FOUNDATION FIELDBUS INTEROPERABILITY TESTING AND SYSTEM CONFIGURATION FOR EMERSON HOST

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
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CERTIFICATION OF APPROVAL

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Approved by,

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(AP Dr. Nordin Bin Saad)
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

JUNE 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgments, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(NURUL NISHA BINTI SAHARUDIN)

ABSTRACT

This report will generally discuss on the progress and basic understanding on selected Final Year Project (FYP) title which is FOUNDATION Fieldbus Interoperability Test (FFIT) and System Configuration for Emerson. Fieldbus is a digital, two way communication link between controls where this technology will replace the conventional 4-20mA standard. This project is concern with technical verification and interoperability of FOUNDATION Fieldbus products involving the ability of communication between different devices and host of different manufacturer. The purpose of this project is to perform interoperability testing of FOUNDATION Fieldbus system namely the basic test, stress test and diagnostic test. The outcome of the tests is aimed to provide familiarization on the fieldbus system for students, scientific researchers, engineers and also for industrial applications. The whole project starts with knowledge gathering and theoretical studies on the related subject. Three laboratory tests will be covered in the interoperability testing which are basic interoperability test including operability and ease of maintenance, stress test and diagnostic capability test of the system. Other than that, an excel calculation for fieldbus design was also developed. The need of interoperability testing is to make sure that the end-user in plant will not face any difficulties when using the vendor's FOUNDATION Fieldbus products. The basic test was successfully conducted and the overall result of this test has shown that the EMERSON host can communicate well with all the tested devices from different vendors of E+H, FOXBORO and HONEYWELL.

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LIST OF ABBREVIATIONS

UTP	University Technology PETRONAS
FF	FOUNDATION Fieldbus
FFIT	FOUNDATION Fieldbus Interoperability Test
GTS	Group of Technical Solution (PETRONAS)
SKG14	Skill Group 14 (Instrument & Control)
DD	Device Description
AMS	Asset Management System
FYP I	Final Year Projct I
FYP II	Final Year Project II

CHAPTER 1
INTRODUCTION

1.1 Background of Study

The fieldbus technology has been widely applied to the producing fields, and it implements the bidirectional, serial, and multipoint communications. In the world market today, various kinds of fieldbus can be found such as FOUNDATION Fieldbus, PROFIBUS, and MODBUS. The desired system architecture made the protocol different from each other.

With collaboration of vendors from Emerson, Honeywell, Yokogawa, and Foxboro, PETRONAS team and UTP students, a FOUNDATION Fieldbus Interoperability Test is conducted. This project will focus on the issues related to the FOUNDATION Fieldbus system using Emerson host.

During the second semester of Final Year Project (FYP) this project is more focused on the data communication issues in stress test. Due to some upgrading work in the fieldbus laboratory, this report will discuss primarily on the theoretical and design part regarding stress test.

1.2 Problem Statement

1.2.1 Problem Identification

In a common process control, 4-20mA application is widely used to control and monitor the process control. Conventional analog and discrete field instruments use point-to-point wiring which uses one pair of wire per device. They are also limited to carrying only one piece of information (usually a process variable or control output) over those wires. In this recent year, fieldbus technology has emerged and may replace the conventional 4-20mA technology. Fieldbus is a digital, two way communication technology and is more preferable because of its vast advantages compared to 4-20mA [3]. Monitoring the performance and safety of a production system is very crucial in process application, therefore the interoperability test is necessary.

Other interoperability issue is regarding a problem on lack of interoperability occurred based on the history of fieldbus. There are so many different protocols in the market and the product can only work with the other product from the same vendor. This previous system has created a limited range for the vendor to provide all parts that a site required. Once the system had been purchased, the plant was essentially "locked in" by the manufacturer. The problem is when the system supplier no longer had any competition, replacement parts and extras would be much more expensive than they were for the first time of purchased [1].

The other factor that leads to the development of the FOUNDATION fieldbus technology is the eagerness of the people nowadays to see the existing technology with the national standards adopted as the international fieldbus by some companies. Other than that, lack of experienced engineers in using FOUNDATION Fieldbus system is also one of the reasons the testing needs to be conducted. PETRONAS needs more engineers that are capable of handling this new technology in the future.

1.2.2 Significant of the project

This project is a continuous project and concern with technical verification and interoperability of FOUNDATION Fieldbus products. The project also aims to design and develop a small plant model using EMERSON FOUNDATION Filedbus software. The interoperability of FOUNDATION Fieldbus will involve the ability of communication between different devices and host of different manufacturers. The outcome of the tests will become the reference to the production of a PETRONAS approved list for FOUNDATION Fieldbus system and field devices. This will involve verification of open standard using several tests.

1.3 Objectives

The seeking of understanding of the FOUNDATION Fieldbus must first be achieved. The test is conducted to implement computer control via FOUNDATION Fieldbus technology to the control of the close loop process in order to do the interoperability testing and diagnostic. The test is also to give more understanding on FOUNDATION Fieldbus and a study to further enhance it.

The main objectives of the FOUNDATION Fieldbus Interoperability Testing (FFIT) project are:

- To perform interoperability testing of FOUNDATION Fieldbus system namely the basic test, stress test and diagnostic test and reports for PETRONAS Technical Standard.
- To provide familiarization on the Fieldbus system for scientific researchers and engineers, as basis for further development of either laboratory or industrial applications.
- Other than that, the research project will look into detail regarding the design and calculation involved towards performing the stress test for FFIT.

1.4 Scope of Study

The whole project would start with knowledge gathering and theoretical studies. The FOUNDATION Fieldbus Interoperability Test (FFIT) project activity consists of doing detail approach in designing, configuring and implementing a Fieldbus test rig from various loose field devices, controllers and actuators, and software development tool. Three laboratory tests will be covered which are basic interoperability test including operability and ease of maintenance, stress test and diagnostic capability test of the system.

Since this is a continuous project and there is only one server to cater for four host Fieldbus systems, the author only focus on doing research and basic interoperability test using EMERSON host to meet the time allocated for Final Year Project 1.

For Final Year Project II, the research is more on design and calculation for matters that are related to stress test. The author discussed about the maximum number of devices allowed in a particular fieldbus segment, the segment's length and how to overcome the issues related. Comparison between fieldbus topologies are also made to analyze the advantages and disadvantages of each topology.

CHAPTER 2

LITERATURE REVIEW

2.1 FOUNDATION Fieldbus

FOUNDATION Fieldbus is an all-digital, serial, two-way communications system that serves as the base-level network in a plant or factory automation environment. Figure 1 below shows the general architecture for FOUNDATION Fieldbus.

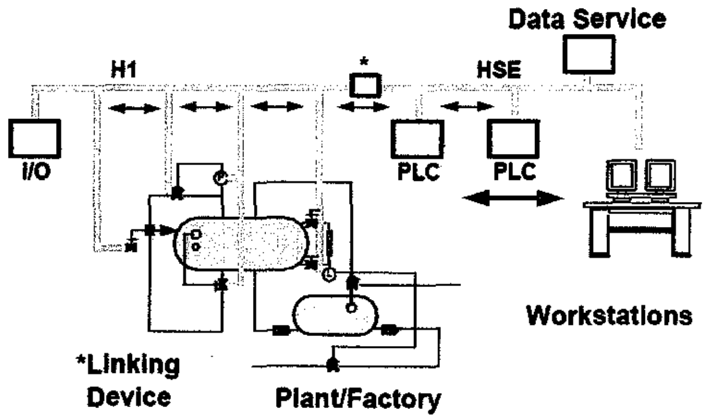

Figure 1 : FOUNDATION Fieldbus architecture

H1 (31.25 kbit/s) interconnects "field" equipment such as sensors, actuators and I/O. HSE (100 Mbit/s) (High Speed Ethernet) provides integration of high speed controllers (such as PLCs), H1 subsystems (via a linking device), data servers and workstations. FOUNDATION Fieldbus is the only protocol with the built-in capability to distribute the control application across the network [4].

Each field device has low cost computing power installed in it, making each device an intelligent device. Each device is able to execute simple functions such as diagnostic, control, and maintenance functions as well as providing bi-directional communication capabilities with other devices.

2.2 How Fieldbus Works

The communication networks, which are HART and FOUNDATION Fieldbus are the serial communication protocols. The FOUNDATION Fieldbus has a bidirectional communication which means that a device can transmit and also receive data, but not at the same time. All of these three networks are all based on the Open System Interconnection (OSI) reference model as defined in ISO 7498 standard. The messages had been passed through all layers and each layer performs a specific function [1].

By referring to Figure 2, layer 1 is the physical media of data communication (normally a wire). Meanwhile, above layer 7 is the device function called the User Layer. The User Layer functions as measurement, actuation, control or operator interface in a host. This layer is where the data formats and semantics are defined to allow devices understand and able to act intelligently on the data, thereby achieving the real interoperability [1].

For Fieldbus, the service of the remaining layers in OSI Layers such as layer 3, 4, 5, and 6 are not required in a process control application. A message makes its way down through the layers in the receiving device. For the requested message, the device attends to it and responds by passing a message back the opposite way [1].

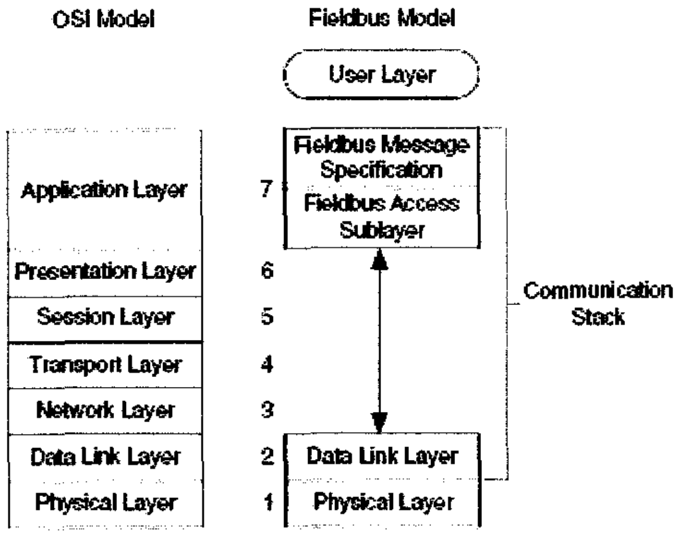

Figure 2 : The Communication Layers

2.3 Advantages of FOUNDATION Fieldbus

An advantage of the FOUNDATION Fieldbus is that it is allows device interoperability which simply means that FOUNDATION Fieldbus devices and host systems can work together while giving you the full functionality of each component. FOUNDATION Fieldbus can also have multidrop wiring. It can support up to 32 devices on a single pair of wires (called a segment) and even more if repeaters are used. In actual practice, considerations such as power, process modularity, and loop execution speed make 4 to 16 devices per H1 segment more typical [4].

System performance is enhanced with the use of fieldbus technology due to the simplification of the collection of information from field devices. Measurement and device values will be available to all field and control devices in engineering units. This eliminates the need to convert raw data into the required units and will free the control system for other more important tasks. The reduction in information complication will allow the development of better and more effective process control systems. FOUNDATION Fieldbus devices can tell you if they are operating correctly and if the information they are sending is good, bad, or uncertain. This eliminates the need for most routine checks and helps you detect failure conditions before they cause a major process problem [4].

2.4 Interoperability and Interoperability Testing

Interoperability is the capability to substitute a field device from one vendor for that of another vendor without loss of functionality. Interoperability offers freedom to choose the right device for an application, the ability of the vendor to add new and useful features, and also elimination of proprietary protocols and custom software drivers and upgrade. Interoperability testing is done to test and verify the host fieldbus system meets these expected capabilities. The primary purpose of interoperability testing is to ensure that the FF protocol and specifications have been followed. That is what earns each device its FF checkmark [4].

2.4.1 Benefits of Interoperability Testing

Every device must pass interoperability testing to be registered by the FOUNDATION™. This test assures users that devices from different vendors have been subjected to common set of tests. It confirms characteristics of devices and definitely assures interoperability. It is also essential to ensure plug and play characteristics of the devices [4].

