced physical layer diagnostics provide the ‘handover’ of a system that will have been fully checked to a highly detailed technical level impossible to achieve with current methods, thus assuring uncompromised segment quality and system availability for the end customer and plant operator.

2 How Commissioning is Achieved with Fieldbus Today

The Foundation Fieldbus™ Engineering Guide ‘AG-181; section 11’ sets out a detailed procedure for installing and commissioning fieldbus segments. Whilst this guide is relevant for Fieldbus testing, it still maintains the need for technically advanced manual testing, using sophisticated manually operated test equipment and hand-completed test sheets.

2.1 AG-181 Overview

The guide assumes that at least one set of test equipment is made available comprised of:

1. Digital multi-meter for current, voltage and resistance
2. Advanced capacitance meter capable of independent RC measurement
3. Digital storage oscilloscope
4. Handheld fieldbus signal and data analyzer
5. Set of paper test sheets, pens and screwdrivers.

The test equipment is used to check and test one segment at a time, and provisions must be made to identify the segment terminals. Special terminals or adaptors should be made available for connection of the various meter probes.

Many correctly installed terminals have no exposed conductors to clip test probes to. Therefore, ‘eyelets’ should be provided for testing, then removed after testing as they are exposed and not insulated. Alternatively, wires must be removed from the terminals and replaced after testing.

The test procedure basically covers the following test activities:

1. Cable continuity and isolation tests
2. Cable resistance and capacitance checks - pole to pole, pole to shield, capacitive unbalance and grounding quality
3. Signal communication level analysis and limits
4. Noise level analysis and limits
5. Oscilloscope signal capture and detailed waveform analysis
6. Completion of paper documentation.

These test requirements demand far more time and expertise when compared to an equivalent 4-20 mA cable, and require a high level of measurement accuracy. Highly skilled engineers have to manually put together data from disparate devices to interpret the information.

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Additionally, manual testing, in accordance with AG-181, requires a degree of electronic signal analysis using oscilloscopes, and AC measuring/analyzing equipment. Whilst oscilloscope data is extremely useful, to understand many of the potential faults that can occur or exist, would require specialist signal analysis knowledge beyond that required for AG-181 implementation.

In-band noise, power supply impedance problems, signal jitter errors or inverted signals are only some of the issues that would not normally be revealed when following the guidelines within AG-181. These unseen failures could create problems during loop checkout or they may create problems much further down the line. Certainly, to perform an adequate test to reveal all of the potential faults or unseen failures would require further lengthy analysis and calculation using more sophisticated test equipment and extensive engineering knowledge.

AG-181 also requires wires, which are already properly installed and terminated, to be disconnected for testing and then reconnected after testing. This can give rise to potential failure issues if the terminals are not correctly re-installed.

Furthermore, hand-completed paper documents can be prone to errors, omissions or ultimately, falsification. Signoffs and handovers may not be complete, particularly when performed under 'time penalty' pressures.

The result is a lengthy test procedure with potential for errors, which will take time and requires expert fieldbus knowledge, particularly if there is a deviation from the test specification limits.

3 Fieldbus Testing Using Advanced Physical Layer Diagnostics

With the introduction of Online Advanced Physical Layer Diagnostics (APLD), it is now possible to test the entire network automatically at the 'touch of a button'. Furthermore, it is now possible to test many more physical layer attributes, above that required for AG-181, with very little knowledge of the fieldbus physics, and create software driven reporting with simplified result summaries that can easily be understood. The APLD is able to test, validate and report:

APLD test and report capabilities
Trunk current measurement
Signal jitter measurement
Signal amplitude and amplitude variations
Shield to pole capacitive and resistive unbalance as a percentage for each pole.
Direct pole to pole short circuit
Full spectral frequency analysis
Trunk voltage measurement
'Signal inverted' warning

The latest generation of APLD, used for automatic test, is integrated within the power supply architecture. Wiring or electrically connecting test equipment into each segment is thus eliminated.

