

**DESIGN, CONFIGURATION AND IMPLEMENTATION OF FIELDBUS
SYSTEM FOR CONTROLLING OF A PROCESS PLANT**

By

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2754

DISSERTATION REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
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CERTIFICATION OF APPROVAL

DESIGN, CONFIGURATION AND IMPLEMENTATION OF FIELDBUS SYSTEM FOR CONTROLLING OF A PROCESS PLANT

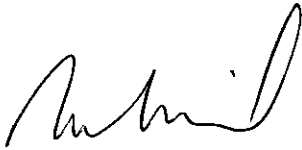
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A project dissertation submitted to the
Electrical & Electronics Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfillment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

Approved:



Dr. Nordin bin Saad,
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December 2005

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 acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ABSTRACT

The first process control systems used mechanical and pneumatic controllers, and were run conservatively for stability rather than economic performance. In the 1950s, the first electronic controllers were introduced that used analog signals with simple devices, and later in the 1970s distributed control system (DCS) emerged, which is the current standard for large control system. In DCS however, a central processor controls all parameters and has limitation in terms of reliability and cost. This led to the introduction of fieldbus system: the digital communication and fieldbus system replaces the DCS architecture by enabling distribution of control function to equipment in the field such as sensors, controllers and actuators. This report discusses the findings on the literature review of fieldbus system and the fundamental issues in the development and implementation of a fieldbus system for controlling a simple process loop using a fieldbus test rig. A configuration and implementation procedure for the development of a fieldbus test rig is presented involving process variables that are pressure, temperature and flow. A complete control system functions implemented are the monitoring, measurement and control. The methodology towards accomplishing the project includes the theoretical and technical research, the installation and commissioning, the configuration of network, device and control strategy, the troubleshooting, operation and maintenance, and the analysis on the fieldbus savings and its benefits. Detailed design, configuration and implementation for a temperature control are presented. The findings demonstrate the benefits of the fieldbus system over the DCS in terms of signal conditioning, loop interconnection and configurations and verify the qualitative characteristics of the fieldbus system in terms of simpler and better controllability.

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LIST OF ABBREVIATIONS

AI	Analog Input
AO	Analog Output
DCS	Distributed Control System
DDC	Direct Digital Control
FYP	Final Year Project
HMI	Human Machine Interface
I.S.	Intrinsic Safe
I/O	Input/Output
LAN	Local Area Network
OLE	Object Linking and Embedding
OPC	OLE for Process Control
P&I	Piping and Instrumentation
PID	Proportional, Integral and Derivative
PLC	Programmable Logic Controller
RTD	Resistive Temperature Detector
SCADA	Supervisory Control And Data Acquisition

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

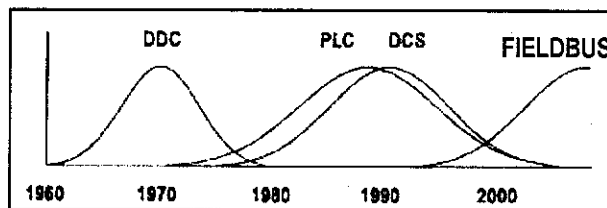


Figure 1 Evolution of Control System Architecture

During the pneumatic era, the controller was located in the field and operated locally. The plants were run conservatively for stability rather than economic performance. With the analog current loop, it becomes easier to bring a signal from transmitter in the field to central controller in the control room and then back to the field again. The concept was applied in Direct Digital Control (DDC-1962) where the complete control functions was directed and executed a computer. Because all the functions were concentrated into a computer the entire system would fail if there were even a single fault.

Clearly, the centralized architecture had some serious availability issues, which led to the introduction of Programmable Logic Controller (PLC-1972) and Distributed Control Systems (DCS-1976) architecture. PLC and DCS emerged with the digital communication technology, but these architectures were also designed based on 4-20mA for field transmitter and valve positioner. As a today's standard, DCS is a great improvement over the DDC in that the controls were distributed over several smaller controllers that shared the task [1].

Figure 1 illustrates the evolution timeline of control system architecture from the DDC to the fieldbus system. Every improvement in control system architecture has

led to an increased level of system decentralization and better access to field information. In other words, a higher level of distribution increased the availability of the system. The fieldbus system is a new architecture which has the built-in capability to perform complete control application that is distributed into the field devices rather than a centralized controller.

1.2 PROBLEM STATEMENT

When introduced, the DCS was considered as “distributed” because it is less centralized than the DDC architecture. This had the immediate benefit where single fault would only affect a part of the plant, not all of it as with the DDC. However this architecture is relatively vulnerable because just one failure may have widespread consequences. As shown in Figure 2, a DCS normally have four different tiers of networking, each with different technology; device, I/O subsystem, controllers, and plant wide integration to business applications. All these level of hardware, software and networking results in a complex and costly control system.

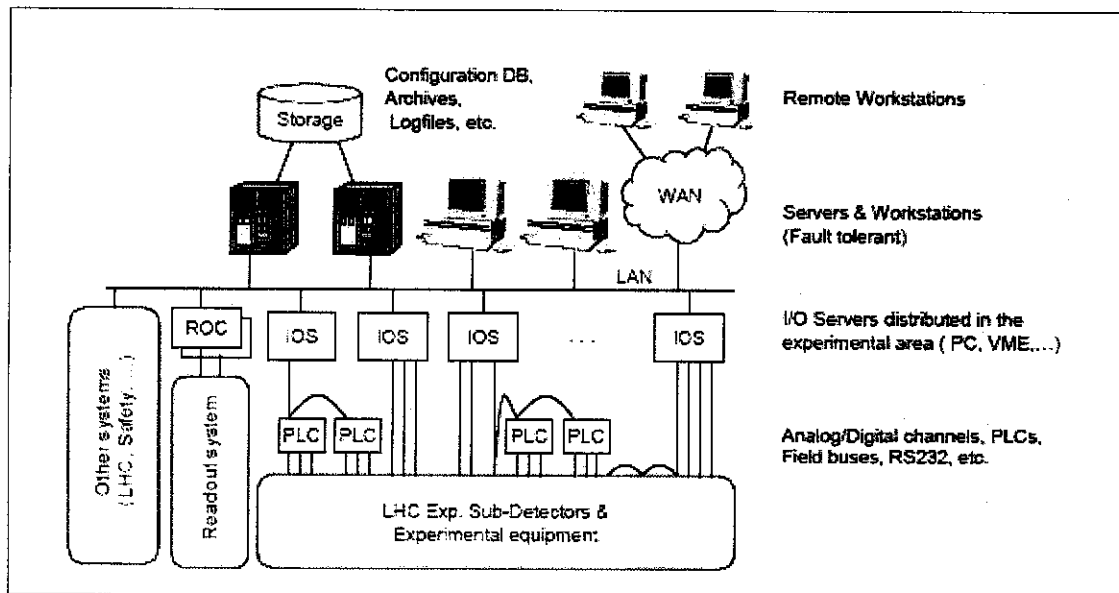


Figure 2 Traditional DCS System with Multilevel Tiers

Because of this vulnerability, redundancy of controllers, I/O subsystem networking, I/O modules, and the like is a must to avoid a total loss of control. Of course, redundancy at every level means complexity and higher price. Due to rising production and processing costs, stiff competitions, and the globalization of market economies, increasing attention has been placed on fieldbus system as platform to

provide efficient and flexible plant. The need to design, configure and implement a fieldbus system on the fieldbus test rig is important to allow a study on the benefits and limitations of the system itself.

1.3 OBJECTIVE AND SCOPE OF STUDY

Motivated by several setbacks of the DCS system, this project aims to find answers on the flexibility and efficiency of the fieldbus system. Importantly, it is a new technology in the area of process and industrial instrumentation where different aspects of the fieldbus problems still need to be addressed. Particularly in this project, a typical process control loop with several control variables such as pressure, temperature and flow are selected to be controlled by a fieldbus network. This work would provide a concise familiarization to the fieldbus system that would be used for improving the issues related to a fieldbus system.

The following outlines the objectives as well as the scope of study of the design, configuration and implementation of fieldbus system:

- Detail familiarization on the fieldbus system architecture.
- Analyzing the deficiency of current control system such as PLC, SCADA and DCS and to be compared with the fieldbus system.
- Designing a simple control loop using several measurement devices such as temperature, flow and pressure.
- Establishing a fieldbus network by device installation and commissioning.
- Configuring a fieldbus network, device setting and control strategy programming.
- Troubleshooting the fieldbus connection should there is any failure.
- Implementing and operating the fieldbus control loop as to ensure the fieldbus test rig is working as expected.
- Ability to make excellent reports and deliverable presentation to conclude the entire project.

CHAPTER 2

LITERATURE REVIEW/THEORY

2.1 WHAT IS FIELDBUS?

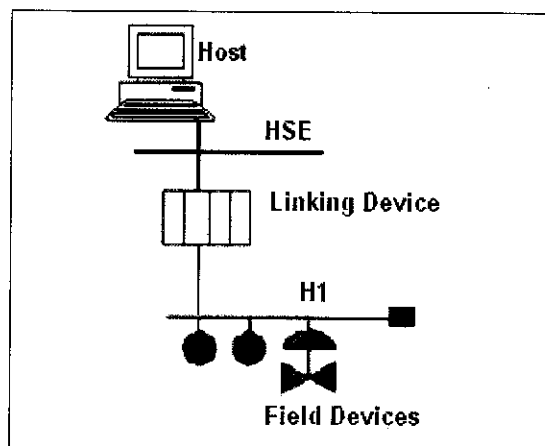


Figure 3 Fieldbus Network

Fieldbus is an all-digital, multi-drop, two-way communication system. As shown in Figure 3, H1 network with speed of 31.25kbit/s interconnects field equipment such as smart sensors, actuators, controllers and I/O. High Speed Ethernet (HSE) with 100Mbit/s provides integration of the H1 subsystem with data servers and workstations via a linking device [7].

The fieldbus devices definition is intended for remote I/O devices having many functions blocks from which data shall be communicated. The function of a fieldbus device is determined by the arrangement and interconnection of several function blocks. As shown in Figure 4, communication over a fieldbus requires fieldbus communication interface in all fieldbus devices.

In other words, fieldbus is a communication protocol with a built-in capability to perform complete control application that is distributed into the field devices rather than a centralized controller [4]. The concept of distributed controller can be viewed

by a large control task is broken up into smaller components and distributed among the field devices. Therefore, the field device handles only one loop at a time. Because of this concept, the problem of a single fault affecting a large part of the plant is eliminated. Also, the number of central controllers is drastically reduced or eliminated altogether.

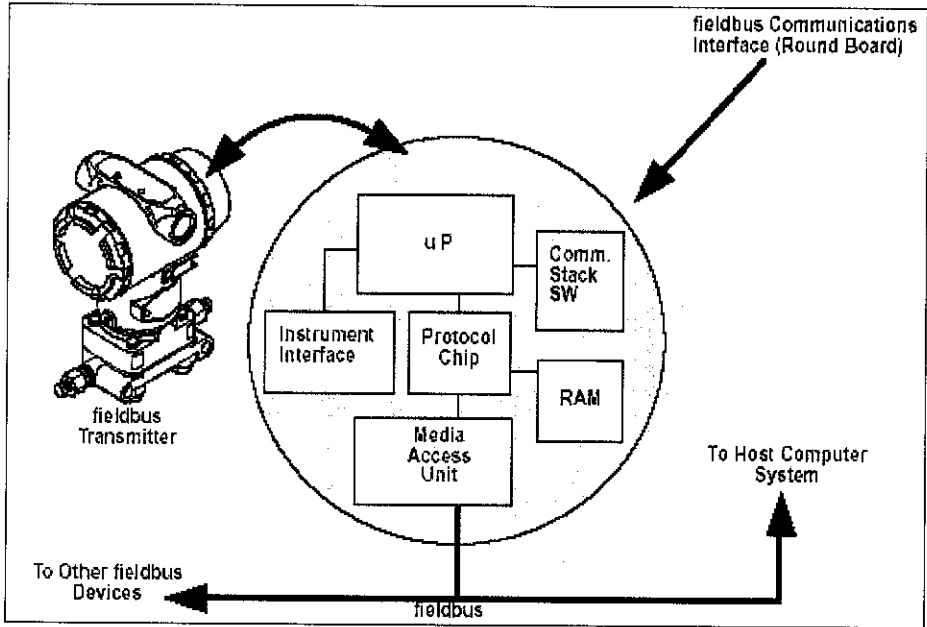


Figure 4 Communication Over a Fieldbus

2.2 A FIELDBUS SYSTEM

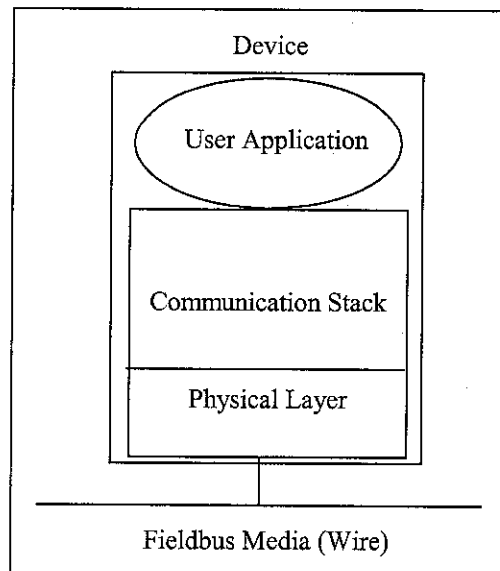


Figure 5 Fieldbus Model

Fieldbus uses the Open Systems Interconnection (OSI) model as a basis and uses three layers [7]. The layers are the physical layer, the communication stack and the user application layer. The layers are illustrated as in Figure 5.

2.2.1 The Physical Layer

The physical layer comprises a 31.25kbps data communications network often referred to as the H1 layer. Digital data is sent on the fieldbus at a rate of 31.25kbits per second. The physical layer receives messages from the communication stack and converts the messages into physical signals on the fieldbus transmission medium and vice-versa.

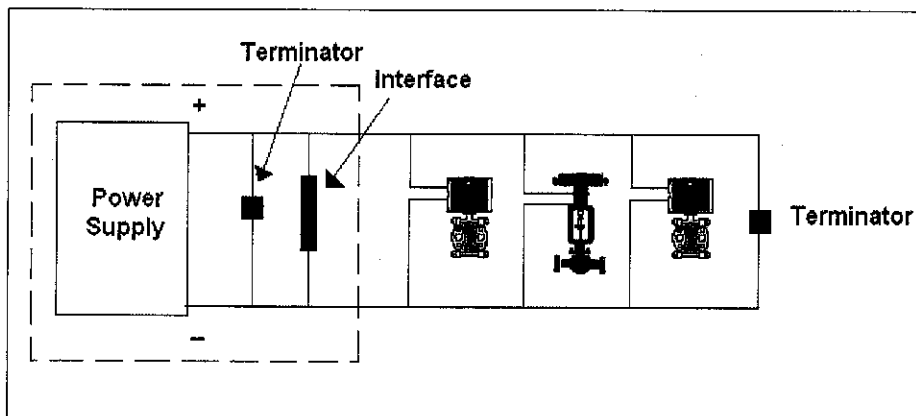


Figure 6 Fieldbus Network Components

As illustrated in Figure 6, both communications signals and the current for each device are conveyed down this pair of wires. A terminator is placed at each end of the pair of wires to eliminate any reflections. The power supply has a conditioner to ensure that the data signals on the main segment do not get drained into the low impedance power supply. The maximum length of the segment is 1900m. In addition, there are spurs that connect off the main segment. These lengths are defined within the Foundation Fieldbus standard.

2.2.2 The User Application Layer

The Fieldbus Foundation has defined a standard User Application Layer based on blocks which is distributed among the devices in the network. The block's parameter must first be configured to achieve the desired functional control network.