CHAPTER 3
METHADOLOGY

3.1 Procedure Identification

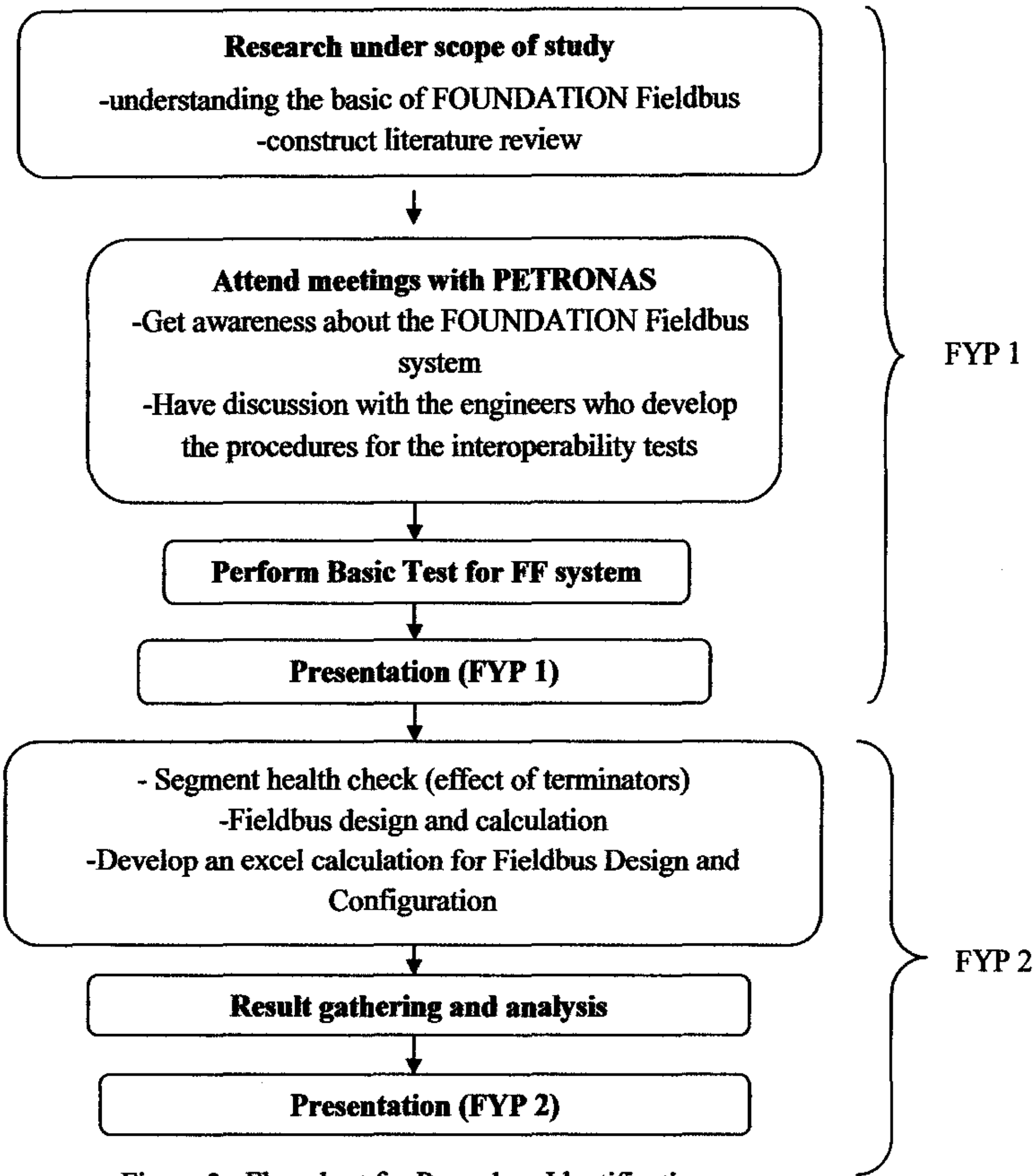

Figure 3: Flowchart for Procedure Identification

3.2 Project Activity

3.2.1 Basic Interoperability Test

This project aims to perform a FOUNDATION Fieldbus Interoperability Test which involves various types of vendors. The Basic Interoperability testing is the first test to be conducted and is about to make sure the device is functioning between the host and device. The test is done in terms of the interoperability test consisting of the Initial Download, Device Commissioning, Device Decommissioning, Online Device Replacement, Physical Layer Inspection, Calibration Function Checks, and Online Parameter Download. These tasks are to be completed using the test bench of the FOUNDATION Fieldbus. The test bench includes four hosts, 28 devices, high power trunk concept, three cabinets and other monitoring diagnostic system.

The first test is Initial Download which needs to be performed every time host switching is done. This is to ensure that all devices are properly recognized by the new host, loaded with the identified host configuration and updated with current data.

For Device Commissioning, the objective is to check whether the host is able to read data from the fieldbus device and to note the time taken for the commissioning to accomplish. At the same time, the Device Commissioning is used to tell how well the FF startup procedure of a completely new system works. This will gauge the difficulty level of commissioning of a FF system. The commissioning process must not interrupt the system or affect other devices on the segment. For Basic Test, the scope covers the pre-registered devices. The details of the procedure done are referred to Figure 4.

Device Decommissioning is also done. The purpose is to note the proper method of putting device in offline mode. An example is detaching the device from the segment. The process must make sure that host does not scan the detached device as error.

The next test is Online Device Replacement, which the steps involved are shown in Figure 5. After the decommissioning procedure is done, the system is now ready to commission a new device. From the fully functioning fieldbus system, a device cable is removed while ensuring the parallel wiring to other devices is not broken. To replace the device, the cable is reconnected to the segment again. This task must cause no major interruption and it is needed to test the effects of an unknown device being introduced into a FF system.

Physical Layer Diagnostic test is also performed. Fieldbus segment will work with two terminators located at both ends. As the terminators can be easily switched on at field barriers, the test will see the effect of having more than two terminators at one segment. Several methods are available for the Physical Layer Inspection such as scaling using fieldbus communicator (375 Field Communicator) and also drop out cable method.

By using 375 communicator, readings of the noise, DC voltage and signal level are taken. Meanwhile, for the drop out cable method, the purpose of the testing is to record the response of the segments after taking out one device cable connected to the segment. The task is used to ensure that physical layer is performing at optimum level. At the end of Physical Layer Inspection, the parameters shall match with the FOUNDATION Fieldbus system guideline. The details of the steps of test are as in Figure 6.

Lastly, for Calibration Function Checks, the test of calibration function was carried out from the Host, 375 communicator or iAMS. The essential steps have been registered when carrying calibration using Host method as shown in Figure 7.

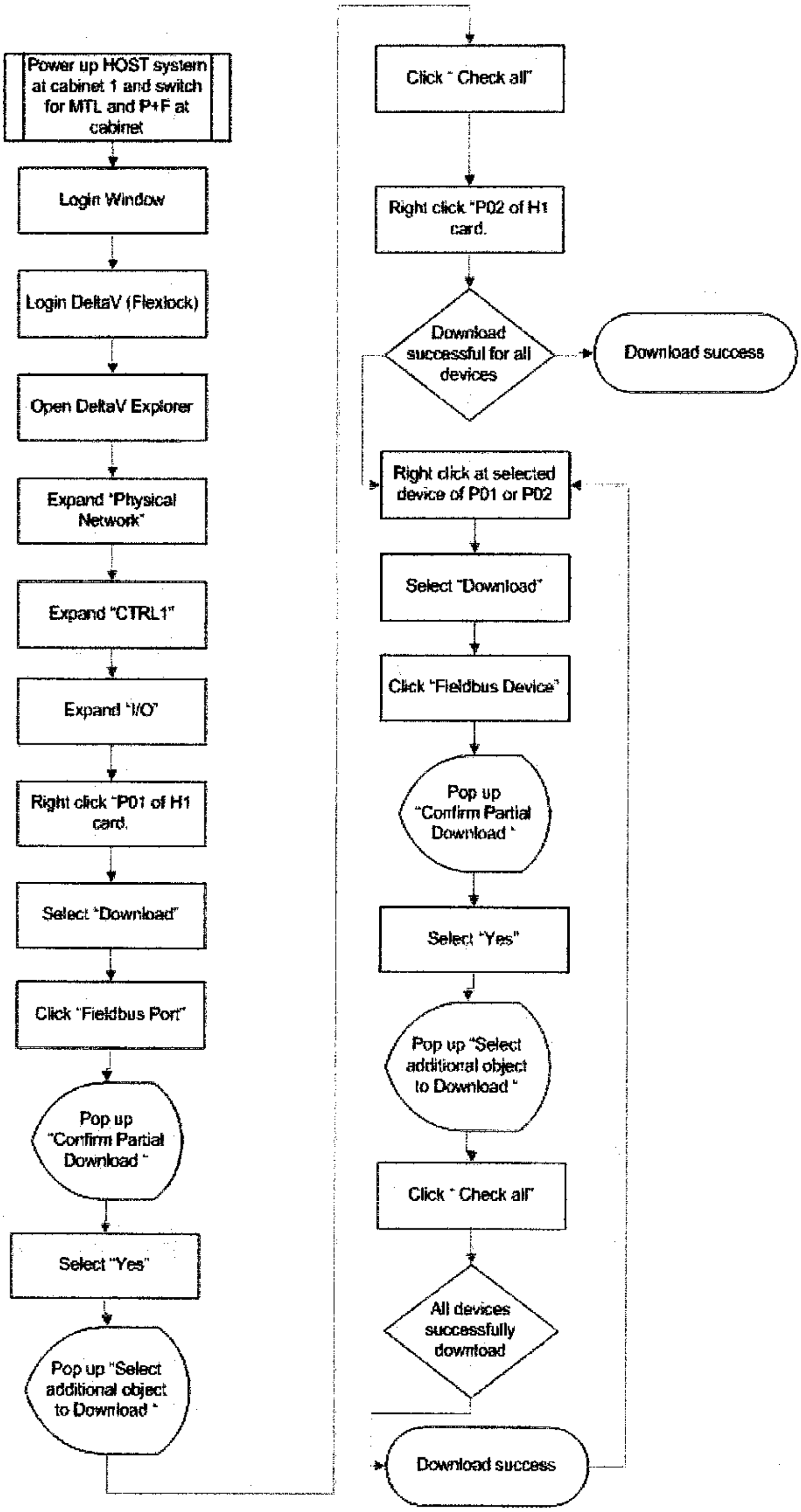

Figure 4: Flowchart for Device Commissioning [12]

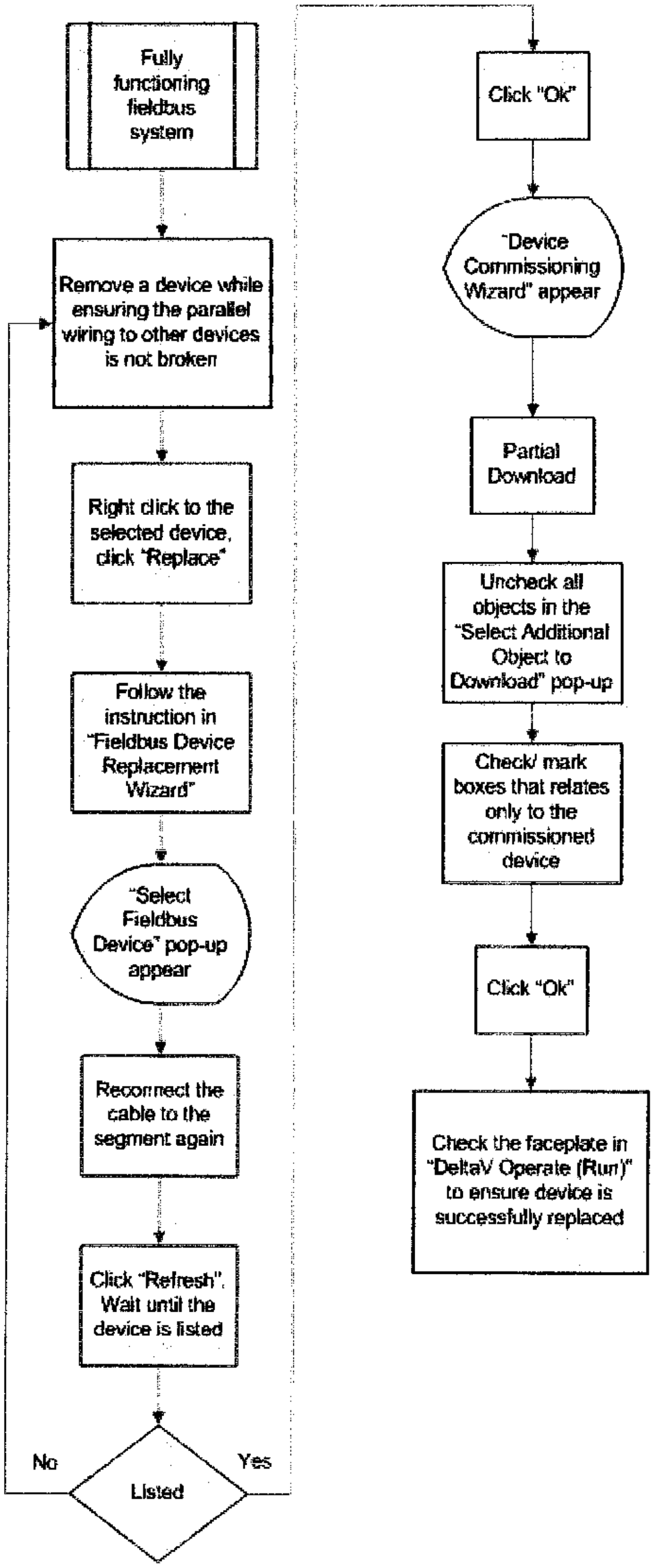

Figure 5: Flowchart for Online Device Replacement [12]