Fig. 3-2 illustrates how the APLD module is integrated within a fieldbus Power Hub. Multiple APLD modules are daisy chained via a diagnostic bus, with a capability of monitoring and testing up to 124 segments for each spur. The diagnostic bus uses simple RS485 hardware and can be connected to the control room via Ethernet interfaces. This simple technology has the advantage of keeping response time fast on both the primary control system and the fieldbus diagnostic system. A separate path for communications to the APLD enables remote troubleshooting even when a detrimental fault hamper communication on the main line.

It can easily be seen that the interconnecting wiring for the test equipment is minimized. It will be left in place, without further connection or disconnection for online diagnostics during the operational lifetime of the plant.

3.1 The New Commissioning Strategy

Today's modern technology with rigorous test requirements will exhibit very low failures when installed. The cable installation generally reveals a failure, of one type or another, of much less than 2%. Based on this figure, only 2 segments per 100 would be expected not to function first time, therefore, 98 segments would function first time without any failures. This reinforces the option for complete installation and test at the same time. After all, where the majority of segments will work first time, it would be pointless to approach testing with a view that all instruments and cable runs will fail.

In conclusion, the new strategy will adapt a faster, more accurate method of testing by way of fully constructing each segment and testing it automatically in one single step. Thereafter, any failure can be dealt with in a sequential manner.

3.2 The New Test Procedure

From the maintenance or test PC, each diagnostic bus home run will test and report 124 segments automatically, one after the other. Each segment will be tested for:

1. Compliance or conformance with AG-181 section 11.

2. Compliance with IEC-61158-2 (fieldbus standard).

3. Compliance with FF-831, power supply impedance and compatibility.

4. Operation, conformance and functionality of cable, devices, terminators, power supplies and protection electronics.

3.3 The Revised Test Procedure

The test procedure for automated test and reporting is shown in Fig. 3-1. Fig. 3-2 shows the connection diagram for the integrated APLD.