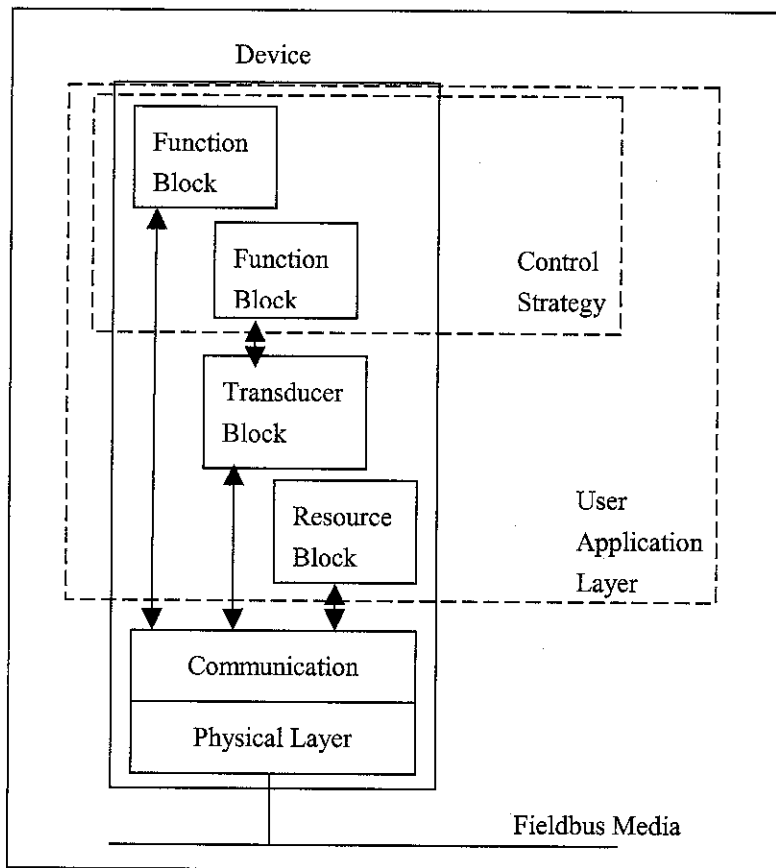


Figure 7 User Application Blocks

2.2.2.1 Transducer Block

Transducer blocks are responsible for interfacing the sensor, actuator, and display hardware to the function block. This is where the calibration is done. They contain information such as calibration date and sensor type.

2.2.2.2 Function Block [6]

By linking several function blocks, various control strategy can be constructed for the fieldbus network. Function block are responsible for executing input, output, control and calculation function. A device is allowing the selection of up to 20 function blocks per device. Details on each function block are attached in Appendix A.

Table 1 Function Blocks and Execution Time

Type	Description	Block Time (ms)
AALM	Analog Alarm	23
AI	Analog Input	22
AO	Analog Output	18
APID	Advanced PID	64
ARTH	Arithmetic	47
CHAR	Characterization	23
CT	Constant Block	9
DENS	Density Block	64
DIAG	Diagnostic Transducer Block	43
INTG	Integrator	26
ISEL	Input Signal Selector	13
LLAG	Lead Lag	22
MAI	Multiple Analog Input	6
MAO	Multiple Analog Output	10
MDI	Multiple Discrete Input	6
MDO	Multiple Discrete Output	10
OSDL	Output Signal Selector and Dynamic Limiter	23
PID	PID Control	43
RES	Resource Block	3
SPG	Set point Generator	20
SPLT	Splitter	21
TIME	Timer	13

The control strategies are configured by selecting, linking and parameterize the function blocks. Function block programming language is an integral part of fieldbus system. It is ideal for control and monitoring the process system. Basically, there are four subclasses of function blocks with different characteristics:

- Input Class
- Control Class
- Calculate Class
- Output Class

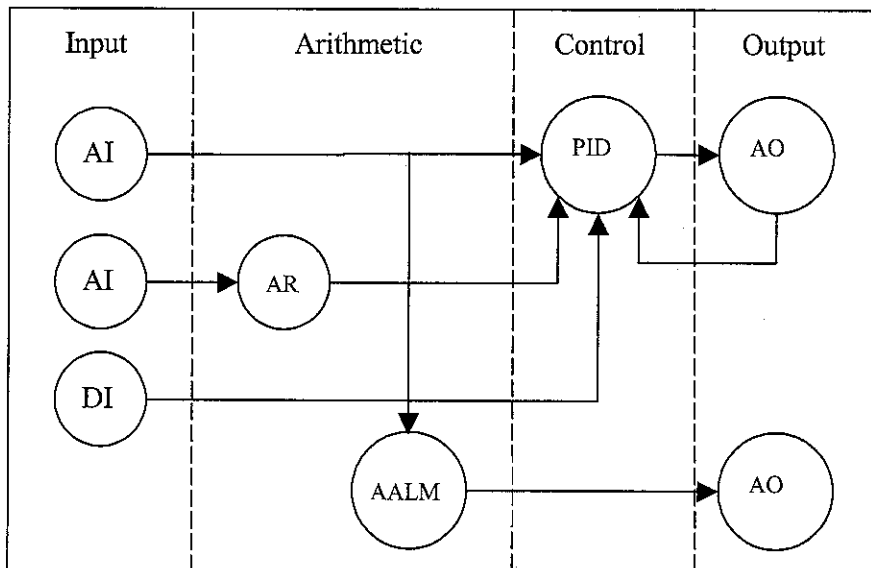


Figure 8 Function Block Classes

The input class blocks connect to sensor hardware via an input transducer block over a hardware channel. Control class blocks perform closed-loop control and have back-calculation functionality to provide bumpless mode transfer and reset windup protection. The output class blocks connect to actuator hardware via output transducer blocks over a hardware channel and support back-calculation mechanism. Calculate class blocks perform auxiliary functions required for control or monitoring.

The input and output parameters of each of the function blocks are linked over the fieldbus. Links between function blocks in different devices are communicated over the network. Links within the device do not have to be communicated on the bus.

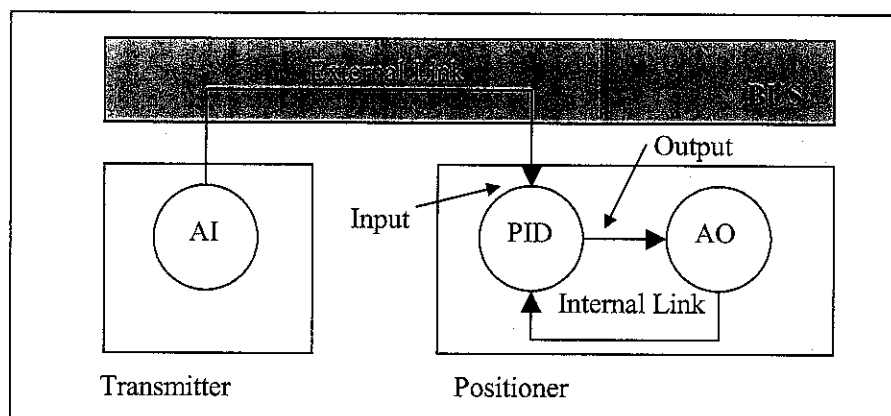
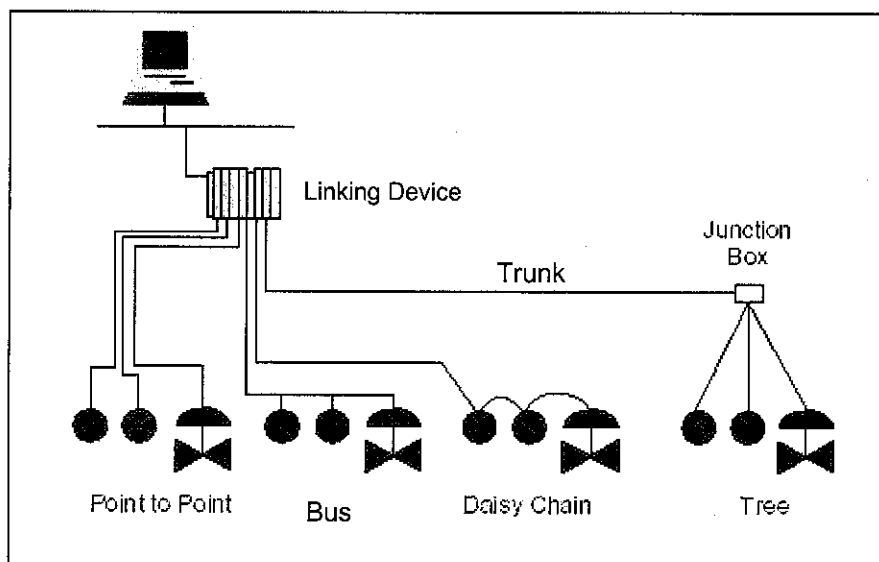


Figure 9 Function Blocks Links

2.3 TYPICAL FIELDBUS TOPOLOGY



2.3.1 Point-to-Point Topology

This topology consists of a segment having only two devices. The segment could be entirely in the field: a transmitter and a valve operating independently, with no connection between each other. Alternatively, it could be a field device connected to a host system. This configuration is often used for the fact that it has only one control device or one measurement per segment. As a result, it does not take advantage of the multi device per segment capability of the fieldbus network.

2.3.2 Bus Topology

For bus topology, the main “trunk” runs from the marshalling panel in the control room out into the field until it reaches the last devices. From the main trunk, shorter wires called “spurs” connect the individual devices. The advantage of bus topology is that it minimizes the amount of cable that is required to connect the devices. However, because several junction boxes are required for the spurs, there will be many connections.

2.3.3 Daisy-Chain Topology

In this topology, the fieldbus cable is routed from device to device on a segment, interconnected at the terminals of each fieldbus device. Installations using this configuration should use connectors or wiring practices such that disconnection of a single device is possible without disrupting the continuity of the whole segment.

2.3.4 Tree Topology

The fieldbus devices on a single segment are connected via individual twisted wire pairs to a common junction box, terminal, marshalling panel or I/O card. It is practical if devices on the same segment are well separated, but in general area of the same junction box. When deal with this topology, the maximum spur length must be taken into consideration.

CHAPTER 3
METHODOLOGY/PROJECT WORK

3.1 PROJECT WORK

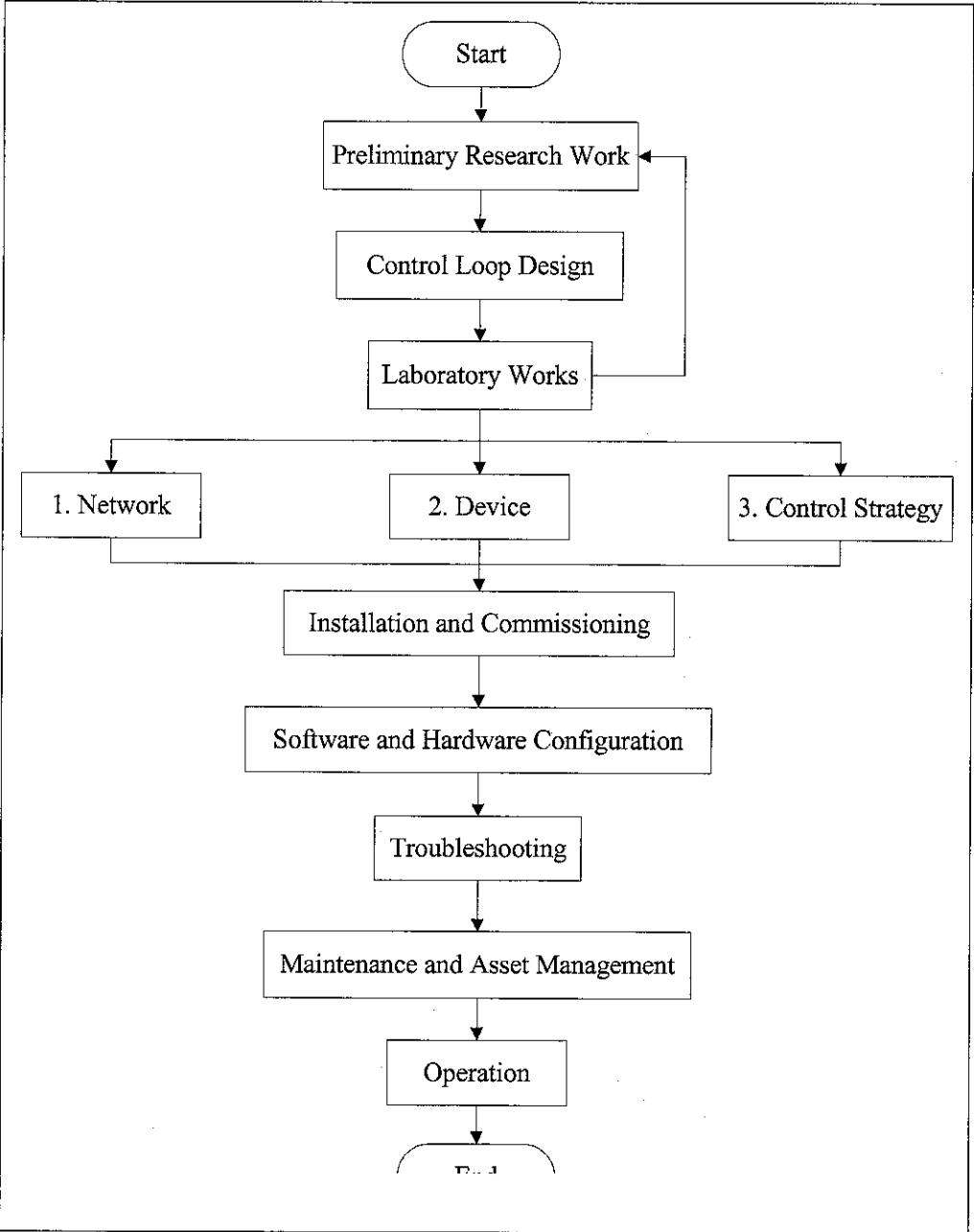


Figure 11 Project Methodology

3.1.1 Research and Information Gathering

This project aims to build a fieldbus network test rig which requires extensive research and literature review to be conducted. Details on the research are discussed Chapter 2. Research scopes include;

- Fieldbus history and evolution of control system architecture,
- Fieldbus definition, functionality and working principle,
- Fieldbus technology, and
- Installation, commissioning and configuration of fieldbus system.

3.1.2 Control Loop Design

The control loop has been designed based on the typical loop in a process plant. Several control strategy are produced particularly involving various field instruments such as transmitter and valve.

3.1.3 Installation, Commissioning and Configuration

After the system design has completed and the instruments have been selected, the device is installed and commissioned as referred to the system manual. Prior to installing any devices, it is crucial to make sure the manual is read carefully to avoid any fault occur in the device wiring and configuration. The device configuration is performed by linking the Function Block inputs and outputs together in each device. The use of Function Blocks attempts to move the control strategy right down to the field level.

3.1.4 Troubleshooting, Maintenance and Operation

Several tests and calibration have been conducted to ensure the connectivity of the fieldbus system. An open loop operation was done after all the above stages have been completed. The Human-Machine Interface (HMI) or the Operator Interface becomes a window into the process displaying data and being used to transfer control information to the instruments and actuators. The operation is remotely monitored, controlled and maintained in real time application. Finally, the system is analyzed over its functionality and availability compared to the DCS.

3.2 TOOLS REQUIRED

The equipments needed are available in the Process/Instrumentation Laboratory of Electrical and Electronics Department, UTP. The field devices and basic components are utilizing SMAR Foundation Series 302. The functional specifications of each device are summarized in Appendix C. Generally, the hardware and software required to implement a fieldbus system in a segment are;

- Cable
- Terminators
- Power supplies
- Measurement and control devices
- Host devices
- Bridges and repeaters (Optional)
- Configuration and Operation Software

3.2.1 *Host Devices*

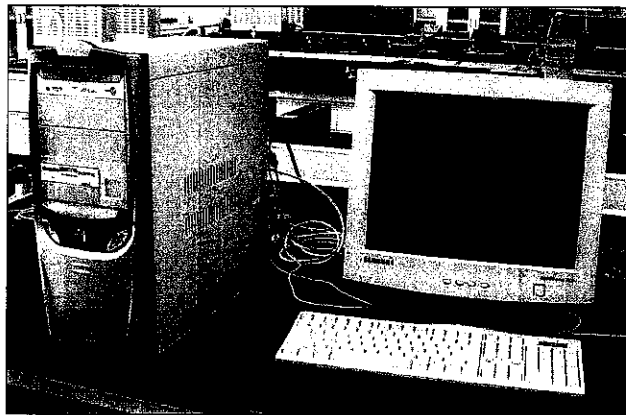


Figure 12 A Host Computer

A host is usually a computer with special integrated software that is located in the control room. Its function is to manage, monitor, control, maintain and operate the operation of the control system made up of devices connected by the fieldbus network.