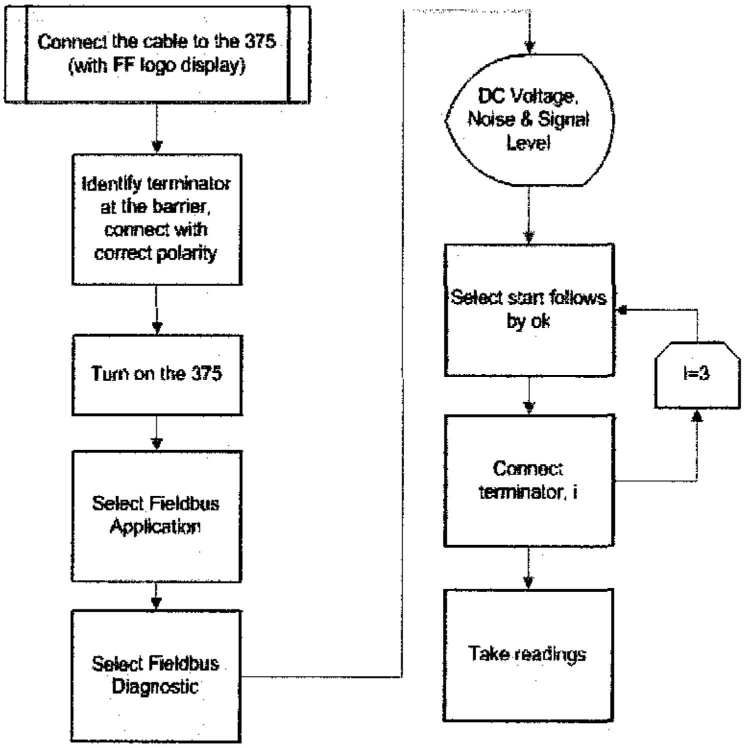

Figure 6: Flowchart for Physical Layer Inspection [12]

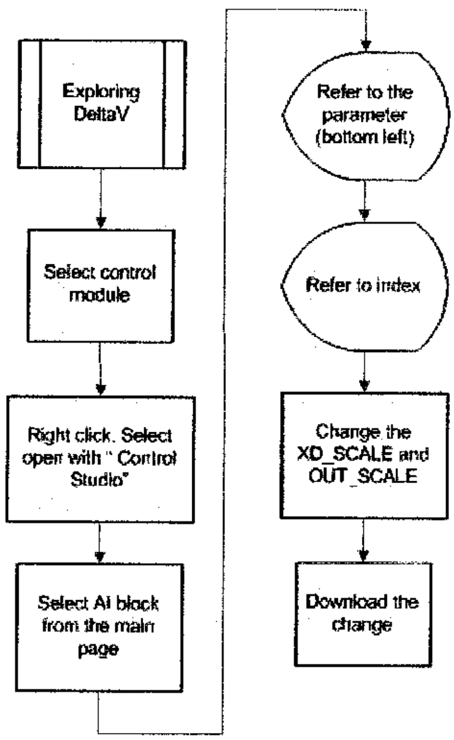

Figure 7: Flowchart for Calibration Function Check [12]

3.2.2 Summary of Test Procedure

The following are the interoperability tests that will be conducted throughout this project:

1. Basic Interoperability Test
   a. Device Commissioning
   b. Interoperability between different Hosts and Devices
   c. Online device replacement
   d. Bus health inspection
   e. Device firmware upgrades

2. Stress Test
   a. Fully loaded segments – confirm maximum number of devices
   b. Stress test
   c. Communication integrity soak test
   d. Back-up of Link Active Scheduler (LAS)
   e. Control in field
   f. Test of maximum cable length and different cable type (e.g. without shield)

3. Diagnostic Capability Test
   a. Verify operation of advanced function blocks
   b. Device health check
   c. Verify interoperability between different vendor devices and host
   d. Ease of calibration check and trim
   e. Others
      i. Driver integration
      ii. Online / offline condition
      iii. Parameter download
      iv. Schedule download

3.2.3 Segment Health Check

As requested by the GTS engineer, the effect of having two terminators at field barrier and none at power conditioner is checked. The segment health check is performed using FBT-6 at the fieldbus plant in Building 23 at UTP.

The test is done at segment 1 P+F (500m) and at segment 2 MTL (300m). The data to be observed are voltage, signal level, noise, shield shorts, and retransmits. These data must meet the expected range of values to ensure that the fieldbus segments are in good condition. By using FBT-6, the measurements that are collected are automatically saved in the tool's memory and can be downloaded to a PC. The point where the segment data is taken is noted.

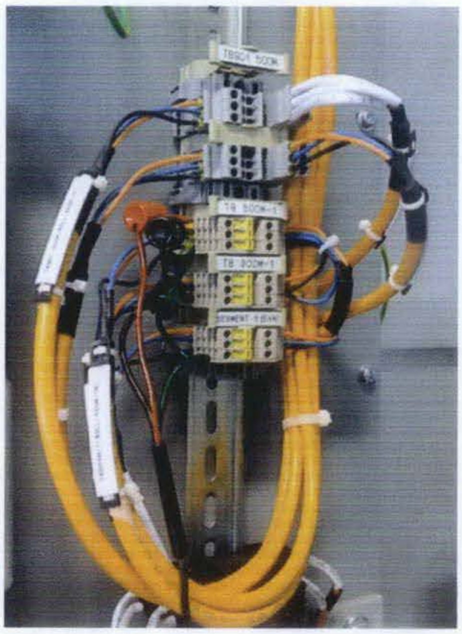

Figure 8: FBT-6 is connected at Terminal Block (TB) 500m – 1 to get measurement

3.3 Tools and Equipments Required

Figure 9 below shows some of the required equipments for the FOUNDATION Fieldbus Interoperability Testing. All the equipments are provided by the vendors for the purpose of study. There are four vendors involved for the host (EMERSON, FOXBORO, HONEYWELL and YOKOGAWA). However, this project will only focus for the EMERSON host only.

Figure 9: FOUNDATION Fieldbus Plant

UTP FF Laboratory also comprises of two segments for the four Hosts, 28 devices and using High Power Trunk concept. Three cabinets are used to house all the Hosts and other monitoring/ diagnostic systems.

Workstations for the Hosts are located in the same laboratory as well. EMERSON as the host in this project contribute their own software to show the performance and as the medium to communicate with the devices from the host. EMERSON has two main stations that are called PROPLUS and Asset Management System (AMS). The PROPLUS functions as the engineering workstation which consist of two main softwares which are DeltaV Operate and DeltaV Explore. The

DeltaV Operate is for the operator to do the monitoring while the DeltaV Explore is functioning more for the configuration and maintenance purpose. The AMS is where the registration of the Device Description (DD) of a particular device is being loaded.

Several tests for this project also involve the usage of 375 handheld communicator which is manufactured by EMERSON. This tool is proven to be in an open standard with all types of devices from other different manufacturers.

Figure 10: The EMERSON's 375 Handheld Communicator

A tool to monitor the segment health of the fieldbus plant is FBT-6. It can measure bus voltage, noise, the number of devices per segment, and indicates when devices are added or removed from a network.

Figure 11: FBT-6

CHAPTER 4
RESULT AND DISCUSSION

4.1 Basic Test

The result for the fieldbus testing is focused on the six tests that have been conducted in the basic test. The tests are Initial Download, Device Commissioning, Device Decommissioning, Online Device Replacement, Physical Layer Inspection / Device Drop Out and Calibration Function Check. The time taken for each device to run its specific task is recorded as part of the performance. Some parts of this testing need to be repeated several times before the author obtains the results. The Emerson Host is quite reliable but the author also encounters some problem in conducting the testing because the fieldbus plant at the lab is sometimes not available for usage due to maintenance purpose. The following results are based on the result for field devices in Segment 2.

4.1.1 Initial Download

Table 1 : Result for Initial Download

No.	VENDOR	DEVICE NAME	INITIAL DOWNLOAD		
			SEGMENT DOWNLOAD	PARTIAL DOWNLOAD	ALARM ACKNOWLEDGED
1	E+H	AT305	F	S	F
2	E+H	LT302	S	-	S
3	E+H	PT303	S	-	F
4	E+H	PDT304	S	-	F
5	E+H	LT301	S	-	S
6	E+H	FT306	S	-	S
7	E+H	FT307	F	F	F
8	HONEYWELL	PT402	S	-	S
9	HONEYWELL	PDT403	S	-	S
10	FOXBORO	FT101	S	-	S
11	FOXBORO	FV102	S	-	S
12	MTL	MTLADM1	F	F	S
13	E+H	TT308	S	-	F

S = Success F = Fail

Initial download to commission all the devices could be easily performed using wizard. Time taken to complete the initial download for Segment 1 was nine minutes and for Segment 2 was ten minutes. The wizard will commission a device and download it to the system. However, commissioning process for some devices was not complete. These devices (AT305, FT307, MTLADM1) required individual download. After the overall initial download, two devices were still in decommissioned mode for Segment 2. The alarms for almost all of the field devices can be acknowledged by the user.

4.1.2 Device Commissioning

Table 2 : Result for Device Commissioning

No.	VENDOR	DEVICE NAME	FULL DOWNLOAD	PARTIAL DOWNLOAD	COMMISSION
1	E+H	AT305	S	-	S
2	E+H	LT302	S	-	S
3	E+H	PT303	F	S	S
4	E+H	PDT304	F	S	S
5	E+H	LT301	S	-	S
6	E+H	FT306	S	-	S
7	E+H	FT307	F	-	F
8	HONEYWELL	PT402	F	S	S
9	HONEYWELL	PDT403	F	S	S
10	FOXBORO	FT101	S	-	S
11	FOXBORO	FV102	S	-	S
12	MTL	MTLADM1	F	-	F
13	E+H	TT308	F	S	S

S = Success F = Fail

First, full download is performed for Segment 2 and the time taken is 13 minutes. However, commissioning process for some devices was not complete (fail). This scenario may occur if host switching is frequently performed. Therefore, the failed devices require partial download at each of that particular device individually. The time taken for partial download was around one minute to two minutes for each device.

Overall, the host is able to recognize and communicate with fieldbus devices after commissioning except for FT307 and MTLADM1. Actually, FT307 is originally not attached to the fieldbus segment, therefore the host is unable to recognize the parameters of the device. MTLADM1 is a power conditioner and it requires an additional device called segment 8 to work. Since segment 8 is not available at the moment, therefore MTLADM1 has no purpose yet towards the functioning of fieldbus system. The commissioning process does not interrupt the fully functioning system or affect other devices in the segment.

4.1.3 Device Decommissioning

Table 3: Result for Device Decommissioning

No.	VENDOR	DEVICE NAME	DECOMMISSION
1	E+H	AT305	S
2	E+H	LT302	S
3	E+H	PT303	S
4	E+H	PDT304	S
5	E+H	LT301	S
6	E+H	FT306	S
7	E+H	FT307	F
8	HONEYWELL	PT402	S
9	HONEYWELL	PDT403	S
10	FOXBORO	FT101	S
11	FOXBORO	FV102	S
12	MTL	MTLADM1	F
13	E+H	TT308	S

S = Success F = Fail

All devices can be successfully decommissioned and the alarm can be acknowledged except for FT307 and MTLADM1. Up to this point, all the devices are found to be healthy and can be recognize by the system. FT307 had been detached from the segment and MTLADM1 is a power conditioner.

Only four devices per segment can be simultaneously decommissioned. Attempted to decommission the fifth device causes the host's wizard to freeze and needed to be cancelled. This resulted in unpredictable system behavior. However, system normalized by putting device in "decommissioned" mode into "standby" mode. Decommissioning a device does not interrupt the fully functioning system or affect other devices on the segment.

4.1.4 Online Device Replacement

Table 4 : Result for Online Device Replacement

No.	VENDOR	DEVICE NAME	RESULT
1	E+H	AT305	S
2	E+H	LT302	S
3	E+H	PT303	S
4	E+H	PDT304	S
5	E+H	LT301	S
6	E+H	FT306	S
7	HONEYWELL	PT402	S
8	HONEYWELL	PDT403	S
9	FOXBORO	FT101	S
10	FOXBORO	FV102	S
11	E+H	TT308	S

S = Success

The built-in online device replacement wizard was able to detect suitable device that can be used as replacement. The wizard automatically performed the decommissioning of the old device and commissioning of the new device. Overall, Online Device Replacement did not affect the fully functioning segment. Based on the result obtained, all devices can be successfully replaced online and function properly when reconnects. This shows that the DD file that store the device information are still in the system after the devices are reconnected.