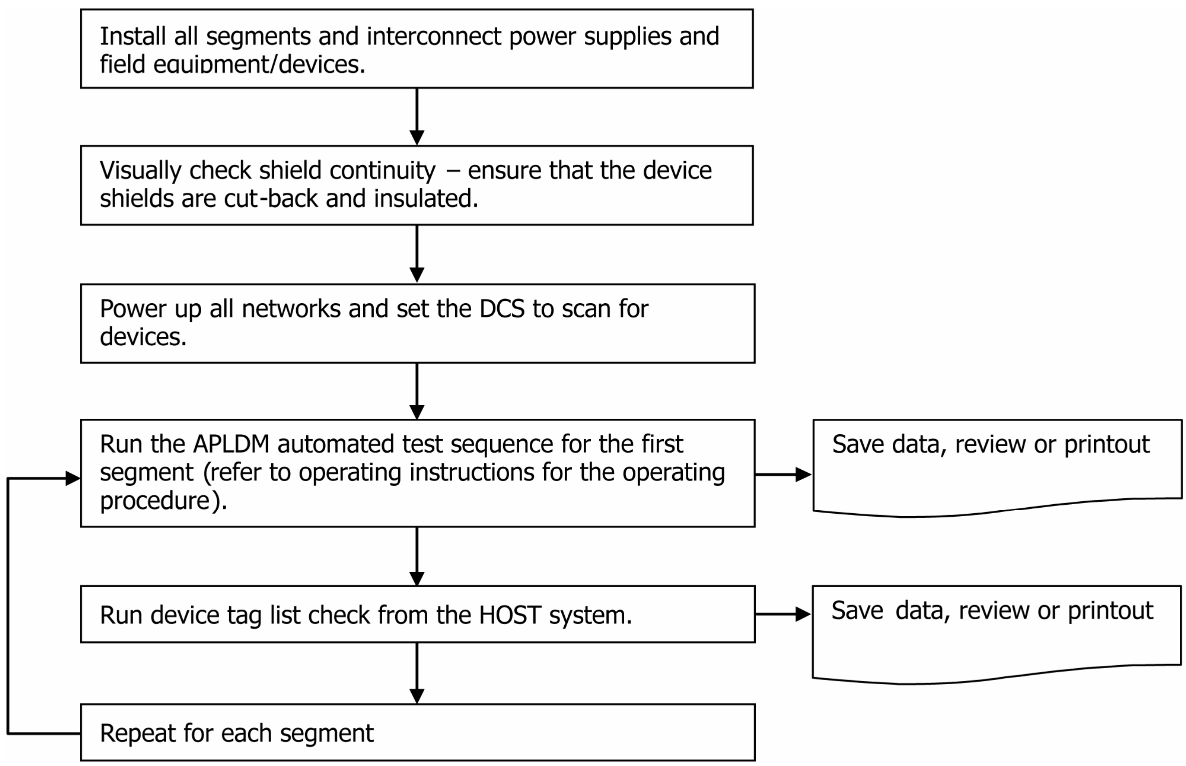

Fig. 3-1: Revised test procedure utilizing APLD for optimized commissioning of fieldbus

14/11/2006 TDOCT-1107_USA

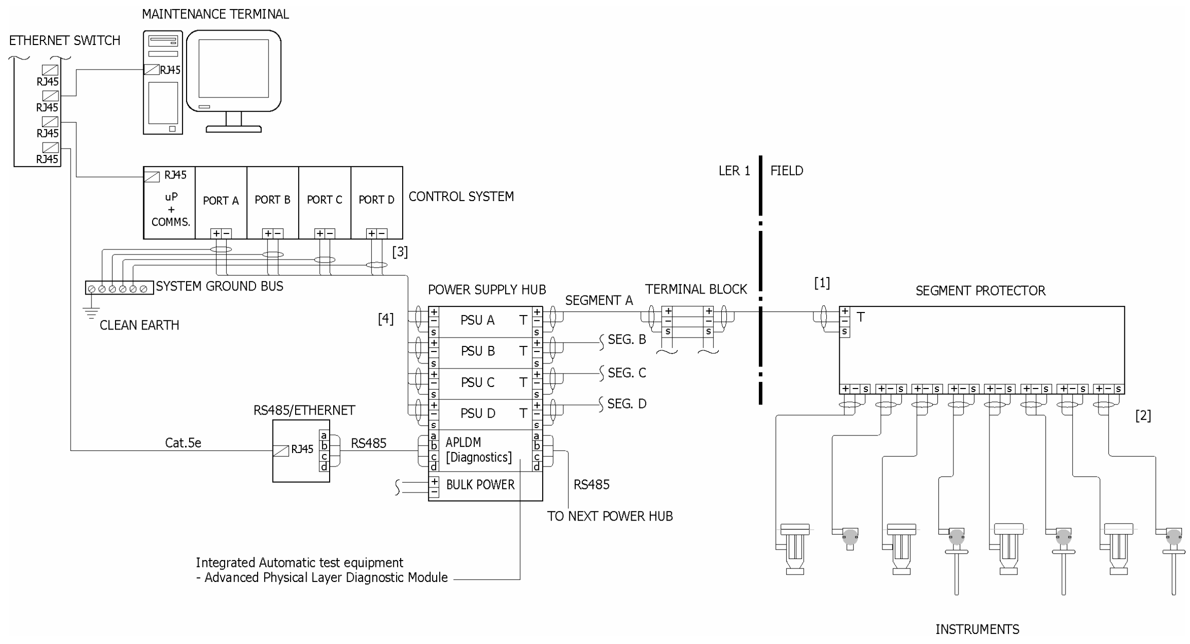

Fig. 3-2: Connection diagram showing stationary APLD

3.4 Partially Constructed Sites

Where the control system and/or supporting fieldbus power supplies are not on site or cannot be installed, mobile diagnostic automatic test equipment (ATE) equipment can be considered where the mobile ATE can provide the same level of automation and reporting albeit on a segment by segment test basis. Fig. 3-3 illustrates the connection of a mobile diagnostic system powered by a portable reference fieldbus power supply with additional integrated terminators. This system can also be used to interrogate devices independent of the fieldbus network.