3.2.2 *Cable*

Fieldbus uses shielded, twisted-pair wires rather than a pair of parallel wires, to reduce interference from external noise.

3.2.3 Hub

The switching hub connects networks. It has the intelligence to examine the Ethernet destination address for the message and only transmit the message on that one corresponding port. They automatically establish what addresses are on which port. The switching hub supports multiple simultaneous operations that connect several networks together. As a result, communication between other ports can occur concurrently without each interfering with the other.

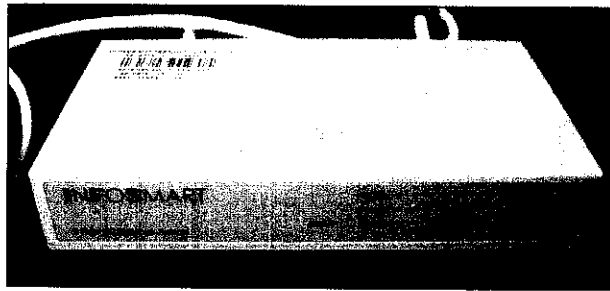


Figure 13 8 Ports 10/100Mbps Switching Hub

3.2.4 Fieldbus Universal Bridge (DFI-302)

The DFI-302 is a single integrated unit with functions of interfacing, linking device, bridge, controller, power supply and distributed I/O system [5]. Concisely, DFI-302 is a multifunction hardware component necessary to manage and control the fieldbus test rig. The modules that available in the DFI-302 include:

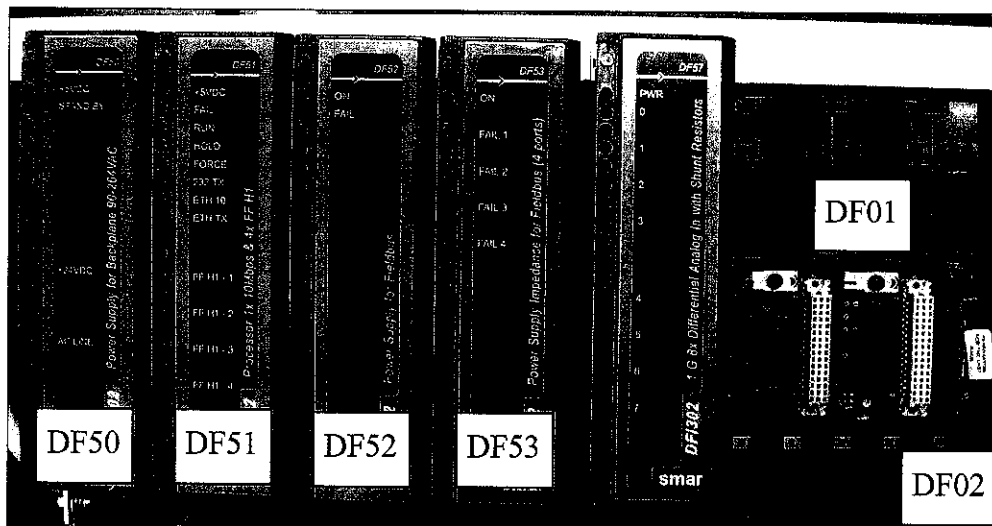


Figure 14 Fieldbus Universal Bridge

Table 2 DFI-302 Hardware Components

Series	Description	Specification
DF01	Rack with 4 slots	Backplane
DF02	Terminator	End terminator for the last rack
DF50	Power supply for backplane	Input: 90-264 VAC, Output: 5VDC (backplane power supply) and 24VDC (external use)
DF51	DFI-302 processor module	1 x 10Mbps Ethernet and 4 x fieldbus H1 channels at 31.25Kbps.
DF52	Power supply for fieldbus	Input: 90-264VAC, Output: 24Vdc
DF53	Power supply impedance for fieldbus (4 ports)	To ensure no short-circuit between the power supply and the communication signal on the fieldbus.

3.2.5 Fieldbus Measurement and Control Device

Below is the list of equipment, measurement and control devices used in the fieldbus test rig. The technical specifications for each device are attached in Appendix B.

3.2.5.1 Fieldbus to Current Converter (FI-302)

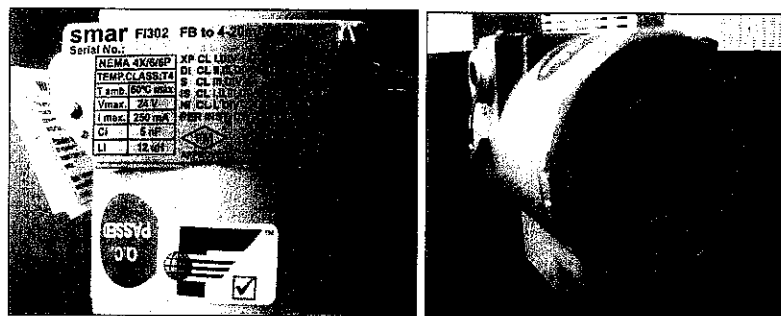


Figure 15 Fieldbus to 4-20mA Converter

It is a converter for interfacing of a fieldbus system to control valve or other actuators. The FI-302 produces a 4-20mA output proportional to input received over the fieldbus network. It has three outputs which reduces the cost per channel.

3.2.5.2 *Fieldbus Valve Positioner (FY-302)*

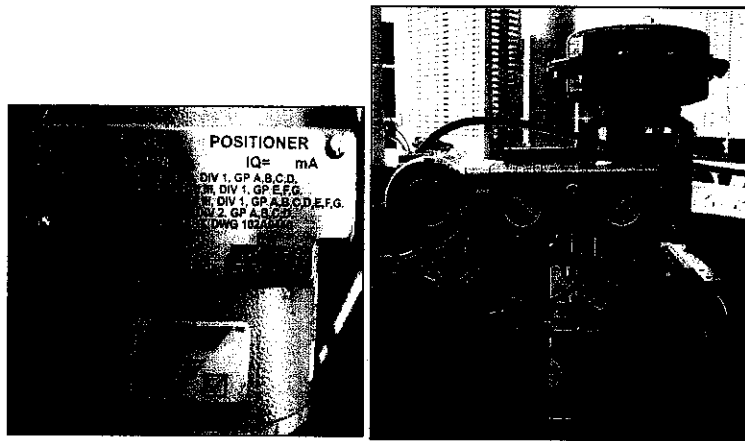


Figure 16 Control Valve and Valve Positioner

The FY-302 produces a pressure output required to position a control valve according to an input received over the fieldbus network or internal controller.

3.2.5.3 *Fieldbus Temperature Transmitter (TT-302)*

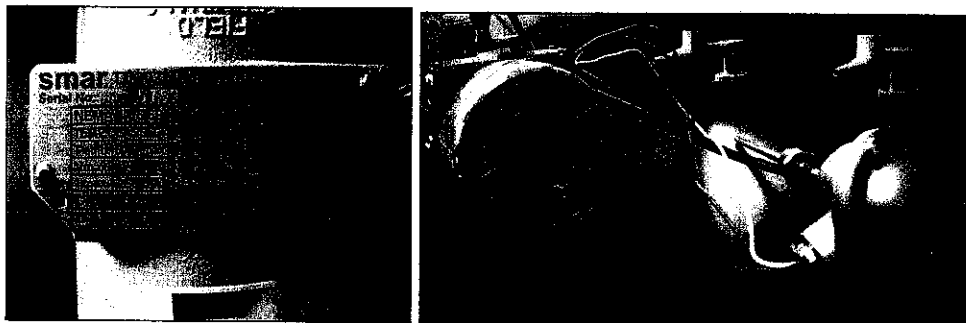


Figure 17 Temperature Transmitter with RTD

It is a transmitter intended for measurement of temperature using RTDs or thermocouples, but can also accept another sensor with resistance or voltage (mV) output.

3.2.5.4 *Fieldbus Pressure Transmitter (LD-302 Series)*

It is a transmitter for differential, absolute and gauge pressure, level and flow measurement. The LD302 series pressure transmitters use capacitive sensors (capacitive cells) as pressure sensing element that provides reliable operation and high performance. The transmitter can be implemented on liquid, gas or vapor process fluid.

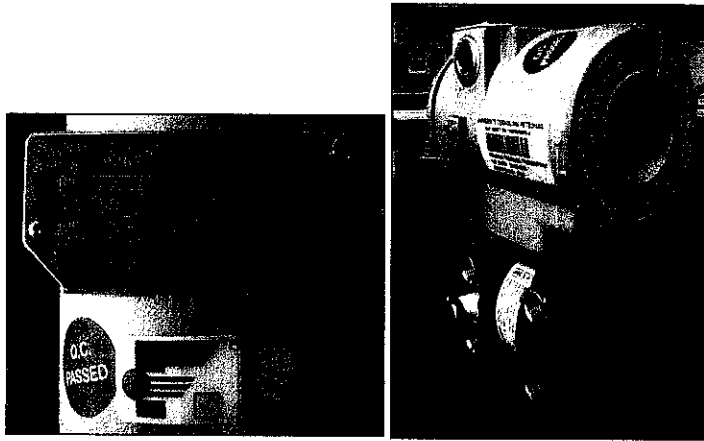


Figure 18 Gauge Pressure Transmitter

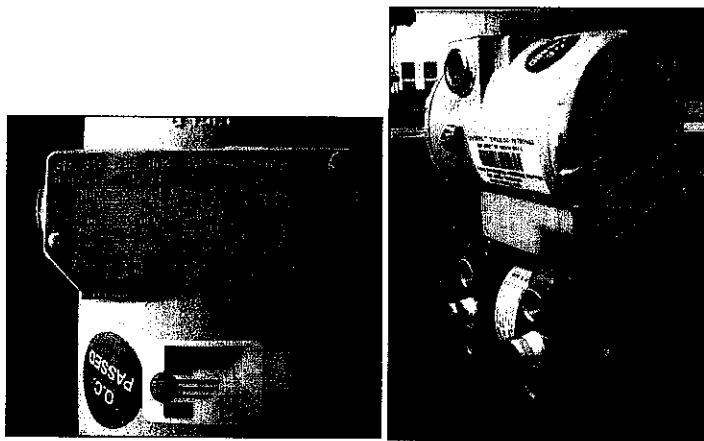


Figure 19 Differential Pressure Transmitter

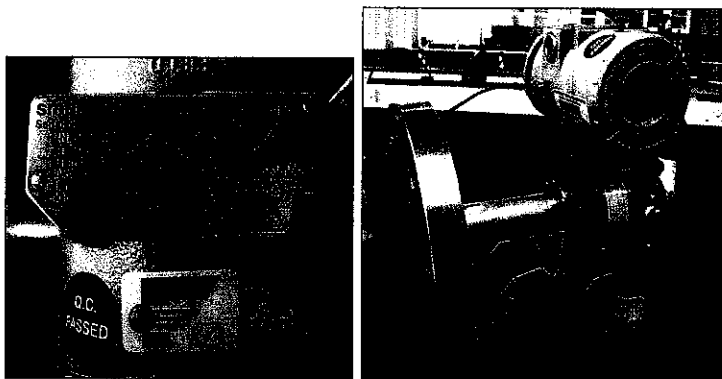


Figure 20 Absolute Pressure Transmitter

3.2.6 Terminator (BT302)



Figure 21 Fieldbus terminator

A terminator has only two terminals and is polarity insensitive. A terminator is needed at each end of the fieldbus network segment. The terminator has the following functions:

- **Signal current shunt:** A device transmits by rapidly changing the current in the network, either by changing its power consumption or injecting a current. The terminator converts the current change produced by a transmitting device into a voltage change across the entire network that is picked up by all devices as the means for receiving the signal.
- **Prevent signal reflection:** The communication signal bounces back when it reaches the end of the wire, potentially distorting itself. The terminator prevents that phenomenon.

3.2.7 System Configurator (SYSCON)



Figure 22 System Configurator (SYSCON)

The SYSCON is a software tool especially developed to configure, maintain and operate the SMAR fieldbus products line, by a Personal Computer with a fieldbus interface. With a user friendly HMI, the SYSCON provides an efficient and productive interaction with the user, without previous knowledge of the software. The SYSCON was developed to run under the Microsoft® Windows NT™ Operating System, version 4.0 or later, or Windows 2000. It has the same functionality of a "Hand Held Terminal", because of its great flexibility and its comfortable operation. This is because of the features a PC computer offers, like saving to a disk, reading from disk, printing into paper sheets, text features and graphics, which can be seen on screen or on printed-paper. The use of a fieldbus protocol provides interoperability between the system and each piece of equipment that uses this feature.

3.2.8 *ICONICS GraphWorX32*

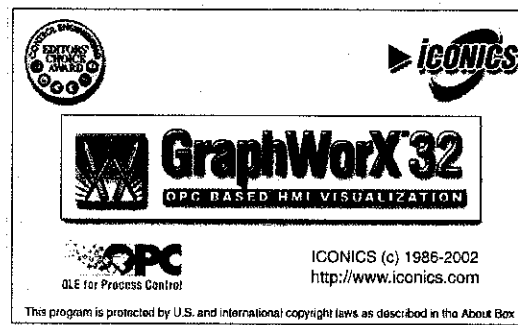


Figure 23 GraphWorX32

It is a software solution of OLE for Process Control (OPC) based Client for HMI, SCADA and control. Object Linking and Embedding (OLE) is a compound document standard developed by Microsoft Corporation. It enables objects creation with one application and then link or embeds them in a second application. Embedded objects retain their original format and links to the application that created them. OPC is a standard-based approach for connecting controllers and I/O devices with HMI client application (e.g. graphics, trending). It enhances the interface between host and devices by providing a universally supported mechanism to communicate data between device to device and between devices to host. The communication does not restricted on passing data, but also specific information on other attributes such as data type, data trend and device range.

Two ICONICS application will be used in this project; GraphWorX32 and ControlWorX32. GraphWorX32 is used to create animated graphics for control display in host computer. This is where the visualization of the process is created for the operator interface. ControlWorX32 is a control application to perform plant control [9].

CHAPTER 4

INSTALLATION AND COMMISSIONING

4.1 DEVICE AND NETWORK INSTALLATION

A fieldbus network has two wires used for both communication and power supply. The devices are connected in parallel, thus it is possible to connect or remove device while the bus is running. Each segment of the fieldbus network has to have two terminators, one in each end. In this network, the power supply, host end terminator and host interface have been integrated into a single device, DFI-302 to simplify wiring in the panel. There are two methods in supplying power to the devices; bus powered and non bus-powered. Bus-powered devices take power from the bus. The non bus-powered devices get power over separates wire.

4.1.1 Wiring of Fieldbus Universal Bridge DFI-302

DFI-302 is the linking device between the instruments and the host computer. The main modules are:

- DF51 - Processor 1x10 Mbps, 4xH1
- DF50 - Power Supply for backplane
- DF52 - Power Supply for Fieldbus
- DF53 - Power Supply Impedance for Fieldbus

Particularly, SMAR 302 system has been designed with bus-powered field devices. The devices take power from DF52 and DF53 as shown in the wiring diagram in Figure 26. The power consumptions vary from one device to other device. There are no upper or lower limits. The power consumption is indicated in each device. Normally, the voltage required by typical fieldbus devices (transmitter and valve positioner) is between 9 and 32 volts, while the current consumption is +/-10mA.