4.1.5 Device Drop Out

The expected result for Device Drop Out is that any device failure would not affect the overall segment or any other healthy devices in the segment. The test carried out for PDT403 showed that TT308 was affected while others did not affect any device. Specific alarm would appear to inform user on devices that are disconnected from the segment. The time taken for the alarms to be normalized varies for each device and was approximately less than one minute.

Table 5 : Result for Device Drop Out

No.	VENDOR	DEVICE NAME	DEVICE AFFECTED	ALARM NORMALIZED(sec)
1	E+H	AT305	-	38.2
2	E+H	LT302	-	60.2
3	E+H	PT303	-	42.4
4	E+H	PDT304	-	52.5
5	E+H	LT301	-	55.5
6	E+H	FT306	-	23.1
7	HONEYWELL	PT402	-	29.3
8	HONEYWELL	PDT403	TT308	20.8
9	FOXBORO	FT101	-	29.1
10	FOXBORO	FV102	-	25.8
11	E+H	TT308	-	21.9

4.1.6 Calibration Function Check

Table 6 : Result for Calibration Function Check

No.	VENDOR	DEVICE NAME	CALIBRATION	
			375 COMMUNICATOR	HOST
1	E+H	LT301	F	S
2	E+H	LT302	F	S
3	E+H	PT303	F	S
4	E+H	PDT304	F	S
5	E+H	AT305	S	S
6	E+H	FT306	S	S
7	E+H	TT 308	S	S
8	HONEYWELL	PT402	S	S
9	HONEYWELL	PDT403	S	S
10	FOXBORO	FT101	S	S
11	FOXBORO	FV102	S	S

S = Success F = Fail

From the host system, the device mode was set to 'OOS' (out of service) and changes was made to 'XD Range' and 'Out Range'. After changing to 'Auto' mode, the response was recorded. The test was also repeated using 375 Field Communicator.

- Host

In Delta V, the range change was done at Control Studio. XD range and OUT range were edited at AI block after mode was change to 'OOS'. When the mode was changed back to 'Auto', the new range was automatically and successfully updated in the device and reflected in human-machine interface.

- 375 Field Communicator

Similar results to host application were obtained. The new ranges keyed in the communicator was sent to device and automatically updated in the system. However 375 Field Communicator was unable to extract from all devices, thus preventing output range trim to these devices using the communicator. Mostly this affected a number of Endress + Hauser transmitters (LT301, LT302, PT303 and PDT304).

By referring to GTS (Petronas Group Technology Solution), it was found that the problems were due to unavailability of 375 DD Files of these transmitters. The matter had been communicated to Emerson and Endress+Hauser. Endress+Hauser informed that the issue is being resolved by their principle in Switzerland with Emerson.

4.2 Segment Health Check using FBT-6

These are some of the result that was obtained during the segment health check. The tool used is FBT-6 and it is connected to the trunk of segment 1 p+f (500m).

Table 7: Three terminators located at Power Conditioner, Field Barrier, and Segment Protector

Segment Measurements	Data	Acceptable Values	OK/BAD
Voltage	29,0V	9,0V Minimum	OK
Lowest Device Signal	549mV	150mV Minimum	OK
Lowest Device Signal Address	35 (23H)		
Lowest Device Signal Date/Time	Not Available		
Avg Fieldbus Frequency Noise (9KHz-40KHz)	5mV	75mV Maximum	OK
Peak Fieldbus Frequency Noise (9KHz-40KHz)	5mV	75mV Maximum	OK
Peak Fieldbus Frequency Noise Date/Time	Not Available		
Avg Low Frequency Noise (50Hz-4KHz)	13mV	150mV Maximum	OK
Peak Low Frequency Noise (50Hz-4KHz)	30mV	150mV Maximum	OK
Peak Low Frequency Noise Date/Time	Not Available		
Avg High Frequency Noise (90KHz-350KHz)	9mV	150mV Maximum	OK
Peak High Frequency Noise (90KHz-350KHz)	12mV	150mV Maximum	OK
Peak High Frequency Noise Date/Time	Not Available		
Shield Short	No Shorts	No Shorts	OK
LAS Address	16 (10H)		
Most Recent Add/Drop Address	33 (21H)		
Device Add or Drop	Add	None Added/Dropped	WARN
Date/Time of Device Add/Drop	Not Available		
Number of Active Devices	13		

Table 8 : Terminator is removed from Power Conditioner

Segment Measurements	Data	Acceptable Values	OK/BAD
Voltage	29,0V	9,0V Minimum	OK
Lowest Device Signal	837mV	150mV Minimum	OK
Lowest Device Signal Address	24 (18H)		
Lowest Device Signal Date/Time	Not Available		
Avg Fieldbus Frequency Noise (9KHz-40KHz)	5mV	75mV Maximum	OK
Peak Fieldbus Frequency Noise (9KHz-40KHz)	61mV	75mV Maximum	OK
Peak Fieldbus Frequency Noise Date/Time	Not Available		
Avg Low Frequency Noise (50Hz-4KHz)	12mV	150mV Maximum	OK
Peak Low Frequency Noise (50Hz-4KHz)	30mV	150mV Maximum	OK
Peak Low Frequency Noise Date/Time	Not Available		
Avg High Frequency Noise (90KHz-350KHz)	10mV	150mV Maximum	OK
Peak High Frequency Noise (90KHz-350KHz)	20mV	150mV Maximum	OK
Peak High Frequency Noise Date/Time	Not Available		
Shield Short	No Shorts	No Shorts	OK
LAS Address	16 (10H)		
Most Recent Add/Drop Address	35 (23H)		
Device Add or Drop	Add	None Added/Dropped	WARN
Date/Time of Device Add/Drop	Not Available		
Number of Active Devices	13		

Table 9: Terminator is removed from Field Barrier

Segment Measurements	Data	Acceptable Values	OK/BAD
Voltage	29,0V	9,0V Minimum	OK
Lowest Device Signal	566mV	150mV Minimum	OK
Lowest Device Signal Address	24 (18H)		
Lowest Device Signal Date/Time	Not Available		
Avg Fieldbus Frequency Noise (9KHz-40KHz)	5mV	75mV Maximum	OK
Peak Fieldbus Frequency Noise (9KHz-40KHz)	61mV	75mV Maximum	OK
Peak Fieldbus Frequency Noise Date/Time	Not Available		
Avg Low Frequency Noise (50Hz-4KHz)	13mV	150mV Maximum	OK
Peak Low Frequency Noise (50Hz-4KHz)	30mV	150mV Maximum	OK
Peak Low Frequency Noise Date/Time	Not Available		
Avg High Frequency Noise (90KHz-350KHz)	12mV	150mV Maximum	OK
Peak High Frequency Noise (90KHz-350KHz)	40mV	150mV Maximum	OK
Peak High Frequency Noise Date/Time	Not Available		
Shield Short	No Shorts	No Shorts	OK
LAS Address	16 (10H)		
Most Recent Add/Drop Address	23 (17H)		
Device Add or Drop	Add	None Added/Dropped	WARN
Date/Time of Device Add/Drop	Not Available		
Number of Active Devices	13		

4.2.1 Voltage

As a guideline, voltage should never be less than 9VDC or greater than 32VDC. However, in this experiment the voltage obtained is said to be quite high compared to the previous experiment done by the GTS engineer. The voltage now is 29 V whereby the previous value is around 23 V with voltage power supply of 32 V. Voltage measurement guideline is listed in the table below. Note that every fieldbus segment is different. The fieldbus power supply, cable length, where the measurement is taken and other factors can drastically affect the actual measurements on the network.

Table 10: General Guidelines for Voltage Measurements [11]

Voltage (VDC)	Condition
>32	Too High
10 - 32	OK
<10	Too Low

4.2.2 Signal Level Voltage

Based on the results obtained, the lowest device signal level is 549mV (Table 7), 837mv (Table 8), 566mv (Table 9), therefore the system is said to be in an 'OK' condition for all of the three experiments done.

Each fieldbus segment must have 2 terminators installed. The signal level will decrease about 30% if the segment has an extra terminator and increase about 70% if a terminator is missing.

Table 11: General Guidelines for Signal Level Measurements [11]

Signal Level (mVpp)	Condition
>1000	Too High – Missing Terminator
250-1000	OK
<250	Too Low

4.2.3 Noise

Fieldbus communicates with a frequency band of 7.8 KHz to 39.1 KHz. The closer the noise frequency is to the fieldbus frequency band, the lower the noise signal strength must be to impact communications on the fieldbus. Fieldbus devices are required to reject signals within the fieldbus frequency band that are less than 75mVpp [11].

Table 12: General Guideline for Noise Level Measurement with FBT-6 [11]

Noise Level in FF Noise Band (mV)	Noise Level in LF Noise Band (mV)	Noise Level in HF Noise Band (mV)	Condition
<30	<50	<50	Good
30-75	50-150	50-150	Marginal
>75	>150	>150	Too High

Based on the results obtained in Table 7, 8 and 9, it is found out that the noise levels are in OK condition when referred to the guideline shown.

4.3 Fieldbus Design and Configuration

4.3.1 Cable length

The total length summing the length of the trunk and that of all the spurs must not exceed the limitation for the particular cable type, for example 1.9 km in the case of type A cable. For longer distances, a network may reach farther that is made from several segments joined by repeaters because the cable limit applies per segment. The shorter the total cable length the better, so unnecessarily long cable routing must be avoided. For most of the distance, the main trunk typically is a multi-core homerun cable that is shared by many networks from a shield junction box into the marshalling panel [1]. The following figure shows the total cable length network example and its calculation.

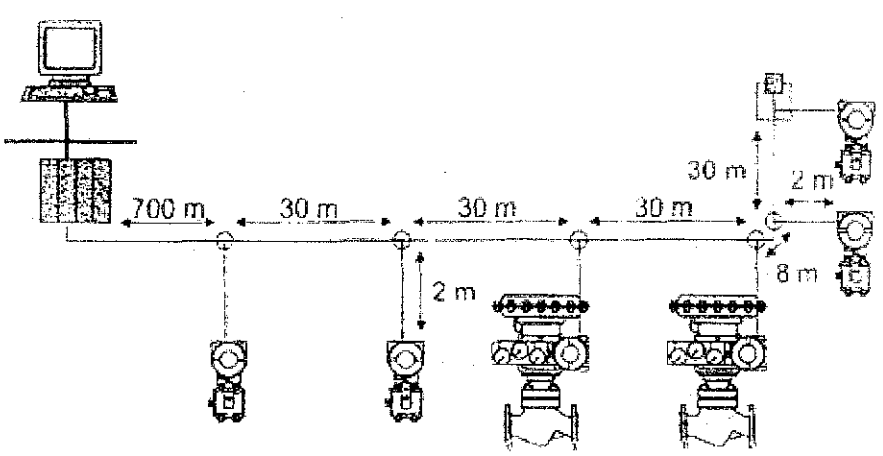

Figure 12 : Example of a network having 840 m total length [1]

The cable length calculation [1] for the network in Figure 12 can be shown as follows:

Trunk	700 m (2300 ft)
Trunk	30 m (100 ft)
Trunk	30 m (100 ft)
Trunk	30 m (100 ft)
Trunk	8 m (24 ft)
Trunk	30 m (100 ft)
Spur 1	2 m (6 ft)
Spur 2	2 m (6 ft)
Spur 3	2 m (6 ft)
Spur 4	2 m (6 ft)
Spur 5	2 m (6 ft)
Spur 6	2 m (6 ft)
Total	840 m (2760 ft)

When bus-powered devices are used, which is almost always the case, the voltage drop along the wire caused by the current consumption of the field devices also limits wire length. For maximum range and number of devices the supply voltage shall be as high as possible, the wire cross-section as large as possible to reduce resistance, and the field device current consumption as low as possible. The maximum distance can be calculated using Ohm's law [1].

If the power supply output voltage is lower, or the device power consumption is higher, the distance will be shorter and vice versa. It is therefore critical for both intrinsically safe and regular installations that the device current consumption be as low as possible. Even many devices that receive separate power still draw some current from the fieldbus network [1].

4.3.2 Wiring Limitation

The size of a fieldbus wiring system and the number of devices on a network segment are limited by power distribution, attenuation and signal distortion.