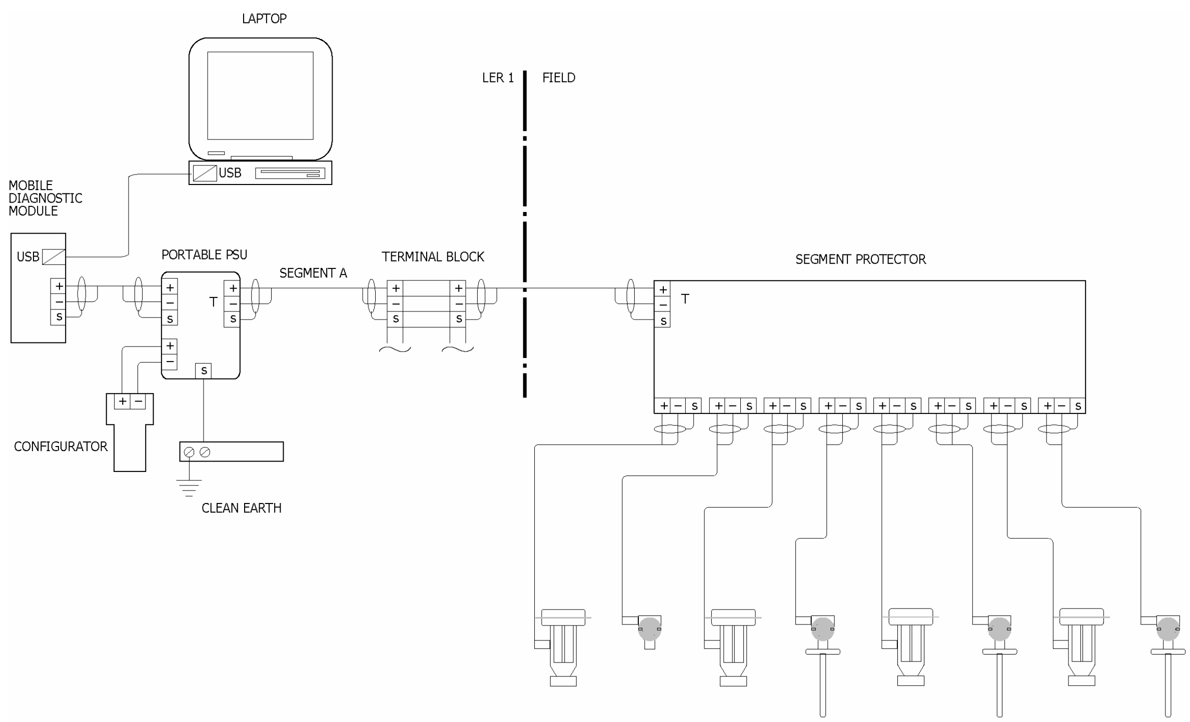

Fig. 3-3: Connection diagram showing mobile diagnostic system assisting in fieldbus analysis and validation

14/11/2006 TDOCT-1107_USA

4 Fault Finding & Troubleshooting Procedure

4.1 Primitive Faults

If the software reports failures, troubleshooting using a 'process of elimination' has to be performed. First, though, primitive failures, such as power supply voltage loss or trunk short circuit need to be ruled out.

4.2 The Process of Elimination

It would be anticipated, but not expected, that a low percentage of segments will fail, some of which may show more than one failure. The automated test system will provide a diagnostic report displaying a number of possible failures. But first, the elimination process will be by far the quickest method to assess the probable type and position of the fault. The flow chart Fig. 4-2 demonstrates how the process of elimination is undertaken.