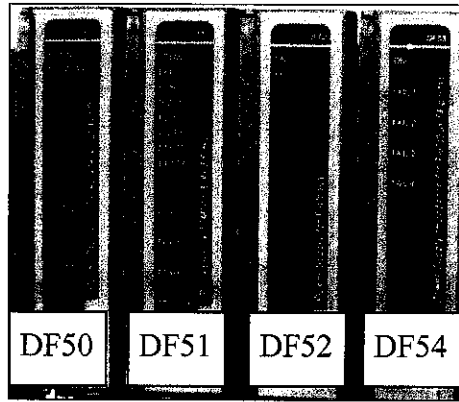


Figure 24 DFI-302 Front View (Close)

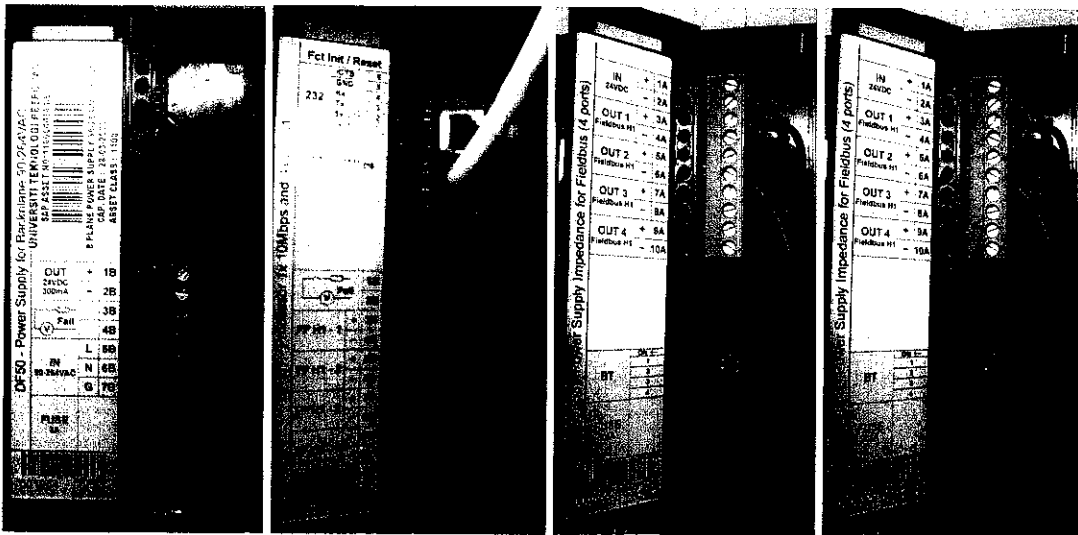


Figure 25 DFI-302 Front View (Open)

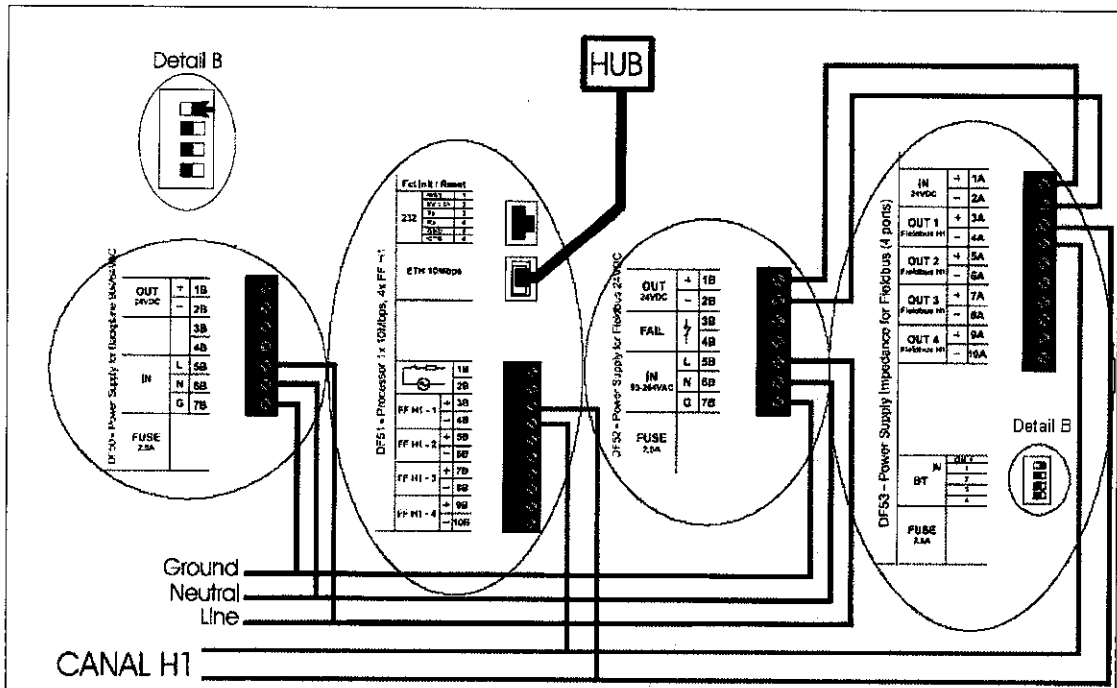


Figure 26 Wiring of DFI-302

In the Figure 26 are shown the electric connections, without the rack view (Rack DF01) and the terminator (DF02). Note in Detail B is shown the switches that enable the internal terminator for each Fieldbus H1 channel. In this design, only a Fieldbus H1 channel powered on, so the corresponding switch 1 is ON.

Shielded twisted-pair cable is used for wiring the DFI302 and hub together. As shown in Figure 27, installation is simple and very fast. LED's indicate active or failure communication. The installation steps are:

- i. The four modules (DF50, DF51, DF52, and DF53) plus the terminator (DF02) is connected in the Rack (DF01).
- ii. The AC is connected in the DF50 and DF52 input.
- iii. The DF52 output is connected to the DF53 input.
- iv. The 10BaseT - twisted pair cable is plugged, connecting DF51 to the hub as shown in Figure 27.

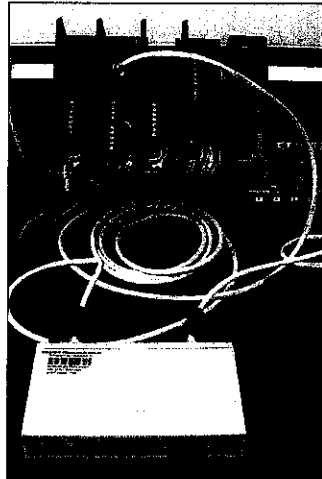


Figure 27 DF51 Connected to the Hub

- v. The Fieldbus H1 bus in the DF51 and DF53 FF H1 ports are connected.

4.1.2 Network Wiring [8]

The test rig comes with Daisy-Chain topology as shown in Figure 28. This fieldbus topology applies end-type terminator for the following reasons. When the fieldbus signal traveling down the wire reaches the end, it is faced with a change in impedance from the characteristic impedance of the wire to the infinite impedance of open air. This will cause a part of the signal power to be reflected back up through the wire. The reflected signal interferes with the oncoming "real" signal. If the reflected signal

is powerful enough, it may distort the "real" signal such that the communication does not work. The terminator has the same impedance as the cable such that when placed at the end the fieldbus signal sees no change in impedance and hence there is no reflection.

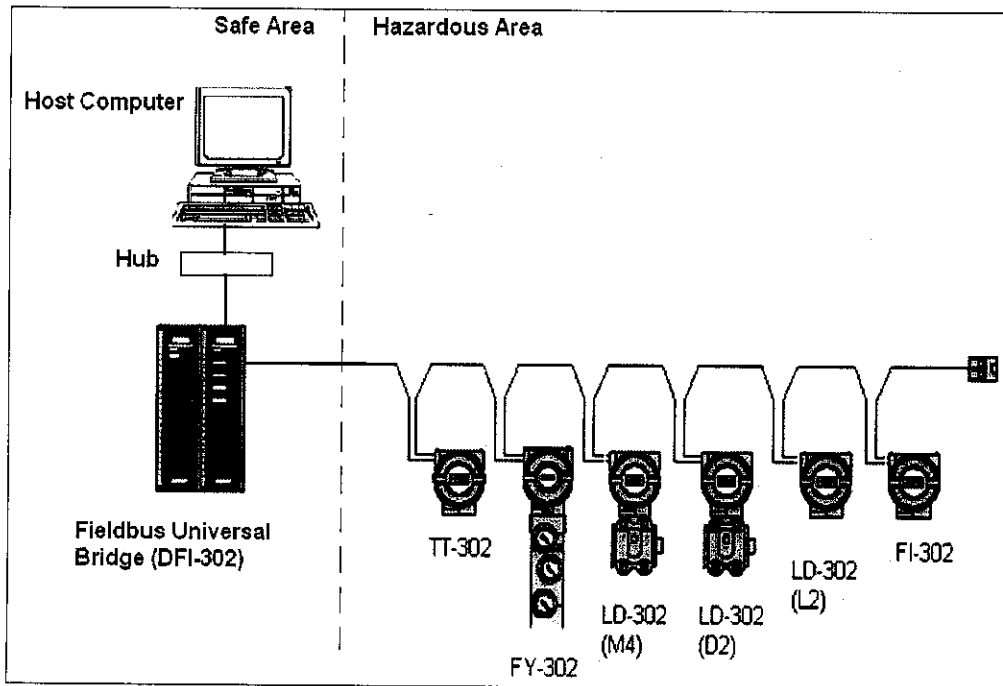


Figure 28 Daisy-Chain Topology

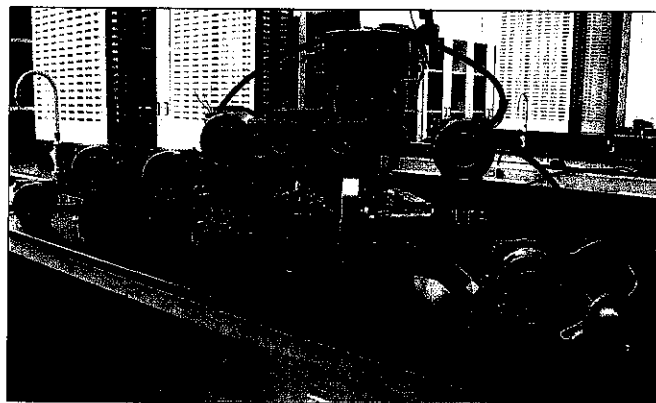


Figure 29 Fieldbus Test Rig

To establish the fieldbus topology, the wiring steps to be conducted are:

- i. The wiring block is accessed by removing the Electrical Connection Cover. The cover can be released by rotating the cover anti-clockwise.

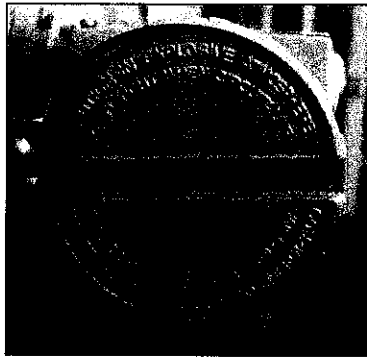


Figure 30 Housing Rotation

- ii. The common rules for routing signal cables also apply to fieldbus. Signal wires must be kept separate from sources and noise. The fieldbus signal is polarized, and bus-powered devices require correct polarity because of the shared power supply. Because on the network all devices are connected in parallel, thus colour-coded crimp is used to unite all negative terminals in same node and all positive terminals in the other node.

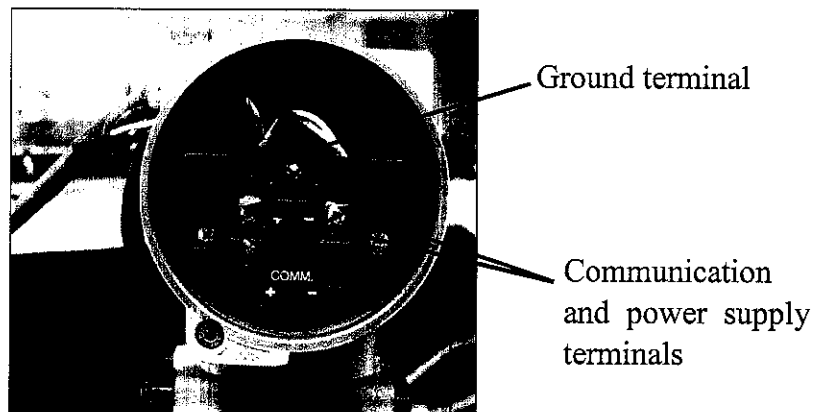


Figure 31 Wiring Block

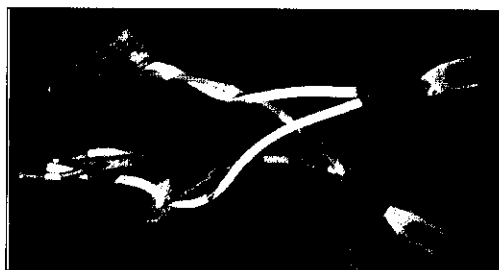


Figure 32 Crimp is used to Separate Polarity

- iii. The cable is chained from device to device. It is important to ensure that a device may be disconnected without other devices also being disconnected. Therefore the same conduit for “in” and “out” wires is used in order to enable removal of device without interrupting bus as shown in Figure 33.

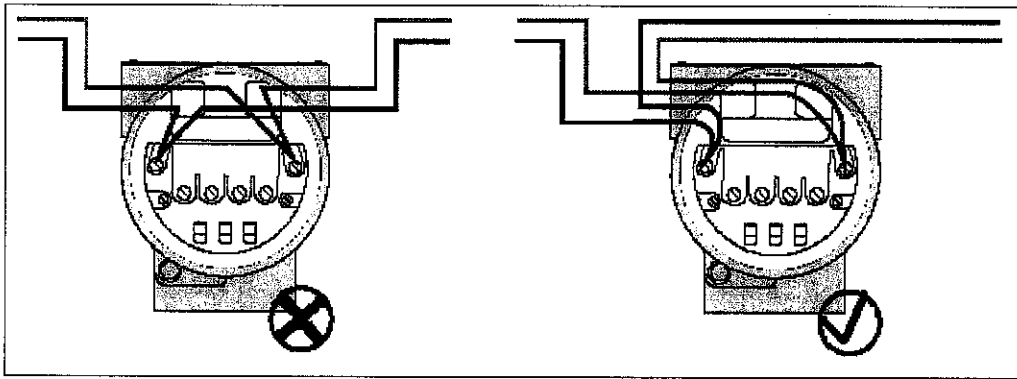


Figure 33 Daisy-Chain Wiring

- iv. The terminator must be at the end of the wire to really work. The terminator has no polarity terminal. Thus, the wire is chained from the last device and terminated in the bus terminator as shown in Figure 34 below.

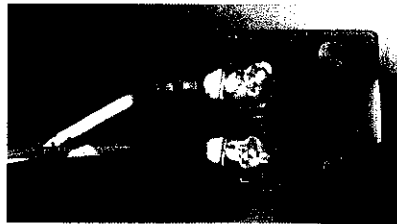


Figure 34 Bus Terminator Wiring

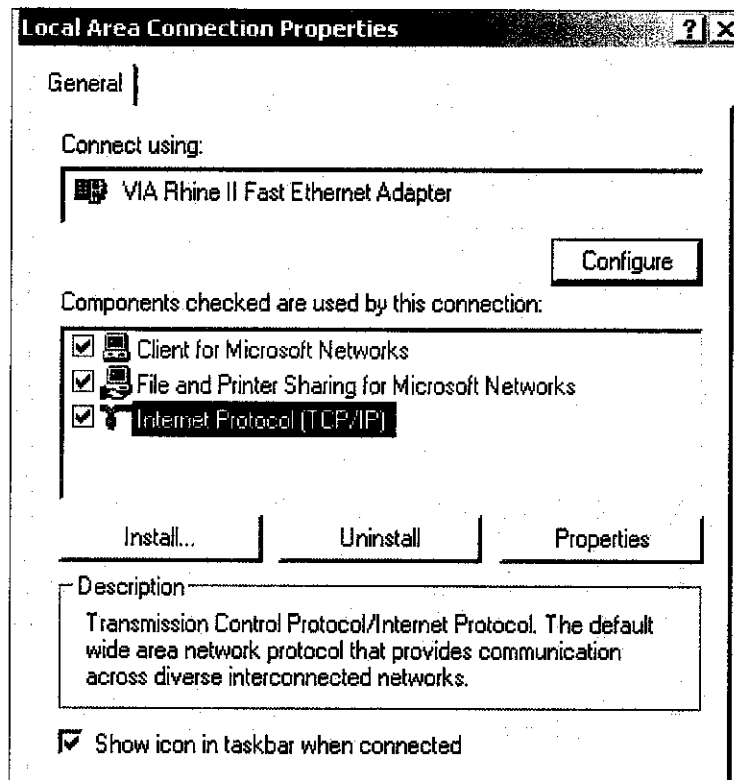
4.1.3 Ethernet and TCP/IP Configuration

The DFI-302 is connected to the host computer by a switching hub to create a Local Area Network (LAN) connection. In most cases, Ethernet wiring and hardware access go hand in hand with the Internet Protocol (IP) for networking and the Transmission Control Protocol (TCP) for data transport between nodes. For fieldbus, the wiring and hardware access is based on the Ethernet IEEE 802.3/ISO 8022.