4.3.2.1 Power

The number of devices on a fieldbus segment is limited depending on the voltage of the power supply, the resistance of the cable and the amount of the current drawn by each device [10]. A design example [10] is considered as follows:

- The power supply and power conditioner output is 20 volts.
- The cable used is 18 GA and has a resistance of 22 ohms/km for each conducter. The home run is 1 km long. Therefore, the combined resistance for both wires is 44 Ohms.
- Each device at the chicken foot draws 20 mA.

As defined in the standard, a Fieldbus device needs a minimum of 9 V to operate. Therefore for this design there are 20 – 9 = 11 Volts that can be used up by the cable. The total current that can be supplied at the chickenfoot is:

$$\frac{\text{Voltage}}{\text{Resistance}} = \text{Current}$$

$$\frac{11\ \text{Volts}}{44\ \text{Ohms}} = 250\ \text{mA}$$

We know that each device draws 20 mA, so the maximum number of devices at the chickenfoot of this example is:

$$\frac{250\ \text{mA}}{20\ \text{mA}} = 12\ \text{devices}$$

Normally Fieldbus is powered by 24 Volts supplies. The maximum voltage that can be on the Fieldbus is 32 Volts. Devices can withstand up to + / - 35 Volts without damage. To keep the maximum voltage on the wiring below this limit, some Fieldbus wiring blocks have built-in voltage limiters [10].

When a number of devices are on the cable at different places, the power distribution calculation becomes more involved. The calculation is shown as follows:

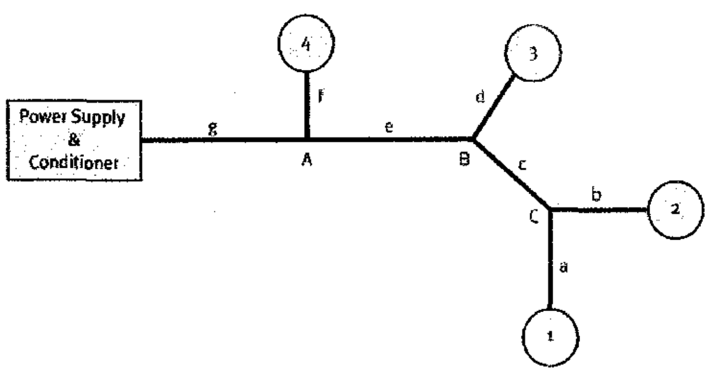

Figure 13: A fieldbus network with four devices [10]

The network shows four devices designated 1 through 4. The network wiring has segments a through g. The junctions of the segments are at A, B and C. These are some of the facts [10] about the network:

Table 13: Current required by each device

Device	Current Required, mA
1	20
2	25
3	30
4	15

Table 14: Resistance in each segment

Segment	Resistance, Ω
a	5
b	10
c	7
d	9
e	6
f	11
g	20

Next, the amount of current in each segment can be calculated. Using the law of voltage equals to current times resistance, the voltage drop in each segment can also be calculated as follows:

Table 15: Current and voltage drop in each segment

Segment	Resistance, Ω	Current in Segment, mA	Voltage Drop in Segment, V
a	5	20 (due to device 1)	0.1
b	10	25 (due to device 2)	0.25
c	7	45 (due to device 1+2)	0.315
d	9	30 (due to device 3)	0.27
e	6	75 (due to device 1+2+3)	0.45
f	11	15 (due to device 4)	0.165
g	20	90 (due to device 1+2+3+4)	1.8

From this, voltage at each node can be calculated:

Table 16: Voltage drop at each node

Node	Voltage Drop, V
A	1.8 (due to segment g)
Device 4	1.965 (due to segment g + f)
B	2.25 (due to segment g + e)
Device 3	2.52 (due to segment g + e + d)
C	2.565 (due to segment g + e + c)
Device 2	2.815 (due to segment g + e + c + b)
Device 1	2.665 (due to segment g + e + c + a)

From the table, it is shown that the largest voltage drop is 2.815 Volts at Device 2. The current flowing in segment g is 90 mA. Therefore, the power supply and conditioner must be able to deliver at least 90 mA. The lowest voltage that can be at the power supply / conditioner is the 9 volt minimum requires by the devices plus the 2.815 voltage drop of the cable segments plus the 1 volt needed for signaling plus a safety margin of about 1 volt for a total of about 14 volts [10].

4.3.2.2 Attenuation

As signals travel on a cable, they become attenuated, that is, gets smaller. Attenuation is measured in units calles dB or deci-Bell. It can be calculated as:

$$\text{dB} = 20\log\frac{\text{transmitted signal amplitude}}{\text{received signal amplitude}}$$

Cables have attenuation rating for a given frequency. The frequency of interest for fieldbus is 39 kHz. Standard fieldbus cable has an attenuation of 3 dB/km at 39 kHz or about 70% of the original signal after 1 km. If a shorter cable is used, the attenuation is less. For example, a 500 m standard fieldbus cable would have an attenuation of 1.5 dB [10].

A fieldbus transmitter can have a signal as low as 0.75 Volts peak-to-peak. A receiver must be able to detect a signal as little as 0.15 volts peak-to-peak. This means that the cable can attenuate the signal by [10]:

$$20\log\frac{0.75}{0.15} = 14\text{ dB}$$

Since the standard fieldbus cable has an attenuation of 3 dB/km, this indicates that the fieldbus can be as long as:

$$\frac{14\ \text{dB}}{3\ \text{dB/km}} = 4.6\ \text{km}$$

Note that this distance may be theoretically possible, but there are other factors that have to be considered. Signals also become distorted as they travel on the cable [10].

4.3.3 Cable Types and their Maximum Lengths

Previously, the author has introduced the "pieces" of basic components in a fieldbus system. Now, it is time to start combining them together to build a network. This part summarizes information on FOUNDATION Fieldbus physical layers, H1 and HSE, including information on sizing and connections.

For new installations, twisted-pair cable designed especially for FOUNDATION Fieldbus should be used. The major characteristics are shown as below.

Table 17 : Fieldbus twisted pair cable characteristics [6]

Type	A	B
Wire size	18 GA (0.8 mm)	22 AWG (0.32 mm)
Shield coverage	90%	90%
Attenuation at 39 KHz	3 db/km	5 dB/km
Characteristic impedance at 31.25KHz	100 Ω ± 20%	100 Ω ± 30%
Capaciatance	2 nF/km	2 nF/km
Resistance	44 Ω/km	112 Ω/km
Maximum propogation delay between 0.25 f_r and 1.25 f_r	1.7 μs/km	1.7 μs/km

As a general rule, the maximum cable run is basically related to the cable type and its characteristics, the chosen topology, and the quantity and type of devices used (refer Table 18) [6].

Table 18: Cable types and their maximum lengths [6]

Type	Description	AWG	Capacitance pF/m	Attenuation, dB/km	Max length, m
X_o	Multiconductor with overall shield	20	75	4	1200
X_i	Multiconductor with individual and overall shield	20	98	5	1900
X_s	Single pair	11	44	6	1900

The maximum overall length of cable when mixing cable types is determined by the formula

$$\frac{L_x}{L_{max_x}} + \frac{L_x}{L_{max_y}} \leq 1$$

where:

L_x = length of cable x

L_y = length of cable y

L_{max_x} = maximum length of cable type x alone

L_{max_y} = maximum length of cable type y alone

In addition to the physical limitations described earlier, which are generic guidelines based on voltage and capacitive limitations, the following equation can be used to calculate the maximum trunk length on a system with approximately equal spur lengths and devices with nearly equivalent current, voltage, and capacitance needs [6].

$$L_{TMax} < \frac{((V_{PS} - V_{Min}) \times 10^6 - I_D \times 2 \times R_S \times L_S)}{\Sigma I_D \times 2 \times R_T}$$

where:

L_{TMax} = maximum voltage of trunk cable, meters

V_{PS} = power supply voltage, volts

V_{Min} = largest minimum voltage of all the field devices, volts

I_D = DC current draw of the field device with the largest minimum voltage, mA

R_S = manufacturer-specified resistance of spur cable, Ω/km

L_S = length of spur cable, meters

ΣI_D = total of DC current draw of all field devices, mA

R_T = manufacturer-specified resistance of trunk cable, Ω/km

If the installation is a "chickenfoot" arrangement, or if each of the field devices has very different minimum voltages (e.g. a temperature transmitter and a valve positioned) and current specifications, then the voltage available at each device on the segment should be calculated using the following formula [6]:

$$V_D = V_{PS} - (\Sigma I_D \times 2 \times R_T \times L_T + I_D \times 2 \times R_S \times L_S) \times 10^{-6} > V_{Min}$$

where:

V_{Min} = minimum voltage of the field devices, volts

V_D = DC voltage available at the field device, volts

V_{PS} = power supply voltage, volts

ΣI_D = total of DC current draw of all field devices, mA

R_T = manufacturer-specified resistance of trunk cable, Ω/km

L_T = length of trunk cable, meters

I_D = DC current draw of the field device, mA

R_S = manufacturer-specified resistance of spur cable, Ω/km

L_S = length of spur cable, meters

Capacitance constraints must also be considered since the effect on the signal of a spur <300 m long is very similar to that of a capacitor. In the absence of actual data from the manufacturer, a value of 0.15 nF/m can be used for Fieldbus cables [6].

$$C_T = \Sigma (L_S \times C_S) + C_D$$

Where:

C_T = total capacitance of network, nF

L_S = length of spur cable, meters

C_S = Capacitance of wire for segment, nF/m (use 0.15 if no other number is available)

C_D = Capacitance of device. nF

The attenuation associated with this capacitance is 0.035 dB/nF. To estimate the attenuation associated with the installation, the following formula provides a useful guideline.

$$A = C_T \times L_T \times 0.035 \frac{dB}{nF} < 14dB$$

where A is Atenuation, dB.

4.4 Devolopment of Tool for Fieldbus Design

This section discuss the work undertaken to develop an excel program to use as a tool for fieldbus design. The software would assist the designers to calculate and design the required value of cable length, power supply/power conditioner, maximum length for trunk cable and the dc voltage available at a particular field device. The tool used for this program is simply using Microsoft Office Excel 2007.

4.4.1 Total Cable Length

An excel calculation was developed based on the network in Figure 12.

	A	B	C	D	E	F	G	H	I
3									
4		No.	1	2	3	4	5	6	Total
5		Trunk (m)	700	30	30	30	8	30	=SUM(C5:H5)
6		Spur (m)	2	2	2	2	2	2	=SUM(C6:H6)
7		Total Cable Length							=SUM(I5:I6)

Figure 14(a): The excel program for total cable length calculation

In Figure 14(a) above, the cell filled with pink color are the data that must be keyed in by the user while the blue font cell contains formula to calculate the total length of spur and trunk and the overall total cable length for the network. Note that these formulas are an example for the particular fieldbus network shown in Figure 12. A little modification at the formula cell can be done to fit the calculation for other fieldbus topologies which may have different number of trunks and spurs. Figure 14(b) shows the result for total cable length calculated by the formula in Microsoft Excel.

No.	1	2	3	4	5	6	
Trunk (m)	700	30	30	30	8	30	828
Spur (m)	2	2	2	2	2	2	12
Total Cable Length							840

Figure 14(b): Result for total cable length

4.4.2 Minimum Voltage at Power Supply / Power Conditioner

This section will show the development of a program to calculate the minimum voltage required at fieldbus power supply or power conditioner. The example below is based on Figure13. First, the amount of current required for all field devices in the fieldbus network are keyed in by the user as shown in Figure 15(a) below.

Device	Current Required, I (A)
1	0.02
2	0.025
3	0.03
4	0.015

Figure 15(a): Current required by each device

The values of resistances are also put in the cells. Next, the current in each segment is calculated as shown in Figure 15(b). This figure also shows the formula that has been created in the cells to calculate the voltage drop in each segment. The current in Segment g is 90 mA, therefore by referring to Figure 13, it can be concluded that the power supply for this example must be able to deliver at least 90 mA.

	F	G	H	I J	K L
13					
14					
15	Segment	Resistance,R	Current in Segment, I (A)		Voltage Drop
16					in segment, V=IR
17	a	5	0.02	due to device 1	=G17*H17
18	b	10	0.025	due to device 2	=G18*H18
19	c	7	0.045	due to device 1 + 2	=G19*H19
20	d	9	0.03	due to device 3	=G20*H20
21	e	6	0.075	due to device 1+2+3	=G21*H21
22	f	11	0.015	due to device 4	=G22*H22
23	g	20	0.09	due to device 1+2+3	=G23*H23

Figure 15(b): Current in segments due to certain devices and the formulas for voltage drop in each segment

Voltage drop for each node and devices can then be calculated and the values are shown in Figure 15(c). Note that the largest voltage drop is 2.815 V. This value is needed to proceed in calculating the minimum voltage that can be at power supply / power conditioner.