4.3 Further Troubleshooting Using the Inline Fieldbus Oscilloscope

As described earlier, there will be a degree of expected failures. Whilst assessing a faulty segment, further detailed oscilloscope data can be viewed for more advanced troubleshooting analysis. The fieldbus oscilloscope bridges the gap between automatic diagnosis and manual troubleshooting. Further in-depth information can be assessed by competent engineers from an inbuilt dedicated digital storage oscilloscope with a vast selection of trigger point options. An oscilloscope is by far the best tool for troubleshooting unusual or complex network faults, and an integrated oscilloscope within the diagnostic module has many advantages:

Valuable time saving during failure tracking

Integrating an oscilloscope into the diagnostic module can save a great deal of downtime/troubleshooting time – time spent finding and reading the drawings, tracking down the correct terminals and connecting the test probes to the terminal points in the control room marshalling cabinets and so on.

Eliminated cable and junction box disturbance

Also, disturbance to the control room marshalling cabinet cable network, patch bays, or having to open field junction boxes to connect oscilloscopes, can lead to additional faults. Using an inbuilt online oscilloscope eliminates the need to disturb any hardware until a specific targeted repair is required.

A record also for remote analysis

The oscilloscope data can be recorded in a very simple way at the maintenance terminal. This way, a record can be found, and the information can also be sent to a remote expert for additional troubleshooting, again saving valuable time.

Fig. 4-1 Oscilloscope example with zoom capability, a host of dedicated trigger point options and digital storage

14/11/2006 TDOCT-1107_USA

4.4 Elimination Method

Finding faults can be tricky. The APLD enables the smart and quick fault finding method displayed below. Compare also to Fig. 3-2 and Fig. 3-3.

1	First disconnect the trunk from the segment protector (1).
2	Now connect a discrete terminator to the open end of the trunk.
3	The diagnostic test cycle is then run to eliminate any trunk, power supply or host failure. If this now passes the test cycle, then it can be inferred that the failure resides from the segment protector to the instruments. Go to task 9 if the trunk, host or power supply is at fault.
4	Remove the terminator and reconnect the trunk to the segment protector (1).
5	Sequentially disconnect each spur cable from the segment protector (2) and each time run the diagnostic test until the fault disappears. It can then be inferred that the fault resides on the last disconnected spur or instrument.
6	If sequential disconnection of all spurs does not clear the fault, then the failure must reside with the segment protector and this can be replaced.
7	If the fault is discovered on one of the spurs, then the spur cable and the instrument can be inspected for visual physical failures.
8	If the instrument is in question, then the instrument can be swapped out for an instrument emulator. If a further test cycle is re-run, and the fault clears, then it can be inferred that the instrument is faulty and can be substituted.
	COMMENTARY: To replace an instrument or device takes time due to the fact that some devices are attached to manifolds, or are inline items. To double-check that the device is faulty before undertaking extensive work, a further autonomous test should be conducted with the instrument electrically isolated from the segment. There are units available that can power up a single device (portable fieldbus power supply or a USB powered fieldbus power supply) and by using the mobile diagnostic system, it is possible validate the performance of the device before major work is undertaken.
9	If a trunk, power supply or host failure, after isolation form the segment protector, is discovered, then disconnect the host spur cable (patch wire) at the host terminal bay (3) and run the test.
10	If the test cycle shows a clear segment, then the host system's I/O card may be faulty and should be replaced.
11	If the fault remains, disconnect the trunk cable from the fieldbus power supply (4), then the host spur cable should be checked. If a cable fault is not found, then replace the fieldbus power supplies.
	NOTE: For the mobile diagnostic system, the above tasks would be applicable up to task 9.

Fig. 4-2: Method of elimination for fault finding in fieldbus networks

14/11/2006 TDOCT-1107_USA

4.5 Savings Case Study

This case study will provide an example of how much time can be saved when using an automated test system. Specifications considered in this case study are as follows:

Case Study – Specifications	
Number of instruments	1,200
Number of segments	100
Instruments per segment	12
Man day	8 hours
Mean time to repair (MTTR) a fault	4 hours

Actual project will vary with regard to engineering staff levels and time schedules. Other factors such as the process or the product to be manufactured and the environment also play an important part in overall expenditure. Though the estimates are general, this case study clearly gives an idea about the vast savings potential.