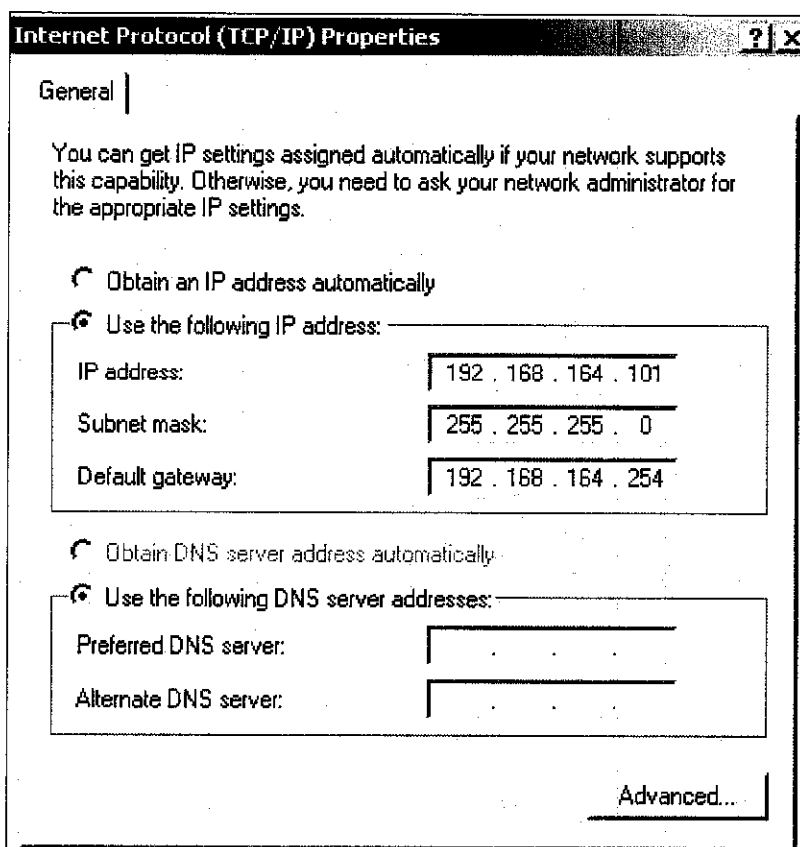
Both Ethernet and IP standards have addressing schemes. The Ethernet address represents the address of DFI-302 and it is uniquely sets in the hardware by the device manufacturer. The unique hardware address consists of a centrally administrated manufacturer code and a unique identifier. This is to eliminate the chance of conflict in a fieldbus network. Whereas, IP address represents the network address and it can be manually configured by user or it can be assigned automatically.

To enable the communication between host computer and the DFI-302, the Internet Protocol (TCP/IP) is manually set to be as followed. The setting is configured based on the user's manual of Fieldbus Universal Bridge (DF1-302).

- i. The 'Properties' of Internet Protocol (TCP/IP) is selected.



- ii. The IP address, Subnet mask and default gateway are set as the following.



- iii. If the connection is active, a bubble will pop up from the network icon in the desktop's taskbar as shown below.

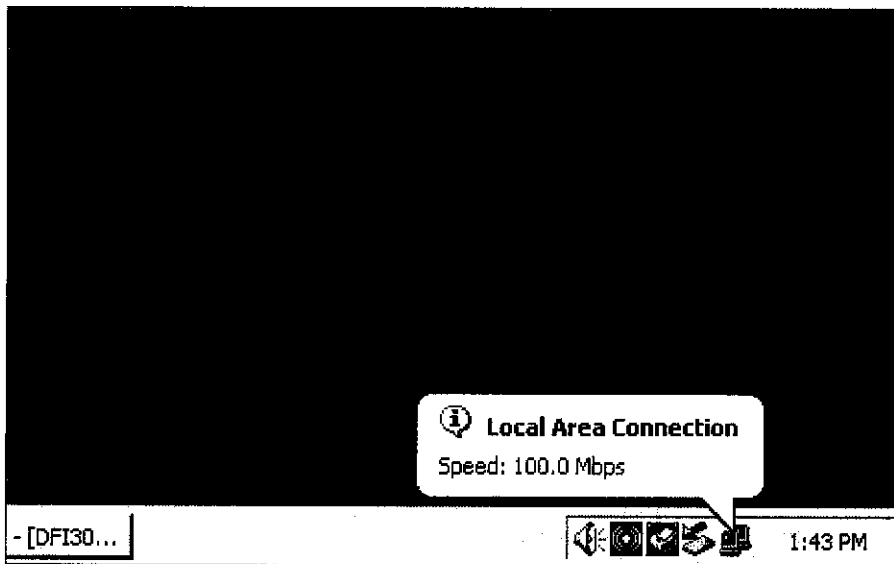


Figure 35 Local Area Connection

CHAPTER 5

HARDWARE AND SOFTWARE CONFIGURATION

5.1 THE SYSCON CONFIGURATION

Fieldbus system requires operators or engineer to configure the network as well as the control strategy and the devices. Because of those configuration is intimately related to each other, it is beneficial to do all of them at once using a single integrated configuration tool, SYSCON.

The project 'TestPlant' is initially divided into two major parts; The Logical Plant and the Physical Plant or named as "Fieldbus Networks". The Logical Plant is where all the logic part is kept, as the connection between function blocks, for instance. On the other side, the Physical Plant is where the physical installation is represented. It is where all the fieldbus segments or networks are configured with all field devices distributed in the same way installed in the field. These two parts are connected by the function blocks which present in both the Logical Plant and the Physical Plant.

The configuration via SYSCON is possible to start from different points and going through different ways. In this project, the Physical Plant was first established by creating fieldbus topology, connecting devices and assigning function blocks in them. The configuration is then completed by attaching the function block in the Logical Plant in making the control strategy.

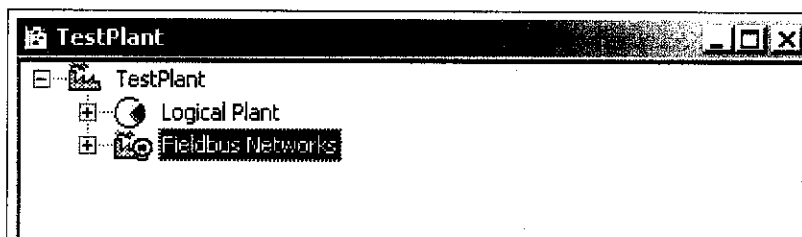
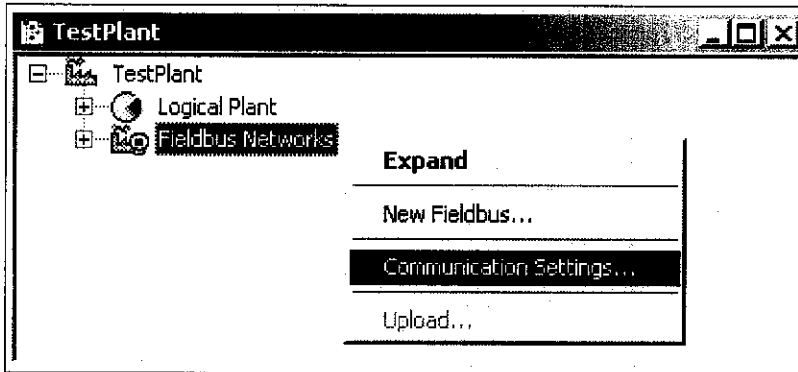


Figure 36 Main Window of SYSCON

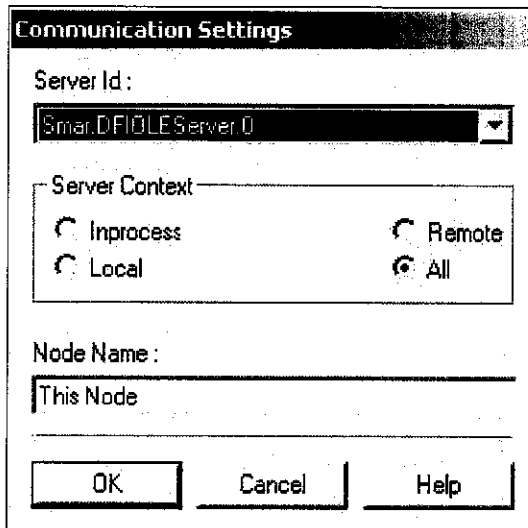
5.1.1 Initializing Communication

Below are the steps to initialize on line communication:

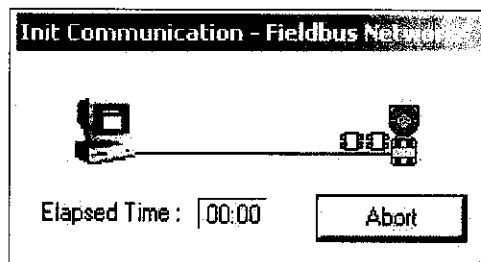
- i. Activate the popup menu by right-clicking Fieldbus Networks icon and Communication Settings is selected as the following figure.



- ii. The Communication Settings dialog box appeared. The server settings on the dialog must be the same as set on the following figure.



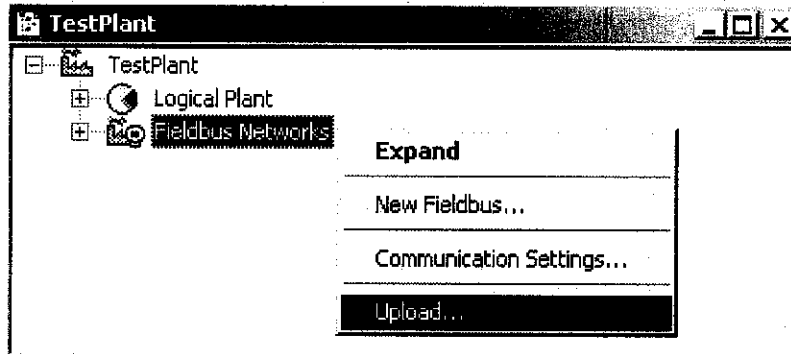
- iii. Again, activate the popup menu as in step (i) and Init Communication is selected.
- iv. The below video clip should appear for a couple of seconds. During this time, SYSCON will identify and attach any bridges installed in the computers to the configuration software.



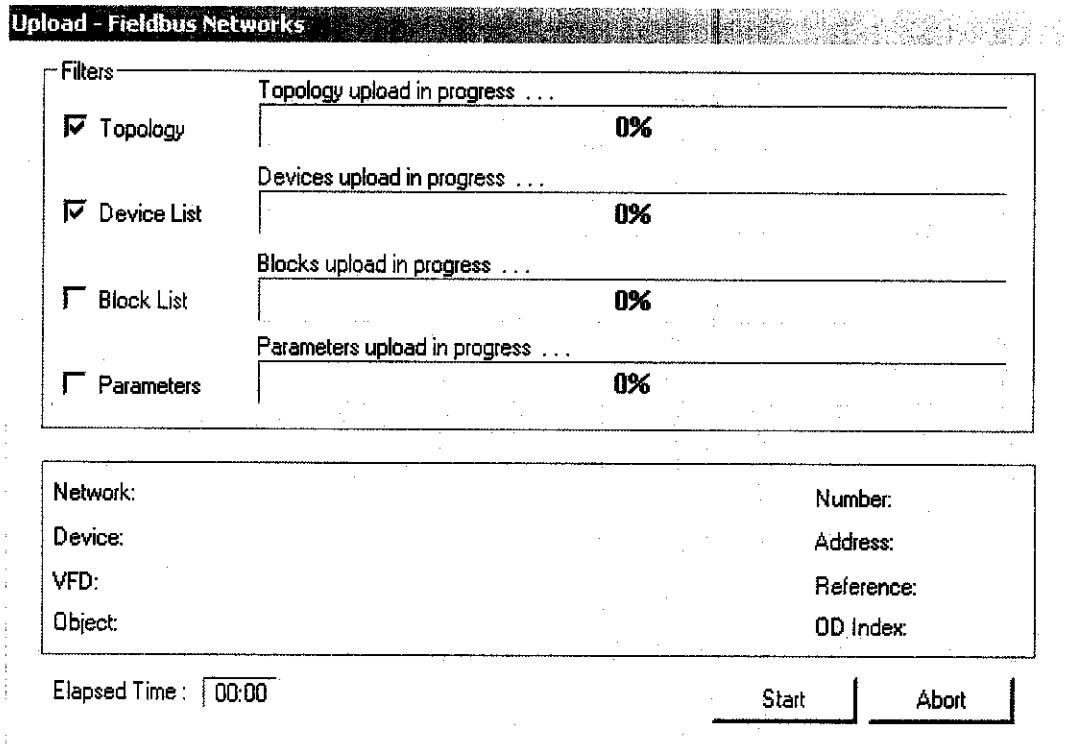
5.1.2 Uploading Fieldbus Networks

After the on line communication has been initialized, the fieldbus topology and device list can be uploaded to the SYSCON for configuration. Below are the steps to upload the fieldbus topology and device list to the Physical Plant.

- i. Activate the popup menu by right-clicking Fieldbus Networks icon and Upload is selected as the following figure.



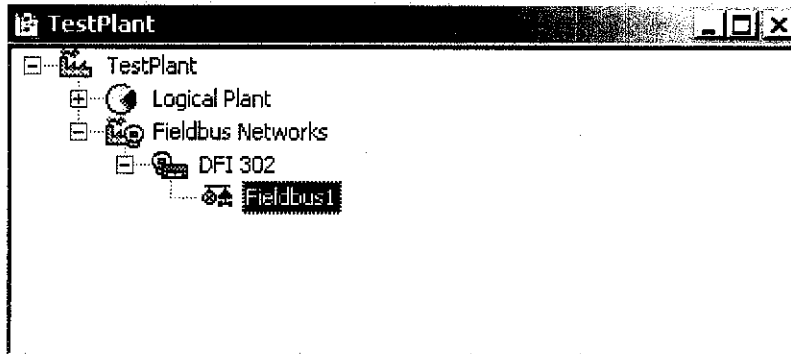
- ii. The Upload-Fieldbus Networks box appeared. In the Filters section, Topology and Device List is ticked and the upload operation is started.



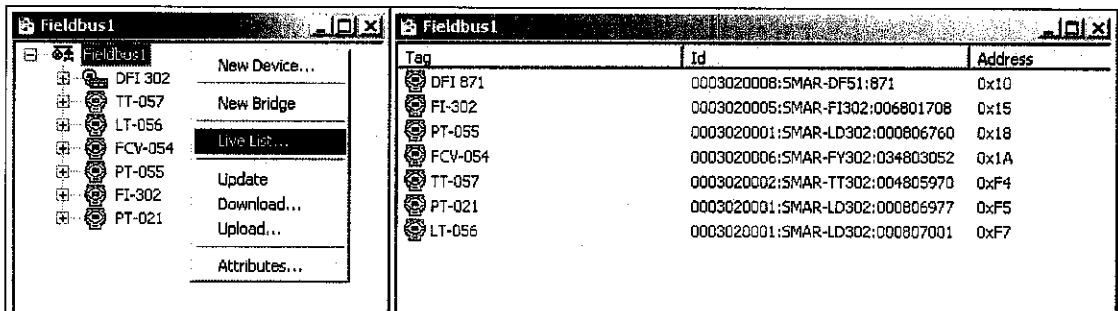
5.2 DEVICE COMMISSIONING

Fieldbus devices can be commissioned from the control room. The node address assignment is automatically handled by DFI-302. Once the communication between DFI-302 and the host is initiated, the installed device is automatically detected within seconds. The communication between SYSCON and field devices can be checked by the following step;

- i. The Fieldbus Networks icon is expanded and Fieldbus1 is selected.



- ii. In the Fieldbus 1 window, the popup menu is activated and Live List is selected. The Live List window is displayed showing all devices connected to the Fieldbus1 segment with their unique ID and node addresses.