	A	B	C	D E
26				
27		Node	Voltage drop, V	
28		A	1.8	due to segment g
29		Device 4	1.965	due to segment g+f
30		B	2.25	due to segment g+e
31		Device 3	2.52	due to segment g+e+d
32		C	2.565	due to segment g+e+c
33		Device 2	2.815	due to segment g+e+c+b
34		Device 1	2.665	due to segment g+e+c+a
35				

Figure 15(c): Voltage drop at each node and devices

	B	C	D	E	F	G	H
45							
46	Largest voltage drop at device / node						2.815
47	Minimum voltage required by devices						9
48	Voltage for signalling / spur protector loss						1
49	Value of voltage for safety margin						1
50							
51	Lowest voltage that can be at power supply / power conditioner						=H46+H47+H48+H49
52							= 13.815 V

Figure 15(d): The excel program to calculate minimum voltage at power conditioner

The values in the cells that are filled with pink in color are entered by user. The value for largest voltage drop is obtained from the previous calculation in this part. The values for minimum voltage required by devices, voltage for signaling / spur protector loss and voltage for safety margin are standard values and obtained from fieldbus expertise based on certain calculation and experience.

4.4.3 Maximum Length for Trunk Cable

	A	B	C	D	E	F	G	H	I
69									
70	Inset values for the following:								
71									
72	Power supply voltage, volts						VPS :		
73	largest minimum voltage of all the field devices, volts						V_{min} :		
74	DC current draw of the field device with the largest minimum voltage, mA						I_D :		
75	manufacturer-specified resistance of spur cable, Ω/km						R_S :		
76	length of spur cable, meters						Ls :		
77	total of DC current draw of all field devices, mA						Σ ID :		
78	manufacturer-specified resistance of trunk cable, Ω/km						R_T :		
79									
80	Result:								
81									
82	Maximum length for trunk cable (m)				LTMax <	=((H72-H73)*10^6-H74*2*H75*H76)/(H77*2*H78)			
83									

Figure 16: The excel program to calculate maximum length for trunk cable

This program can automatically calculate the maximum length for a trunk cable on a fieldbus system provided with approximately equal spur lengths and devices with nearly equivalent current, voltage, and capacitance needs [6]. The user must key in the specified input in the cells with pink filled color based on the requirement mentioned. As discussed earlier, the formula that was programmed in Cell F82 is based on the formula below [6] :

$$L_{TMax} < \frac{((V_{PS} - V_{Min}) \times 10^6 - I_D \times 2 \times R_S \times L_S)}{\Sigma I_D \times 2 \times R_T}$$

4.4.4 DC Voltage at Field Device

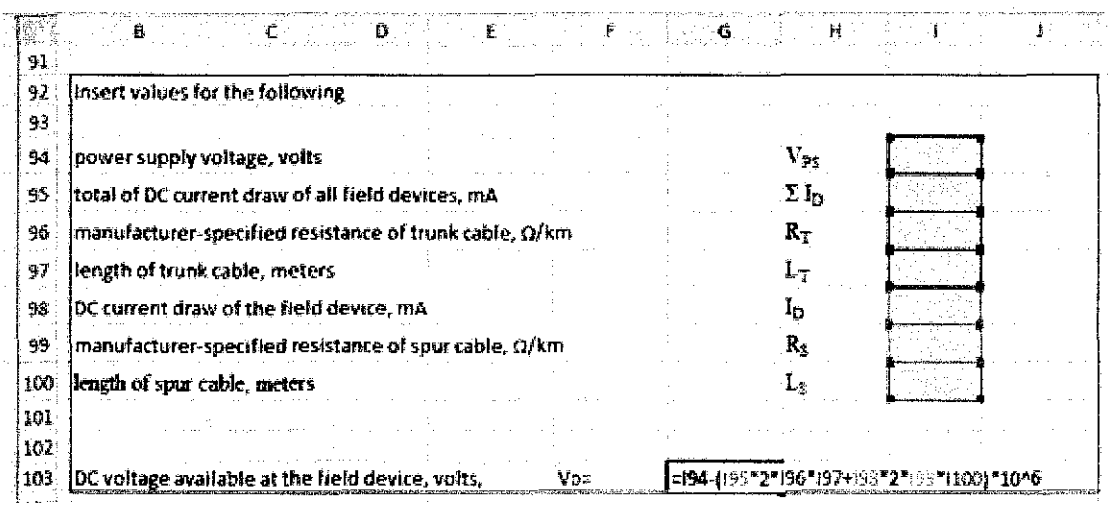

Figure 17: The excel program to calculate DC voltage available at the field device

The conditions applied for the program in Figure 17 above is when the installation is a "chickenfoot" arrangement and if each of the field devices has very different minimum voltages. By entering the necessary values in the pink colored cells, the program will automatically calculate the DC voltage available at the field device and the result will be displayed at Cell G103. As discussed earlier, the formula that was programmed in Cell G103 is based on the formula below [6] :

$$V_D = V_{PS} - (\Sigma I_D \times 2 \times R_T \times L_T + I_D \times 2 \times R_S \times L_S) \times 10^{-6} > V_{Min}$$

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Project conclusion

Overall, the project is achieving the main objectives which are to come out with a report from interoperability test and reports for PETRONAS Technical Standard. The Fieldbus research and testing is beneficial for students and for future training of PETRONAS people in order to deepen their knowledge on FOUNDATION Fieldbus. By referring to the manual constructed, it will put the PETRONAS trainer at ease in working with the host configuration. Furthermore, FOUNDATION Fieldbus should become a technology that may increase profit, decrease cost in many aspects and it is easy to handle.

Other than that, so far the author has done a research to investigate the different types of fieldbus topologies and found out that the 'tree' type has more advantages and is the most commonly used in the industry. Research and calculation design is also done to verify voltage drop and current limitation in powering a FOUNDATION Fieldbus segment. This result can be as a further reference when the stress test procedure that has been developed by the PETRONAS engineers is conducted in the fieldbus lab.

The data presented in the fieldbus design and calculation section will also be a reference to the student that are currently doing FYP I to develop a software tool, probably a "calculator" for fieldbus calculation.

5.2 Future planning

The author had been working on the basic test for FOUNDATION Fieldbus Interoperability test during FYP 1 (Final Year Project 1). This project is proceeding with more progress in FYP 2 focusing on data communication issues in stress test. Due to the current upgrading work in the UTP Fieldbus lab, the author is focusing on fieldbus configuration which involves design and calculation which should also be in line with the procedures in the Fieldbus Interoperability Testing for Stress Test.

The Fieldbus Interoperability Test is still ongoing and in the future, it will proceed with stress test guided by the SKG14 engineers from PETRONAS Group Technology Solution. This test should involve the fully loaded segment which confirm the maximum number of devices that could be used, the power failure recovery, communication integrity soak test, back up of LAS (Link Active Scheduler), the control in field and the test of maximum cable length and different cable type.

Stress test will also look into the usage of power conditioner in the fieldbus system:

- Test for the use of only MTL (four MTL) in the system
- Test for the use of MTL and PNF in the system

Regarding the development of basic tool for excel calculation, it is highly recommended to validate the proposed work with EMERSON in the future since this project is working closely with the EMERSON host. The proposed calculation should also be tested at the UTP fieldbus plant to prove the effectiveness of the excel tool.

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APPENDICES

APPENDIX A

Milestone for the First Semester of 2-Semester Final Year Project

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Topic	■	■						Mid-semester break							
2	Preliminary Research Work		■	■	■											
3	Submission of Preliminary Report				●											
4	Seminar 1 (optional)					■	■	■								
5	Project Work					■	■	■								
6	Submission of Progress Report									●						
7	Seminar 2 (compulsory)										■	■	■	■		
8	Project work continues									■	■	■	■	■		
9	Submission of Interim Report Final Draft														●	
10	Oral Presentation															●

● Suggested milestone

■ Process

APPENDIX B

Milestone for the Second Semester of 2-Semester Final Year Project

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Project Work Continue	■	■	■					Mid-Semester Break							
2	Submission of Progress Report 1				●											
3	Project Work Continue				■	■	■	■								
4	Submission of Progress Report 2									●						
5	Seminar (compulsory)										■	■	■			
5	Project work continue									■	■	■	■			
6	Poster Exhibition											●				
7	Submission of Dissertation (soft bound)													●		
8	Oral Presentation														●	
9	Submission of Project Dissertation (Hard Bound)															●

● Suggested milestone

■ Process

APPENDIX C

FOUNDATION FIELDBUS INTEROPERABILITY TESTING WORK INSTRUCTION: BASIC TEST (EMERSON) BY PETRONAS GROUP TECHNOLOGY SOLUTIONS

1. Initial Download

Switching Host

1. Power up host system at Cabinet 1.
2. Power up switch for MTL and P+F at Cabinet 2.
3. At the selector switch (front panel of Cabinet 2), select Emerson for Segment 1 and Segment 2.
4. Login to windows using the following username and password:

   Username: Administrator

   Password: deltav
5. FlexLock will appear. Click DeltaV Operate to open the operator viewing station.

   Username: Admin

   Password: deltav

Using Host System

6. Open DeltaV Explorer 

.
7. Expand "Physical Network" (Add figure).
8. Expand "Control Network".
9. Expand "CTRL1".
10. Expand "I/O".
11. Expand "CO2".
12. Right click at "P01" (Note: Port 1 of H1 card). Select "Download" and click "Fieldbus Port".
13. Establish the communication with fieldbus devices (initial download).
    a. A pop-up "Confirm Partial Download" will appear. Select 'Yes' to confirm.
    b. Two new pop-ups will appear. At "Select Additional Objects to Download", click "Check All" to check all objects. Click 'OK'.
14. Repeat step 12 and 13 to download Port 2 (P02).

15. Perform individual device download in the following manner if step 12 and 13 cannot be completed.
    a. Right click at selected device under "P01".
    b. Select "Download".
    c. Click "Fieldbus Device".
    d. A pop-up "Confirm Partial Download" will appear. Select 'Yes' to confirm.
    e. At "Select Additional Objects To Download", click "Check All" to check all objects. Click 'OK'.
    f. Repeat steps for other devices.
16. View through the host HMI and record response of the host for each fieldbus device.
17. At "DeltaV Operate (Run)", click "Overview" icon.
    a. Call-up faceplate of each device.
    b. Faceplate will appear. Acknowledge alarm, if any.
    c. If alarm clears, then device has been commissioned successfully.
    d. If alarm does not clear, click "Detail" icon at the faceplate and note down the error message displayed in the "Detail" window.
    e. Check faceplate for all devices.
    f. Refer to Step 15 to attempt recovery of failed devices. If not successful, note down the affected device(s).

2. Device Commissioning

** The scope covers the pre-registered devices only. These steps assume control module for the device has been created and required DD file is pre-loaded into the system.*

3. Decommissioned devices that are attached to the segment would appear under "Decommissioned Fieldbus Device". Select a device to be commissioned and make sure it is on standby mode. Placing the decommissioned device on standby mode is necessary before the device can go online.
4. To commission the device, drag the device under the "Decommissioned Fieldbus Device" and drop under the device placeholder i.e. the tag name.
5. Follow the instruction in "Device Commissioning Wizard". Click 'Yes' when asked whether to proceed with the commissioning step.

6. Perform device download (refer to step 15 in Initial Download) on the commissioned device. Make sure only the related box to the selected device is marked when the "Select Additional Object to Download" pop-up appear.
7. Check the status in "DeltaV Operate" to confirm the commissioning is successful.

3. Device Decommissioning

8. Select any device to be decommissioned.
9. Right click at the device, select "Decommission".
10. Select "Take Off-line"
11. The device will take some time before it is placed under "Decommissioned Fieldbus".
12. Check the status in "DeltaV Operate".
13. At "Decommissioned Fieldbus", select the device tag, right click and select "Place in Standby". Placing the decommissioned device on standby mode is necessary before the device can go online.
14. Scan the segment to ensure the device is fully decommissioned i.e. not in the loop.

(Note: The standby mode is only applicable for the second time commissioning i.e. after the device had been commission).

4. Online Device Replacement

1. From a fully functioning fieldbus system, remove a device cable while ensuring the parallel wiring to other devices is not broken.
2. In "DeltaV Explorer", right click at the selected device, click "Replace".
3. Follow the instruction in "Fieldbus Device Replacement Wizard".
4. New "Select Fieldbus Device" pop-up will appear. To replace the device, reconnect the cable to the segment again. Click "Refresh". Wait until the device is listed. Click OK.
5. "Device Commissioning Wizard" will appear. Complete the replacement according to the wizard. Continue with the Partial Download.
6. Uncheck all objects in the "Select Additional Object to Download" pop-up.
7. Check/ mark boxes that relates only to the commissioned device. Click 'OK'.
8. Check the faceplate in "DeltaV Operate (Run)" to ensure device is successfully replaced/ commissioned.