Some contractors will allow a team up to 30 minutes for construction testing, pre-commissioning checks and repair per instrument loop. The time seems to range from 10 minutes per loop (a check) to up to 2 hours per loop (a check inclusive of repair work) depending on the project definition. For a 4-20 mA system, 30 minutes per 4-20 mA loop will result in over 2¼ months worth of qualified and experienced engineering based on an 8 hour shift per day, and a full working week. This case study will consider a shorter time estimate of 5 minutes per instrument and cable loop.

Pre-commissioning is defined as work steps taken to install and validate the hardware configuration and the physical layer. It can be grouped with construction, but for simplicity, pre-commissioning is grouped with commissioning. For commissioning the common aspect of control loop checking is ignored as this will be the same for any hardware model. It is also assumed that during construction and pre-commissioning/commissioning, there will be 1.5% failure with 1% attributed to cable failures and 0.5% due to hardware failures.

Task	Model	4-20 mA	Fieldbus without diagnostics	Fieldbus with advanced diagnostics
Constructional checks: Each cable will be checked for: continuity, pole to pole and each pole to shield isolation and a test sheet completed. Allowing for time to read the drawings and locate the terminals and connect the cable testers. **NOTE:** For fieldbus, additional cable resistance and capacitance checks are required. For fieldbus with diagnostics, the cable can be checked at the same time as pre-commissioning checks are performed.	**Time/Unit**	5 min	10 min	Not required
	Units	1200 loops	100 segments	Not required
	Total Time	6000 min = 12½ days	1000 min = 2 days	0
Construction failures: Anticipated percentage of cable failures and the time taken to repair the fault based on a 4 hour 'mean time to repair' (MTTR). Failure rate is assumed at 1% of total cable connections. **NOTE:** Fieldbus has the same number of spur cables as the 4-20 mA model, plus an additional trunk cable for 12 instruments.	**Time/Unit**	4 h MTTR	4 h MTTR	Not required
	Units	12 loops	1 Trunk, 12 Spurs	Not required
	Total Time	48 h = 6 days	52 h = 6 ½ days	0

14/11/2006 TDOCT-1107_USA

Task	Model	4-20 mA	Fieldbus without diagnostics	Fieldbus with advanced diagnostics
Pre/commissioning instrument checks: **4-20 mA Analogue** - each instrument should be tested with a loop calibrator or handheld tester to ensure correct device polarity, operational voltage test and loop current check for both analogue inputs and analogue outputs with a test sheet completed. **Fieldbus** - each network should be tested to ensure correct device communication, signal and noise quality, tag number and address validation, power supply voltage test with a test sheet completed.	Time/Unit	10 min	60 min	8 min
	Units	1200 loops	100 segments	100 segments
	Total Time	12,000 min = 25 days	6000 min = 12½ days	800 min = 1.6 days
Pre/commissioning failure: Anticipated failures and the time taken to repair the fault based on a 4 hour 'mean time to repair' (MTTR) **NOTE:** Fieldbus with advanced diagnostics will include the predicted cable failures as the new one-step-testing procedure will reveal such failures at this point.	Time/Unit	4h MTTR	4h MTTR	4h MTTR
	Units	0.5% = 6 loops	0.5% = 1 segment	1.5% = 2 segments
	Total Time	24 h = 3 days	4 h = ½ day	8 h = 1 day
Totals		46.5 days	21.5 days	2.6 days

NOTE: The advanced diagnostics model will test many more physical layer parameters in a shorter time.

5 Summary

Construction and pre-commissioning/commissioning time saving is a very important consideration, but it should not compromise accuracy, quality and reliability.

Using Advanced Physical Layer Diagnostics during construction and pre-commissioning will increase the test performance, reduce time spent and accurately report findings without additional skill sets or an increase in staffing levels. In fact, it is possible to reduce the skill sets and staffing levels to only one on-site and/or off-site fieldbus specialist to focus only on the anticipated or more complex failures if and when they occur. One might consider that the equipment supplier provides expert engineers to aid construction and commissioning, but only during failure assessment when they are needed.