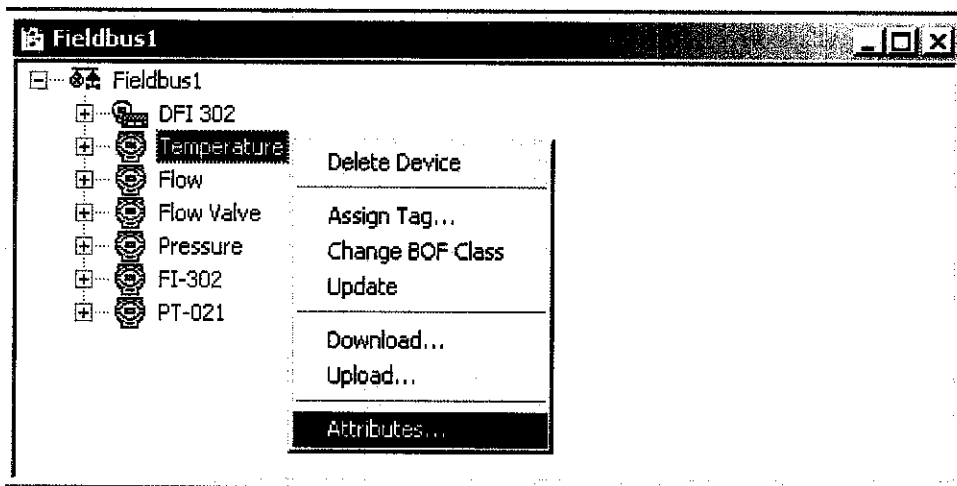


All the devices are displayed together on the same network in the Live List. Each fieldbus device has a unique device identifier (Device ID) that is used to distinguish one device from the others. This address is set in the circuit board by the manufacturer and cannot be changed. For practical purpose, the users interact with the system based on the device tags, not the node address. As shown in the Live List, the initial tag number is automatically set by the manufacturer. However, the tag number can be changed by the user depends on the control application. Once all devices are associated with their respective tags, the configuration can be downloaded, either for the entire network at once or individually.

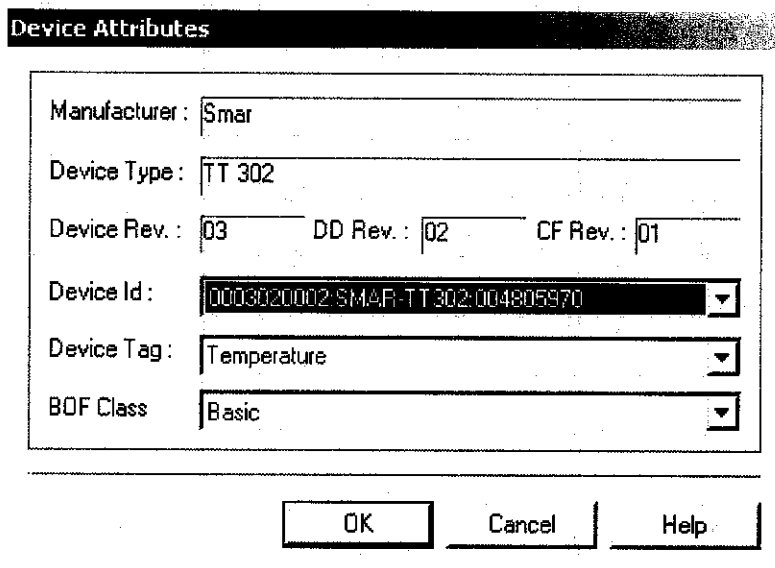
5.2.1 Changing Device Attributes

Most of the device attributes are unique and assigned by manufacturers to avoid network conflict. This unique attributes is also one of the fieldbus benefits to enable interoperability where devices from different manufacturers can work together in the same network. As discussed before, the device tag can be changed by the user depends on the control application used for control strategy. In order to change the device attributes, the following steps should be taken.

- i. Activate the popup menu by right-clicking on the any device in the Fieldbus1 window. In the popup menu, Attributes is selected.



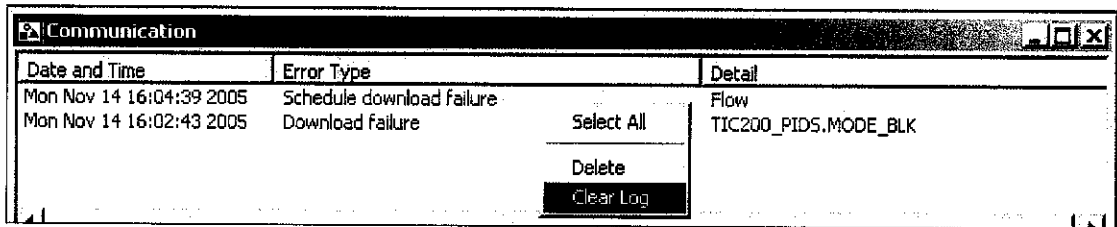
- ii. The Device Attributes box appeared as figure below. The device tag is changed manually by the user.



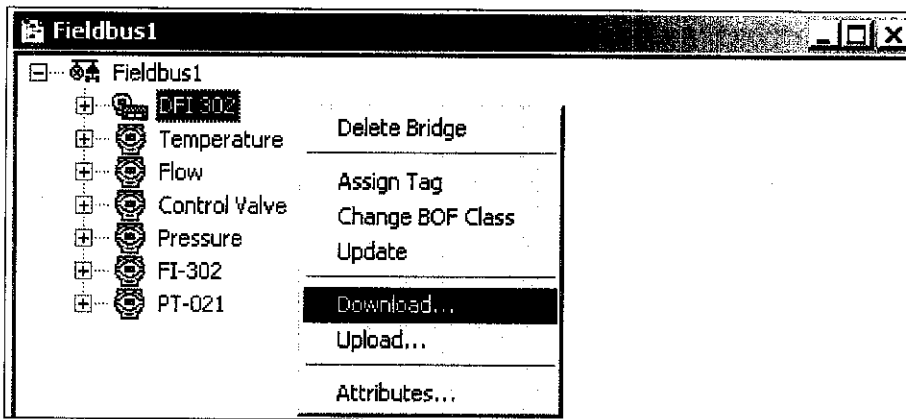
5.2.2 Downloading the Configuration

Any configuration or changed done in the Physical Plant may have to be downloaded to the device's block in the field. However, it is important to clear the Error Log Registry before downloading the configuration, because any eventual error that might occur during the download process will be easily detected as the Error Log windows pops up automatically at the first occurrence of its error.

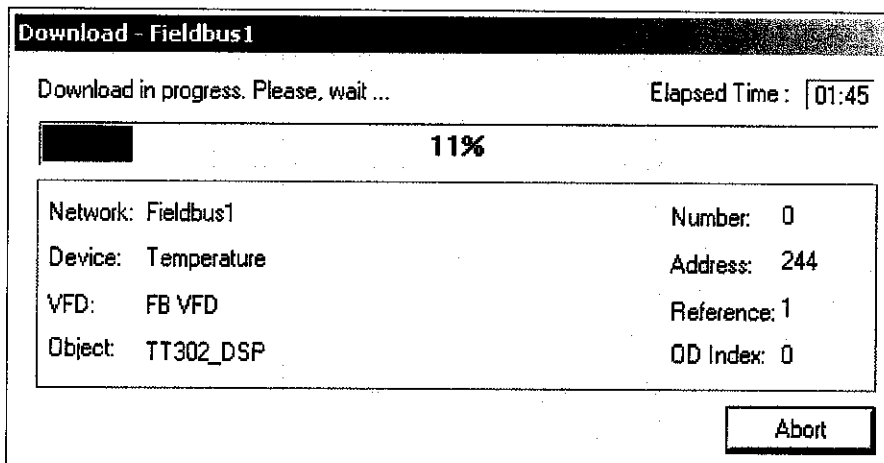
- i. Activate the popup menu by right-clicking inside the Communication window. The option Clear Log is selected.



- ii. In the Fieldbus1 window, the popup menu is activated by right-clicking the Fieldbus1 icon and the option Download is selected.



- iii. While configuration is being downloading to the plant, the following dialog is prompted.



5.3 CONTROL STRATEGY DESIGN AND CONFIGURATION

For experiment and testing purposes, three control strategies have been combined together to individually control the process of heat exchanger. The control strategies involved are:

- a. Single loop feedback control
- b. Cascade control
- c. Feed forward and feedback control

5.3.1 Single Loop Feedback Control

Feedback control strategy is the simplest control scheme involve only temperature transmitter and control valve. The temperature transmitter senses the temperature change in the end product to provide a feedback response to the valve controller.

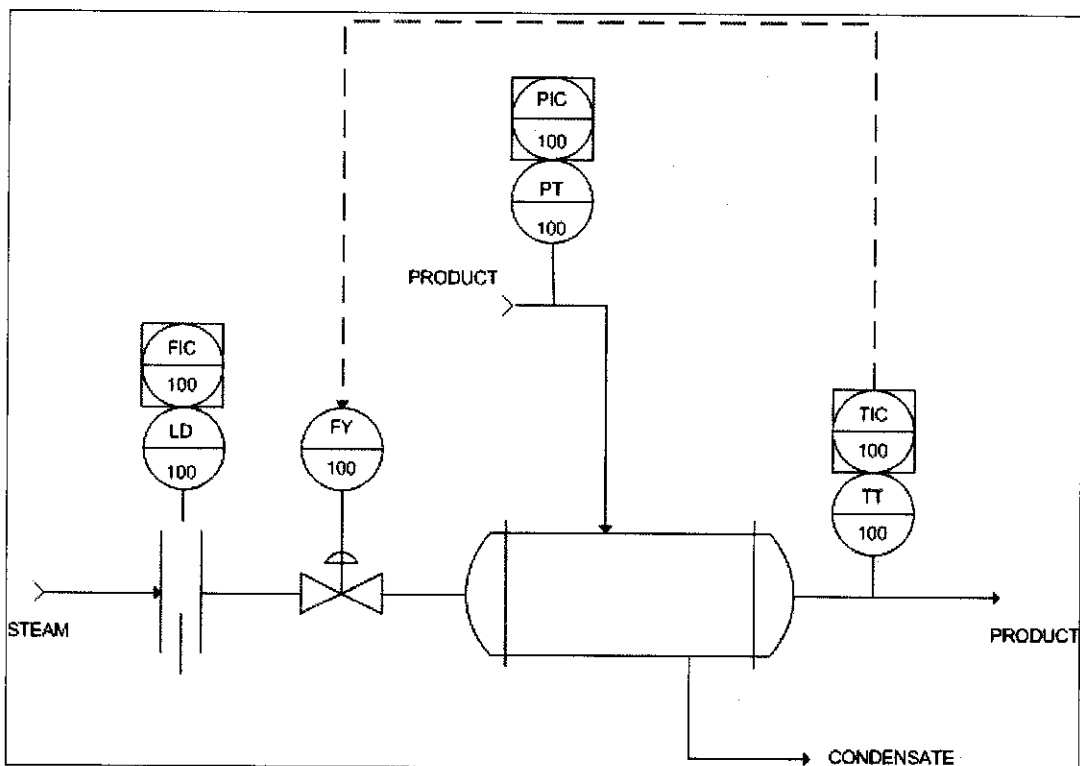


Figure 37 P&ID of Single Loop Feedback Control

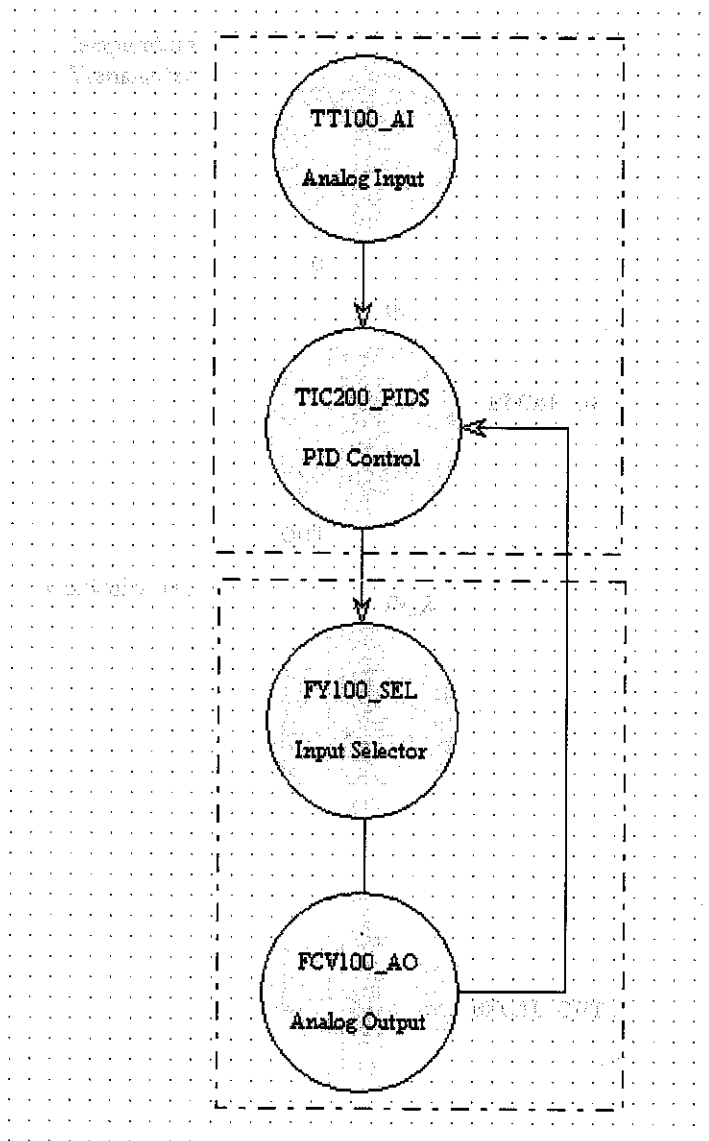


Figure 38 Function Block Design of Single Loop Feedback Control

Table 3 Function Block for Single Loop Feedback Control

Device	Block Type	Block Tag
Temperature	Analog Input	TT100_A1
	PID Control	PID200_PIDS
Control Valve	Input Selector	FY100_SEL
	Analog Output	FCV100_AO

Table 4 Function Block's Parameterization for Single Loop Feedback Control

Block	Parameter	Element	Mode
TT100_A1	MODE_BLK	TARGET	Auto
	PV_SCALE	EU_100	600
		EU_0	0
		UNITS_INDEX	°C
	OUT_SCALE	EU_100	200
		EU_0	0
UNITS_INDEX		kg/h	
TIC200_PIDS	MODE_BLK	TARGET	Auto
	PV_SCALE	EU_100	200
		EU_0	0
		UNITS_INDEX	kg/h
	OUT_SCALE	EU_100	100
		EU_0	0
UNITS_INDEX		%	
FY100_SEL	MODE_BLK	TARGET	Auto
	OP_SELECT	VALUE	2
FCV100_AO	MODE_BLK	TARGET	Auto
	PV_SCALE	EU_100	100
		EU_0	0
		UNITS_INDEX	%
	XD_SCALE	EU_100	100
		EU_0	0
UNITS_INDEX		%	

5.3.2 Cascade Control

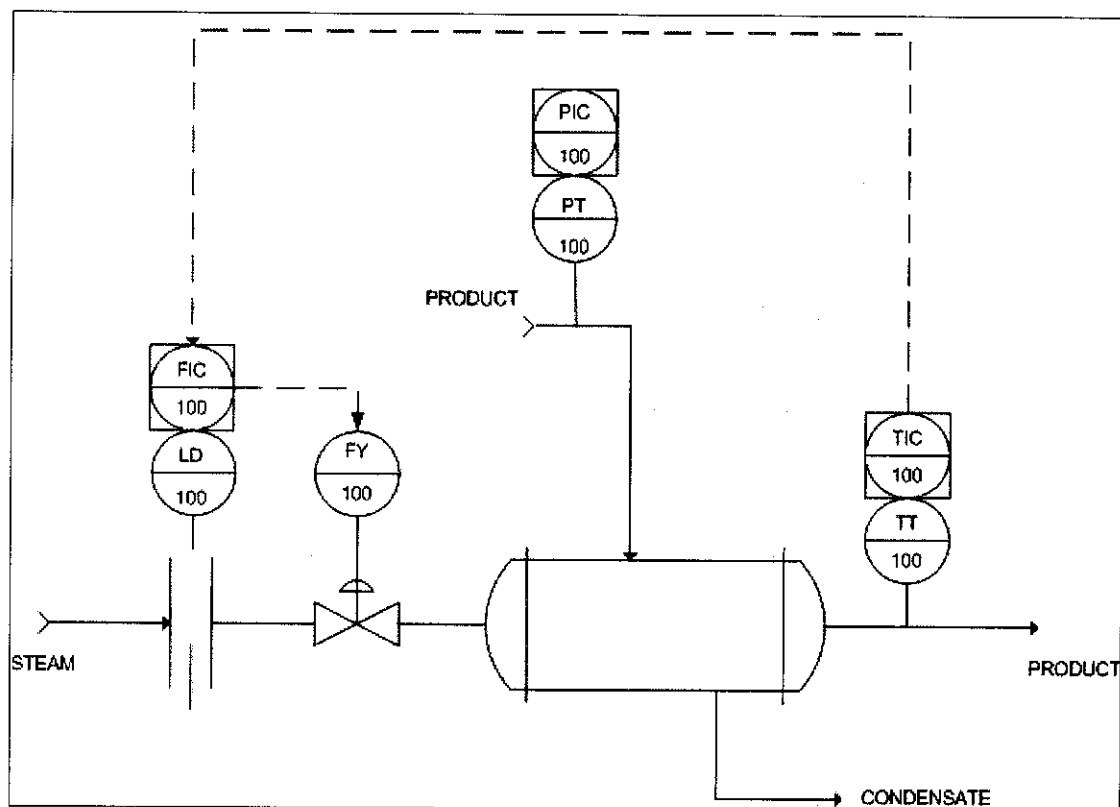


Figure 39 P&ID of Cascade Control

Cascade control combines two PID feedback controllers with the primary controller's output serves as the set point to the secondary controller. Note that additional secondary variable is measured to indicate the occurrence of key disturbance which is the steam's feed flow. The purpose for configuring a cascade control system is to eliminate the influence of disturbance on the primary process which enters through the secondary loop [2]. The main control objective is to achieve tight control on the output temperature of the product. In this process, temperature controller is the primary (master) loop, while flow controller is the secondary (slave) loop.