9. Record the response of the host and other devices in the system.

5. Physical Layer Inspection

1. Using fieldbus communicator (375 Field Communicator):
   a. Connect the cable to the Fieldbus Port (Ensure Fieldbus logo can be seen).
   b. Press 'On' button.
2. Identify terminator at the last field barrier. Connect the communicator to the terminal. Ensure the polarity is correct (red is positive, black is negative). *Note: The communicator will inform if the cable is not connected properly.*
3. On the communicator screen, select "Foundation Fieldbus Application".
4. Select Fieldbus Diagnostic. The screen will show DC Voltage, noise and signal level.
5. Select 'Start' and then select 'OK'. The screen will now show the mentioned diagnostic features. Ensure all values are within acceptable region by selecting on the parameter and select "Help".
6. Terminator:
   a. Segment 1 is now connected to two terminators.
   b. Record all the readings (DC voltage, low frequency noise, signal level of each device).
   c. Switch on another terminator. The segment is now connected to three terminators.
   d. Record all readings.
   e. Repeat the step c and d until have the maximum of 6 terminators.
7. Repeat step 6 for segment 2.
8. At the end of the test, connect the segments back to two terminators only.

Device drop out:

1. Take out one device cable connected to the segment. Record the response of the segments (device should be marked as offline and other devices should not be affected). Connect the cable and record time taken for alarm to be normalized.
2. Repeat for all devices.

6. Calibration Function Checks

Carry out calibration function from the Host, 375 communicator or iAMS.

Using Host:

1. From "Exploring DeltaV", expand "Physical Network".
   a. Expand "Control Network".
   b. Expand "CTRL1".
   c. Expand "Assigned Modules".
2. Select control module of the device that need to be rescaled.
3. Right click on the module and open using "Open Online with Control Studio".
4. Select AI Block from the main page.
5. Refer to the "Parameter" on the bottom left.
   a. Under "Operating", double click "MODE". "Mode" properties will popup. Note down the initial range.
   b. Change "Target" to "Out of Service".
   c. Refer to Index. Change the XD_SCALE and OUT_SCALE (randomly select any value).
   d. Change "Target" back to "Auto".
6. Monitor the effect on the other devices/ Host.

Using 375 Communicator:

1. Use Fieldbus Application in 375 Communicator.
2. Select Online. The communicator will upload information on all devices connected to the segment.
3. Select one device that needs to be rescaled.

   Note: the communicator will take some time to upload the device
4. Select AI block. Select "Quick Config". Change Mode to "OOS" (previous mode in "Auto"). Change XD Scale (Transducer Block) and Output Scale. Click 'Send'. Change mode back to "Auto".

   Note: This step may be performed using other than "Quick Config" option.
5. Monitor the faceplate and effect on the other devices.

   Note: Action by host and Communicator cannot be performed on the same device at the same time. At one time, only either host or the communicator may change the setting of the device.

Using iAMS

1. *(Rescale cannot be performed using Emerson AMS).*

**Index: Relationship between XD_SCALE and OUT_SCALE (Refer to "Operating Instructions Deltabar S FMD76/77/78, PMD70/75, page 62).*

7. Online Parameter Download

1. Refer to steps in Physical Layer Inspection and monitor the impact for the rest of the device in the segment.
2. Record observation.

APPENDIX D

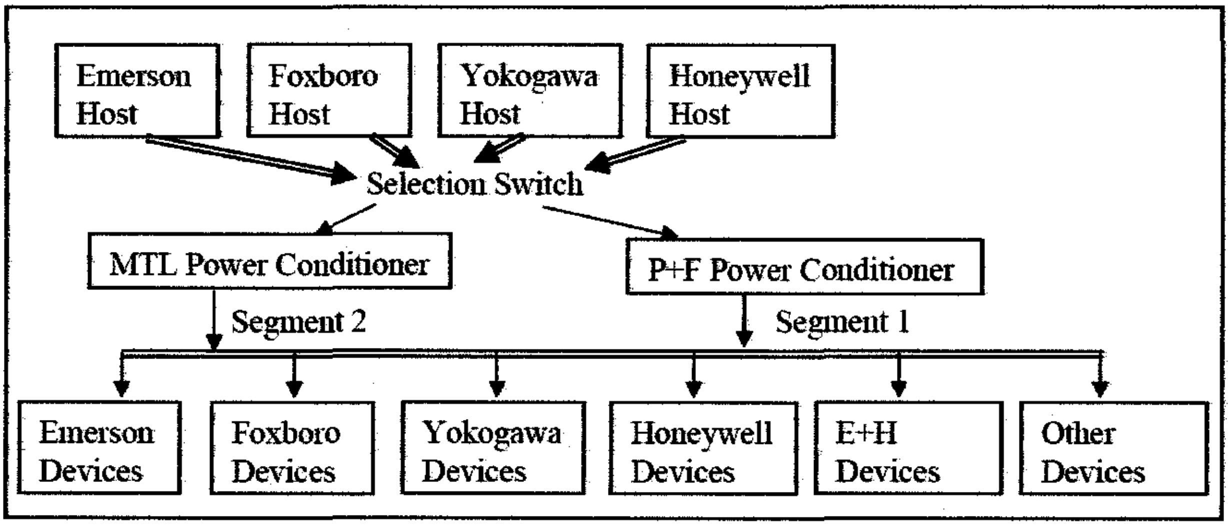
LIST OF FIELDBUS DEVICES USED IN FFIT

SEGMENT 1			
NO	DEVICE NAME	ADD	MANUFACTURER
1	TT201	22	Rosemount
2	PT202	23	Rosemount
3	TT203	24	Rosemount
4	PDT204	25	Rosemount
5	FV205	26	Fisher
6	FT206	27	Micro Motion
7	AT207	28	Rosemount
8	AT208	29	Rosemount
9	PDT501	30	Yokogawa
10	PT502	31	Yokogawa
11	TT503	32	Yokogawa
12	FT504	33	Yokogawa
13	TT901	34	Pepperl & Fuchs
14	VC902	35	Pepperl & Fuchs

SEGMENT 2			
NO	DEVICE NAME	ADD	MANUFACTURER
1	LT301	22	Endress & Hauser
2	LT302	23	Endress & Hauser
3	PT303	24	Endress & Hauser
4	PDT304	25	Endress & Hauser
5	AT305	26	Endress & Hauser
6	FT306	27	Endress & Hauser
7	FT307	28	Endress & Hauser
8	TT308	29	Endress & Hauser
9	TT401	30	Honeywell
10	PT402	31	Honeywell
11	PDT403	32	Honeywell
12	FT101	33	Honeywell
13	FV102	34	Foxboro
14	MTLADM1	35	Foxboro