There is no doubt that using non-intrusive automatic test equipment for construction or commissioning will save significant time, eliminate interference with properly installed cable, perform many more and more comprehensive test measurements. Automatic test and reporting will be accurate and complete. It can accurately and reliably uncover faults that would have been overlooked and that could cause failure during operation. Project managers can assess progress effectively. They will be able to assess repair time as a percentage of testing time and prepare for effortless and cost-effective transition into the operational phase. Finally, the handover to the customer would have followed a thorough and accurate test sequence that will cost effectively guarantee quality, performance and reliability.

The online Advanced Physical Layer Diagnostics will stay in place during operation. History trending and continuous monitoring with alarming integrated in the DCS enables operators and maintenance personnel to respond in a timely and educated manner. Expensive reactive repair work on the fieldbus is eliminated and plant operation is thus improved.

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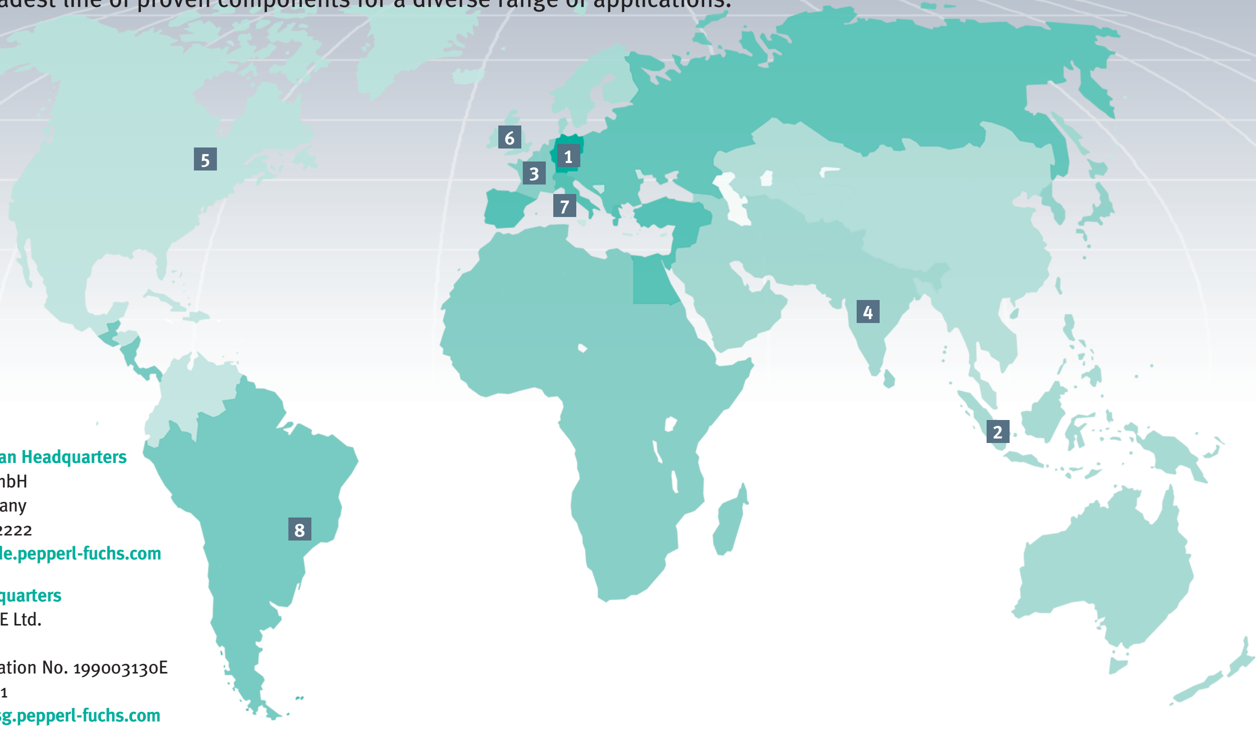

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