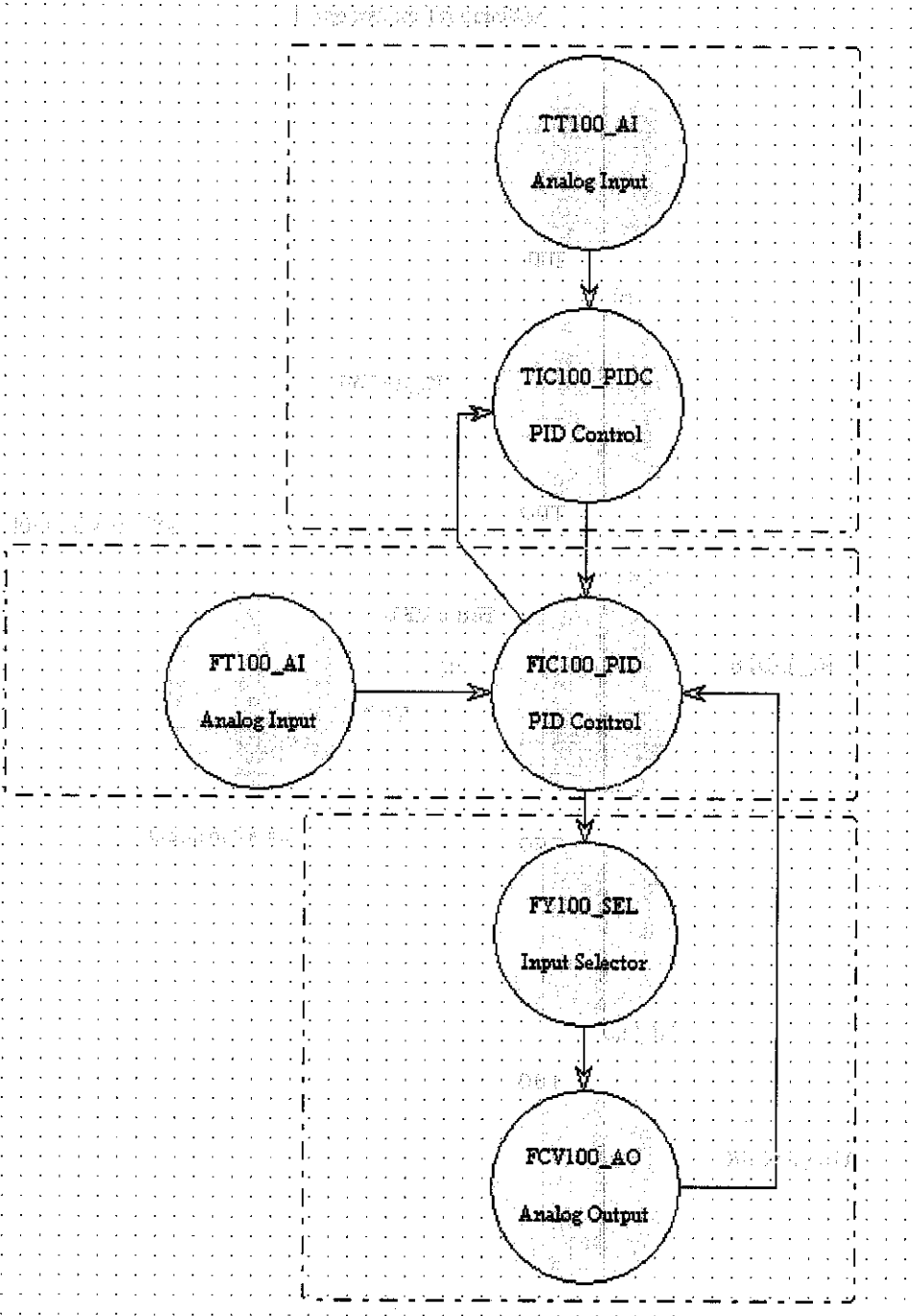


Figure 40 Cascade Control

Table 5 Function Block for Cascade Control

Device	Block Type	Block Tag
Temperature	Analog Input	TT100_A1
	PID Control	PID200_PIDC
Flow	Analog Input	FT100_AI
	PID Control	FIC100_PID
Flow Valve	Input Selector	FY100_SEL
	Analog Output	FCV100_AO

Table 6 Function Block's Parameterization for Single Loop Feedback Control

Block	Parameter	Element	Mode
TT100_A1	MODE_BLK	TARGET	Auto
	PV_SCALE	EU_100	600
		EU_0	0
		UNITS_INDEX	°C
	OUT_SCALE	EU_100	200
		EU_0	0
UNITS_INDEX		kg/h	
TIC200_PIDC	MODE_BLK	TARGET	Auto
	PV_SCALE	EU_100	200
		EU_0	0
		UNITS_INDEX	kg/h
	OUT_SCALE	EU_100	100
		EU_0	0
UNITS_INDEX		%	
FT200_A1	MODE_BLK	TARGET	Auto
	PV_SCALE	EU_100	200
		EU_0	0
		UNITS_INDEX	inH2O
	OUT_SCALE	EU_100	200
		EU_0	0
UNITS_INDEX		kg/h	
FIC200_PID	MODE_BLK	TARGET	Cas
	PV_SCALE	EU_100	200
		EU_0	0
		UNITS_INDEX	kg/h
	OUT_SCALE	EU_100	100
		EU_0	0
UNITS_INDEX		%	
FY100_SEL	MODE_BLK	TARGET	Auto
	OP_SELECT	VALUE	2
FCV100_AO	MODE_BLK	TARGET	Auto
	PV_SCALE	EU_100	100
		EU_0	0
		UNITS_INDEX	%
	XD_SCALE	EU_100	100
		EU_0	0
UNITS_INDEX		%	

5.3.3 Combination of Feedforward and Feedback Control

In feed forward control, an input disturbance is measured to determine an adjustment to an input manipulated variable before the controlled variables deviates from its set point. However, feedforward control alone cannot eliminate the steady state offset. Hence, feedforward is combined with feedback control as each has important advantages that compensate for deficiencies of the other [3]. The major advantage of feedback control is that it reduces steady-state zero offset to zero for all disturbances.

Figure 41 represents a control system which objective is to have a tight control on the end product temperature. In this control scheme, the feed flow serves as the feedforward variable while the output product temperature serves as the feedback variable. The combined controller output is the set point to control the opening and closing of the inlet steam control valve. The input steam valve is chosen as the manipulated variable which influences the amount of steam pressure in order to maintain the product output temperature to the desired set point.

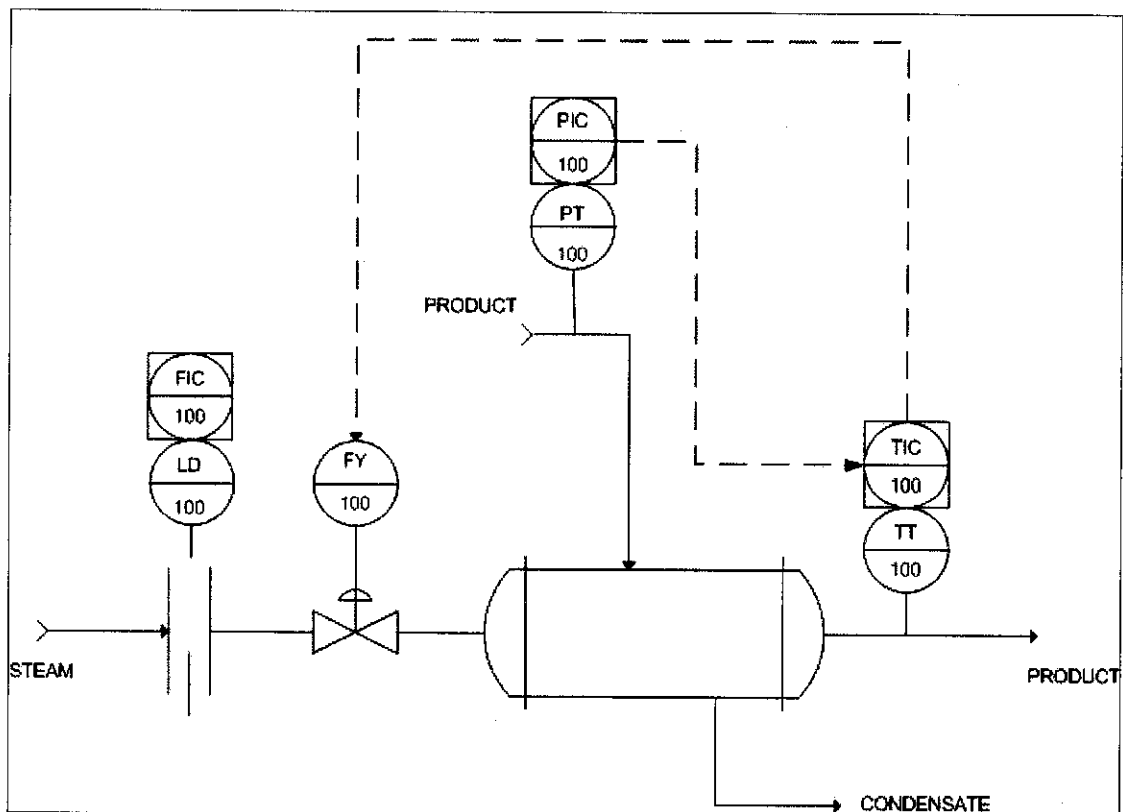


Figure 41 P&ID of Feedback and Feedforward Control

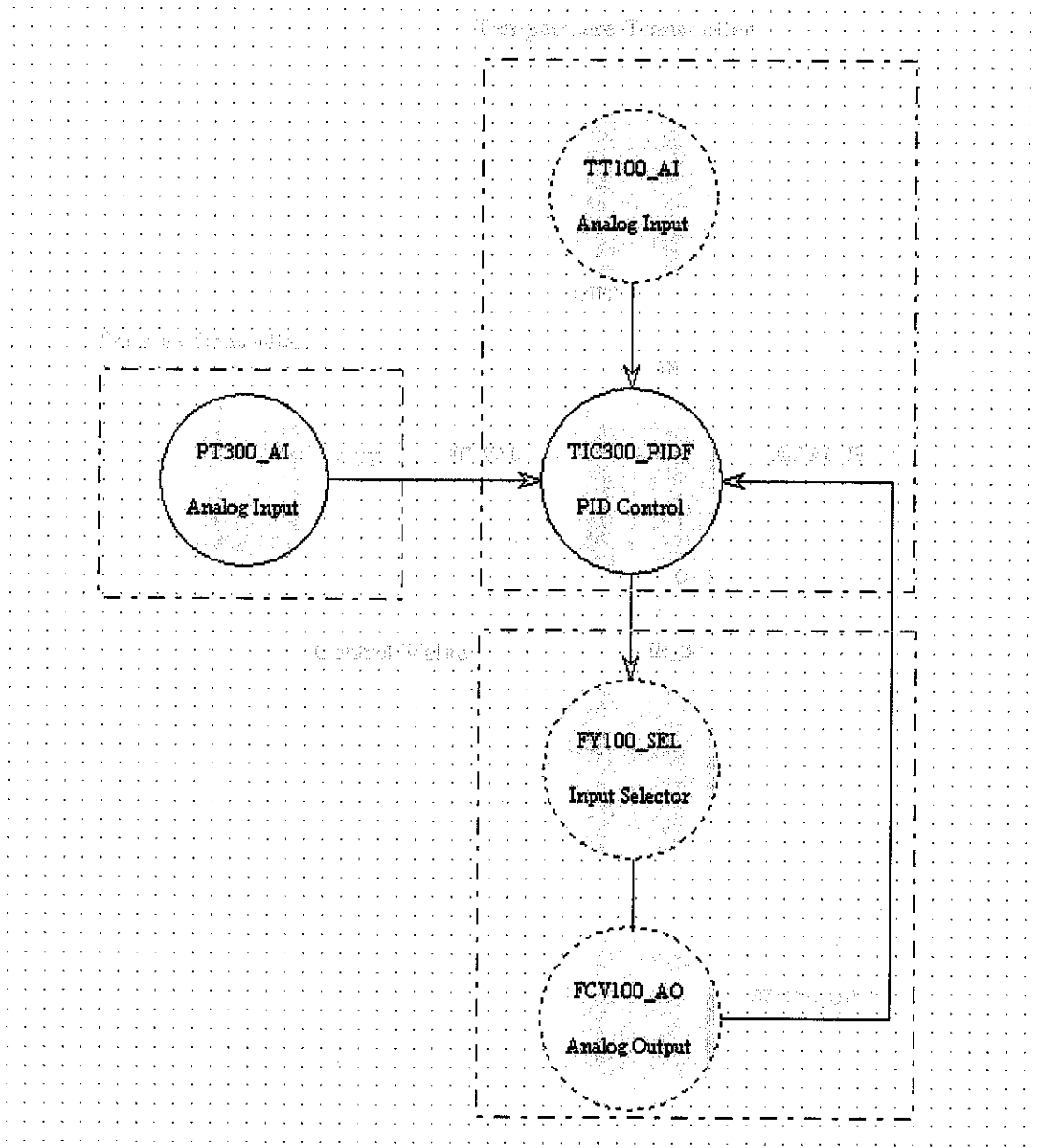


Figure 42 Feed forward and Feedback Control

Table 7 Function Block's Parameterization for Single Loop Feedback Control

Device	Block Type	Block Tag
Temperature	Analog Input	TT100_AI
	PID Control	PID200_PIDC
Flow	Analog Input	FT100_AI
	PID Control	FIC100_PID
Flow Valve	Input Selector	FY100_SEL
	Analog Output	FCV100_AO

Table 8 Function Block's Parameterization for Feedforward Control

Block	Parameter	Element	Mode
TT100_A1	MODE_BLK	TARGET	Auto
	PV_SCALE	EU_100	600
		EU_0	0
		UNITS_INDEX	°C
TIC300_PIDF	MODE_BLK	TARGET	Auto
	PV_SCALE	EU_100	600
		EU_0	0
		UNITS_INDEX	°C
	OUT_SCALE	EU_100	100
		EU_0	0
		UNITS_INDEX	%
	FF_SCALE	EU_100	500
		EU_0	0
		UNITS_INDEX	GAL/min
FF_GAIN	VALUE	0.1	
PT300_A1	MODE_BLK	TARGET	Auto
	L_TYPE		Indirect, Square root
	XD_SCALE	EU_100	125
		EU_0	0
		UNITS_INDEX	inH2O
	OUT_SCALE	EU_100	500
EU_0		0	
UNITS_INDEX		Gal/min	
FY100_SEL	MODE_BLK	TARGET	Auto
	OP_SELECT	VALUE	1
FCV100_AO	MODE_BLK	TARGET	Auto
	PV_SCALE	EU_100	100
		EU_0	0
		UNITS_INDEX	%
	XD_SCALE	EU_100	100
		EU_0	0
UNITS_INDEX		%	