APPENDIX E

SIMPLIFIED BLOCK DIAGRAM FOR THE FF SYSTEM



APPENDIX F

GRAPHICAL VIEW OF BASIC TEST RESULT AT EMERSON DELTA V

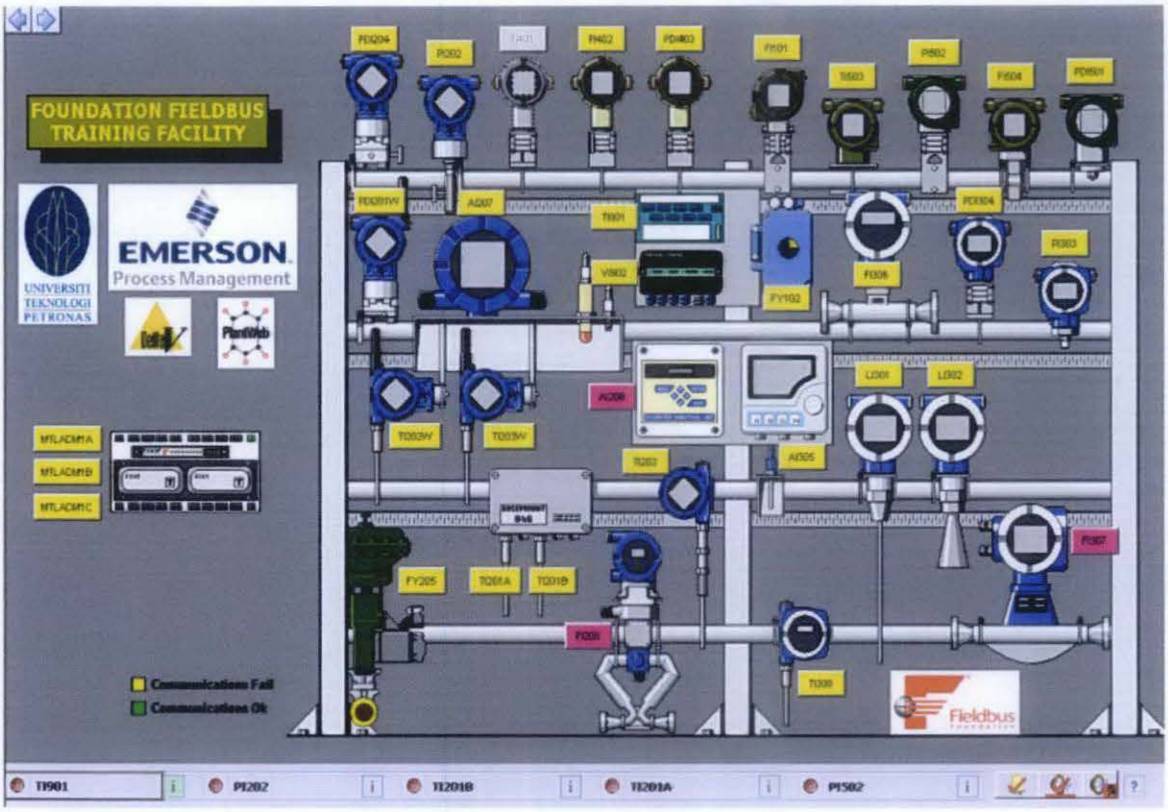


Figure F.1: The status of field devices before commissioning

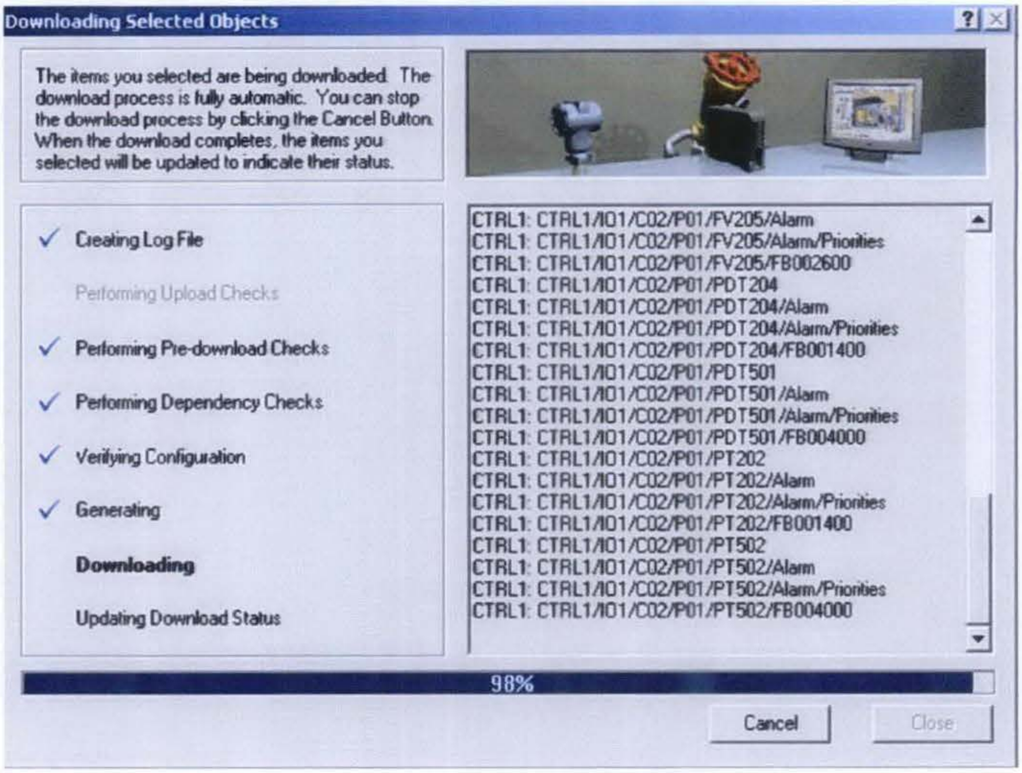


Figure F.2: Performing download for all devices in Port 1

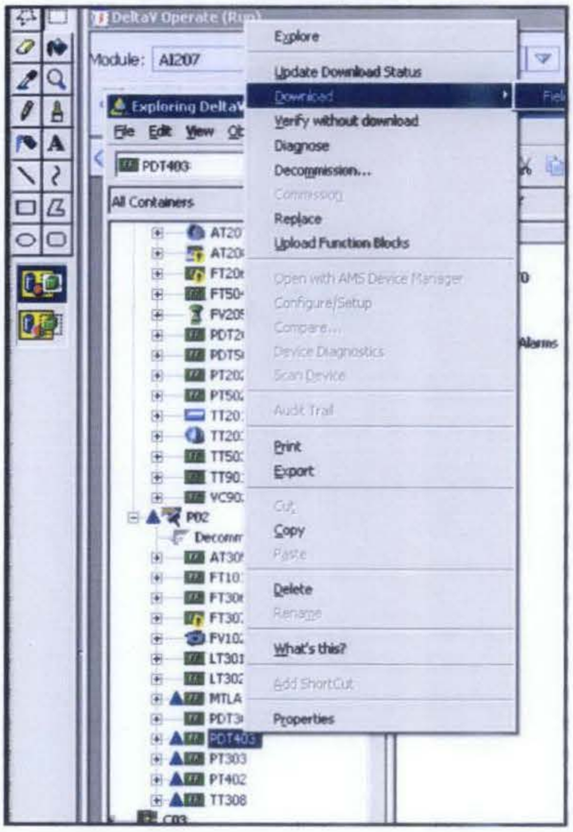


Figure F.3: Perform individual download for PDT 403

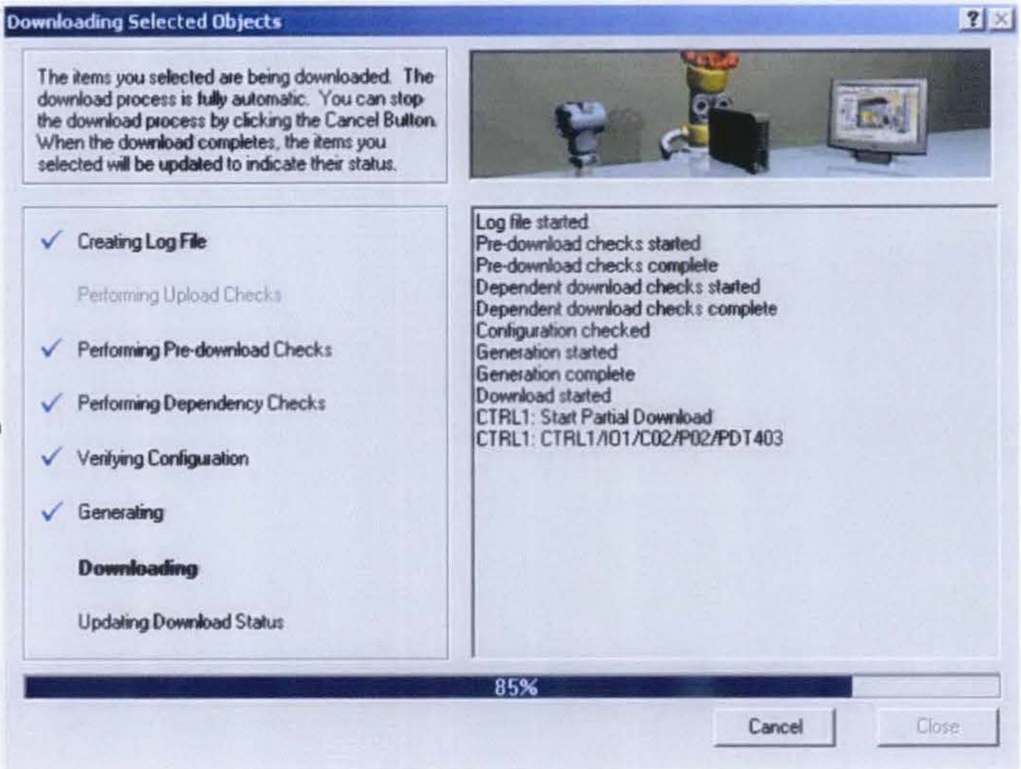


Figure F.4: Download for PDT 403 is 85% completed

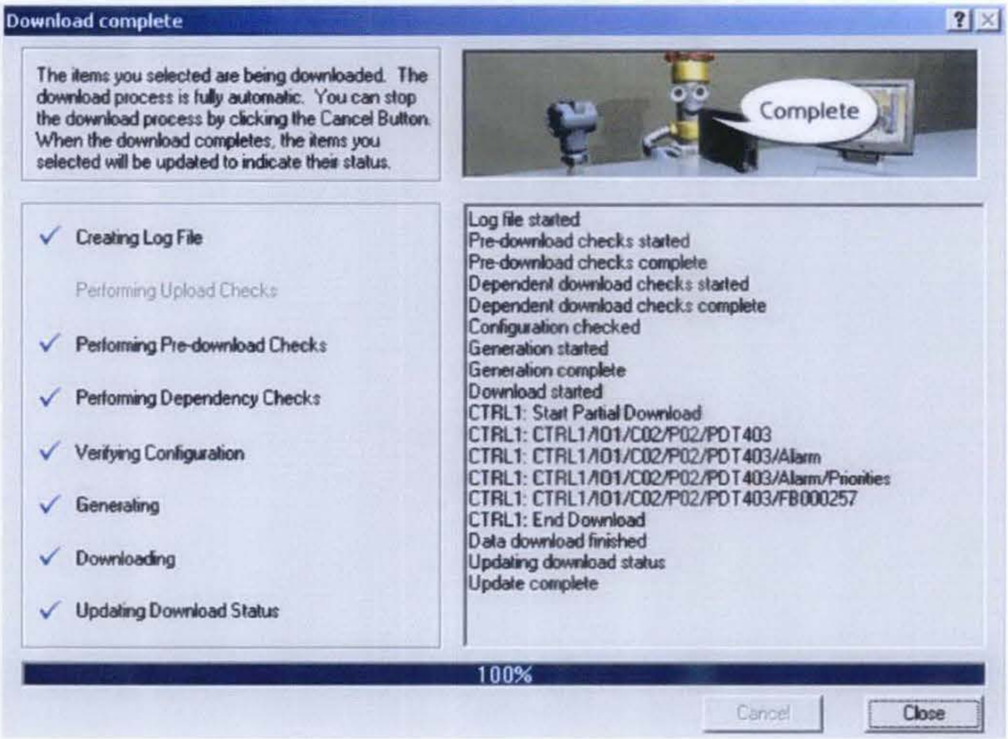


Figure F.5: Download for PDT 403 is 100% completed

Figure F.6: Alarms that appear when performing download for field devices

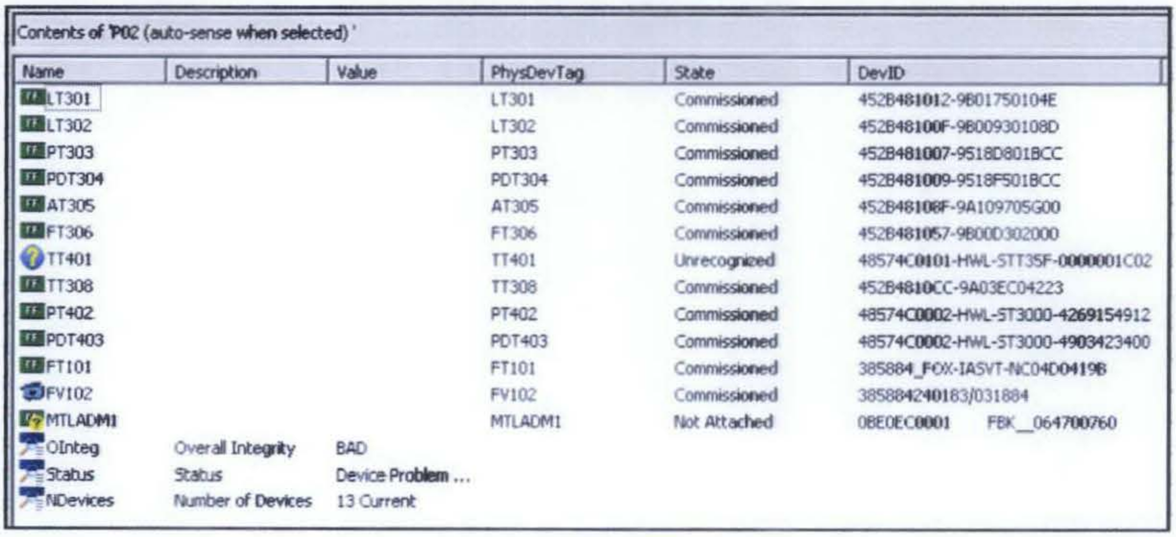


Figure F.7: Result for device commissioning

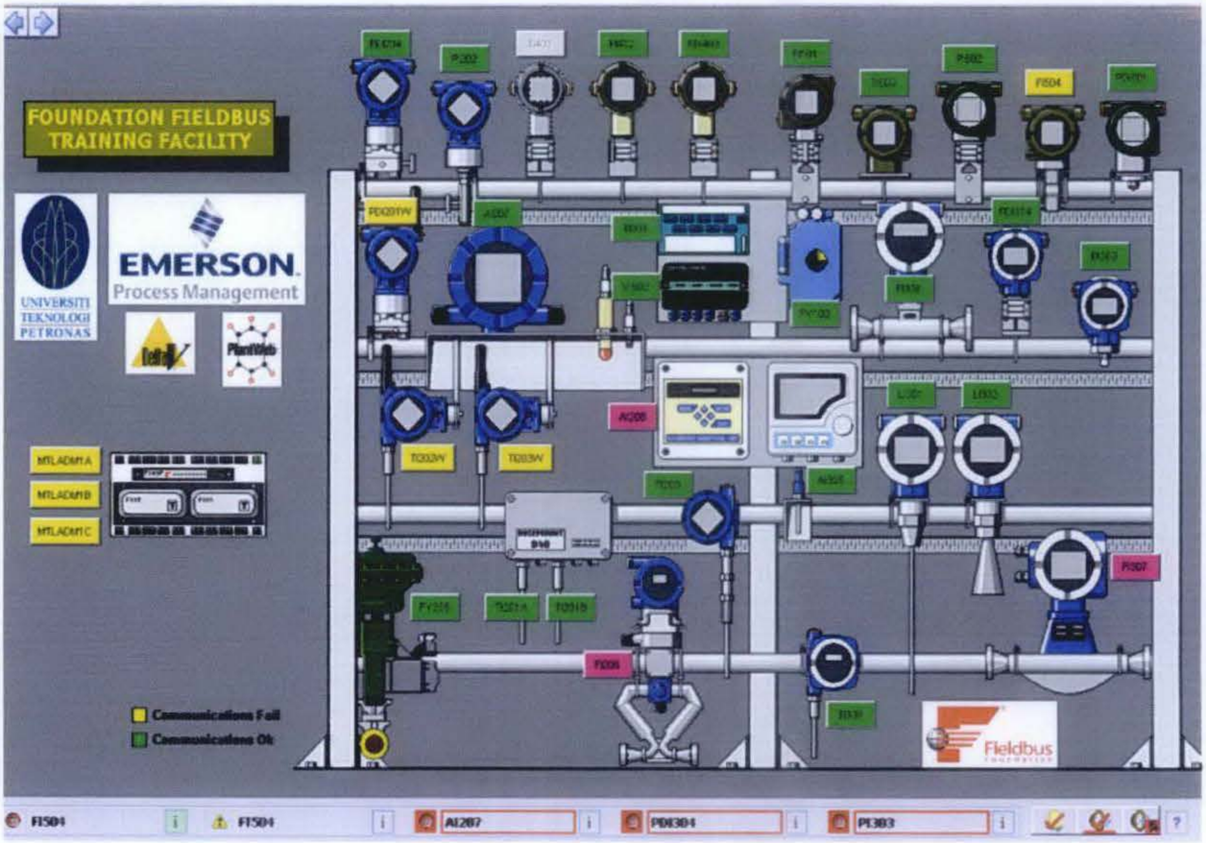


Figure F.8: Status of field devices while performing online device replacement

Figure F.9: Fieldbus Device Replacement Wizard assists in performing Online Device Replacement

Name	Description	Value	PhysDevTag	State
TT201			TT201	Commissioned
PT202			PT202	Commissioned
TT203			TT203	Commissioned
PDT204			PDT204	Commissioned
FV205			FV205	Commissioned
AT207			AT207	Commissioned
PDT501			PDT501	Commissioned
PT502			PT502	Commissioned
TT503			TT503	Commissioned
FT504			FT504	Commissioned
TT901			TT901	Commissioned
VC902			VC902	Commissioned
OInteg	Overall Integrity	BAD		
Status	Status	1 or more function block problems on...		
NDevices	Number of Devices	12 Current		

Figure F.10: Result for online device replacement