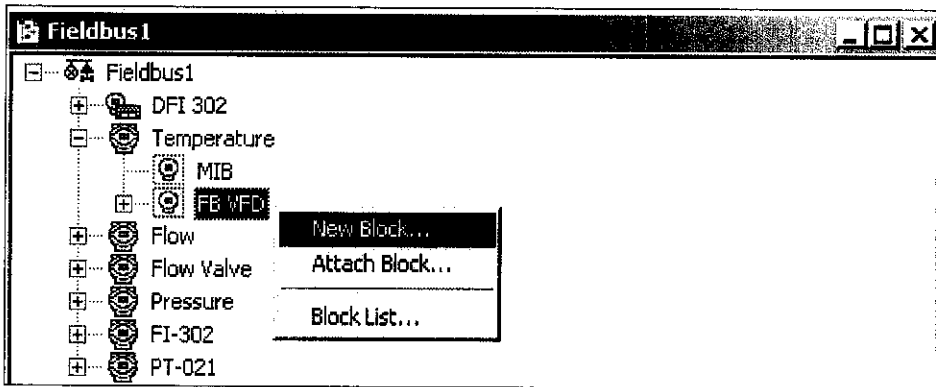
Note that the connection between each block in Figure 38 is determined by the following relations:

- OUT=analog value calculated as result of executing the function
- IN=primary input value/process variable value
- BCKAL_IN=the value and status from lower block's BCKAL_OUT that is used to prevent reset windup and to initialize the control loop
- BKCAL_OUT= the value and status required by upper block's BKCAL_IN so that the upper block may prevent reset windup and provide bumpless transfer to closed loop control
- CAS_IN=remote set point value, come from another fieldbus devices

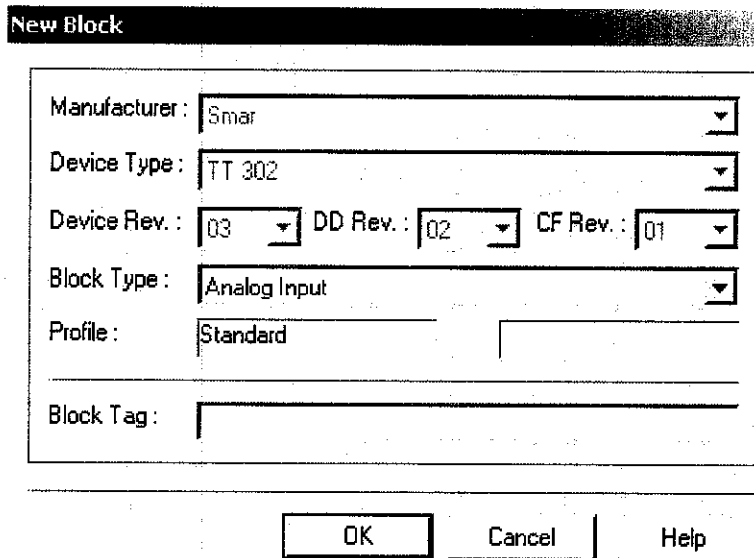
5.3.4 Creating the Control Strategy

By linking several function blocks, various control strategy can be constructed for the fieldbus network. A device is allowing the selection of up to 20 function blocks per device. Below are the steps to create the control strategy for the single loop feedback control.

- i. To add new block, the shortcut menu is activated with the right mouse button. The item New Block is selected as seen in the following picture.

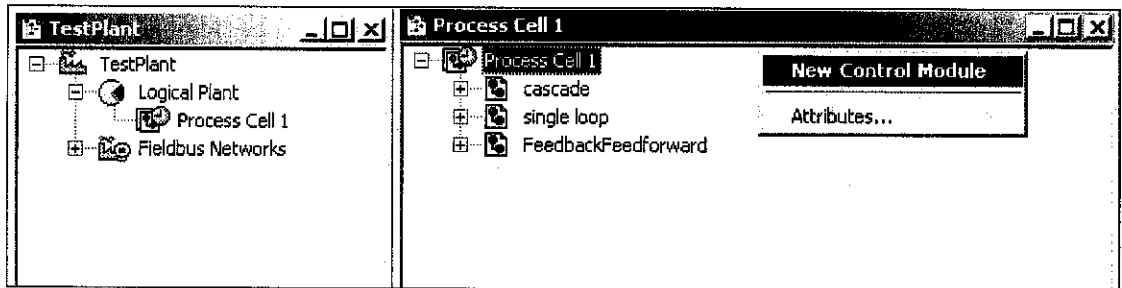


- ii. The Function Block Characterization showed up. Based on the detail of single loop control strategy in Figure 37 and Table 3, the block type is selected and the block tag is identified.

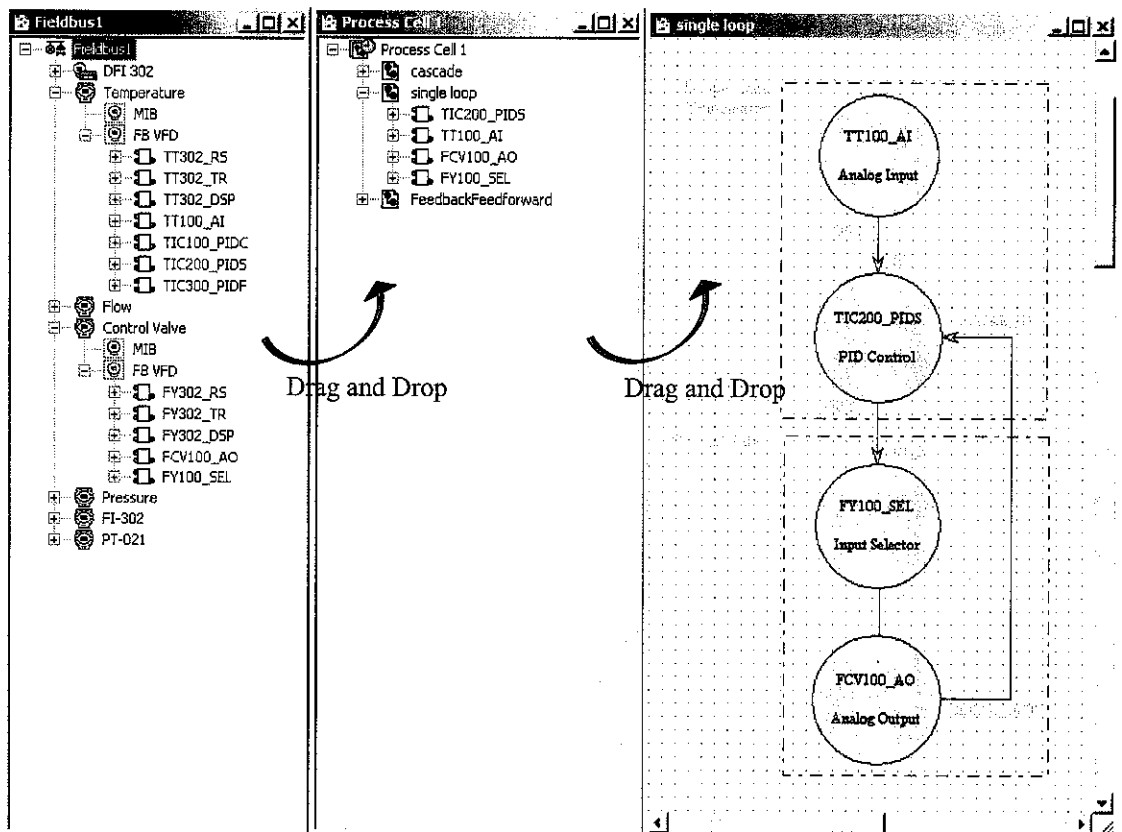


5.3.5 Creating the Logical Plant

- i. New Process Cell is created under the Logical Plant with the right mouse button activated the shortcut menu. Using the same step, New Control Module in created under the Process Cell Window. The new Control Module is renamed as 'single loop'. The Control Module is also known as the strategy window.



- ii. The 'single loop' icon is double-clicked to open its own window. Three windows are opened together as shown in figure below. The desired block is dragged from the Fieldbus1 window to the Process Cell 1 and to the 'single loop' window.



- iii. The procedure is repeated for the function block added in the previous section. The blocks are dragged and positioned according to the project design as shown in Figure 38.

5.4 DEVICE CONFIGURATION

Device configuration includes selecting devices and setting actuator type, sensor type, making connections and the like. The device characterization can be accessed by the steps below.

- i. The shortcut menu is activated with right click mouse button on the block's icon.
- ii. The online or offline characterization is selected.
- iii. The desired parameter to be changed is selected and changed.

The configuration allows strategy changes that can be done online or offline. Offline means that the configuration changes are only stored in the database, not in the devices. Once the offline configuration complete, it can be downloaded to the devices. Since online changes are made to devices directly, for safety reasons, it is restricted to parameter changing only. Normally, initial configuration is done offline during the engineering stage. Once the plant is operating, minor adjustments are usually done online.

Common function block configurations are discussed in detail below [1].

5.4.1 *Scaling*

The scaling parameter defines the operating range and the engineering units associated with a parameter. Scaling information is used for two purposes. Display devices need to know the range for bar graphs and tending as well as the unit code. Control block need to know the range to use internally as percent of span, so that the tuning constant may remain dimensionless. Control, calculate and output class blocks have a process variable scale (PV_SCALE) parameter for the input. Input, control and calculate class blocks typically have an output scale (OUT_SCALE) parameter for the output. Input and output class blocks have a transducer scale (XD_SCALE) parameter for the value on the I/O hardware channel. The scaling parameters have four elements:

- Upper Range Value (EU_100)
- Lower Range Value (EU_0)
- Unit
- Number of decimal places to be displayed

The PID blocks take the error and convert it to percent of span using the PV_SCALE. The algorithm operates on percent of span to produce an output in that form. This is converted back to a number with engineering units by using the range OUT_SCALE. The AI_BLOCK has the XD scale parameter to define the engineering units expected from the transducer block, which is also the engineering unit of the read back value.

5.4.2 Block Mode

The main purpose of the block mode (MODE_BLK) parameter is to determine the source of the block setpoint (SP) and primary output (OUT). The source for the setpoint or output may be the operator or another block. There are 8 modes available:

Table 9 Type of Block Mode

Mode	Setpoint source	Output Source
Out of Service (OOS)	Operator (SP)	Operator (OUT)
Initialization Manual (IMan)	Operator (SP)	Lower Block (BKCAL_IN)
Local Override (LO)	Operator (SP)	Other Block (TRK_VAL)
Manual (Man)	Operator (SP)	Operator (OUT)
Automatic (Auto)	Operator (SP)	This block
Cascade (Cas)	Higher Block (CAS_IN)	This block
Remote Cascade (RCas)	Other Application (RCAS_IN)	This block
Remote Output (Rout)	Operator (SP)	Other Application (ROUT_IN)

5.4.3 Analog Input (AI)

The AI block takes value from transducer block and make it available to other function blocks. At a minimum configuration, the following parameters must be set; _SCALE, block mode (MODE_BLK), input channel (CHANNEL) and linearization type (L_TYPE). As shown in Figure 43, the characterization is set based on the design control strategy listed in Table 4.

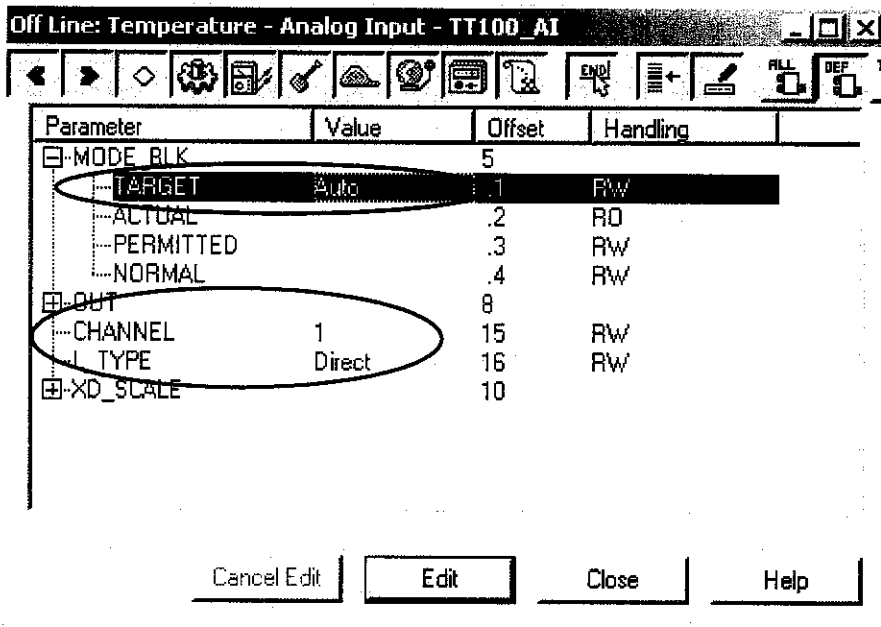


Figure 43 Off Line Characterization for Analog Input (TT100_AI)

5.4.3.1 Input Channel (CHANNEL)

This parameter is used to select the transducer block from which the primary variable is taken. Many transmitters only have a single integral sensor, which means that the channel parameter only has one option: 1. However, a multivariable device such as density transmitter may have both a density and process temperature sensor and may therefore require two corresponding AI blocks. The channel parameter is used in both AI blocks to select whether the block shall have access to the density or the process temperature.

5.4.3.2 Linearization type (L_TYPE)

For most measurements, the value from the transducer block is used directly, but for indirect measurements linearization may be applied. The following standard linearization options are available:

- Direct
- Indirect, linear
- Indirect, square root extraction

When the “Direct” option is selected, the measured value from the transducer directly passes to the AI block with no further processing. No-rescaling of the measurement is performed. As a result, there is no need to configure the scaling parameters; neither XD_SCALE nor OUT_SCALE is applicable. This option is always used for

temperature, level and flow transmitter as well as for pressure transmitters used to measure pressure.

For the indirect options, the XD_SCALE and the OUT_SCALE comes into play. The engineering unit and range of the actual measurement are set in the XD_SCALE, and the engineering and range of the inferred measurements are set in the OUT_SCALE. The “Indirect, square root” is used when a differential pressure transmitter is used for flow measurement. Square root extraction is made on the field value.

5.4.4 PID Control

The PID (Proportional, Integral and Derivative) control block receives a controlled variable on its input (IN) parameter. These variables are typically received from an AI block. At a minimum configuration, these parameters must be set: _SCALE, MODE_BLK and tuning constant. As shown in Figure 44, the PID Control block is configured based on the strategy designed in Table 4.

Parameter	Value	Offset	Handling
MODE_BLK		5	
TARGET	Auto	.1	RW
ACTUAL		.2	RO
PERMITTED	<None>	.3	RW
NORMAL		.4	RW
BLOCK_ERR		6	RO
SP		8	
CAS_IN		18	
GAIN	5	23	RW
RESET	10	24	RW
RATE	2	26	RW
PV_SCALE		10	
EU_100	600	.1	RW
EU_0	0	.2	RW
UNITS_INDEX	°C	.3	RW
DECIMAL		.4	RW
OUT_SCALE		11	
EU_100	100	.1	RW
EU_0	0	.2	RW
UNITS_INDEX	%	.3	RW
DECIMAL	2	.4	RW

Figure 44 Off Line Characterization for PID Control (TIC200_PIDS)

5.4.4.1 Tuning

To make the tuning constants dimensionless, control range must be configured in the PV_SCALE parameter. The engineering unit does not matter, only the range values are used. In other words, the range is usually not set in the AI block but rather in the PID block. There are three tuning parameters:

- Proportional gain (GAIN) – dimensionless
- Integral reset time (RESET) – in seconds per repetition
- Derivative time constant (RATE) – in seconds

The integral action can be disabled by setting RESET parameter to positive infinite (+Inf). The derivative action is disabled by setting the RATE parameter to zero.

5.4.5 Analog Output

Parameter	Value	Offset	Handling
MODE_BLK		5	
TARGET	Cas:Auto	.1	RW
ACTUAL		.2	RO
PERMITTED		.3	RW
NORMAL		.4	RW
BLOCK_ERR		6	RO
SP		8	
ID_OPTS		14	RW
CAS_IN		17	
CHANNEL		22	RW
FSTATE_VAL		24	RW
BKCAL_OUT		25	
PV_SCALE		11	
EU_100	100	.1	RW
EU_0	0	.2	RW
UNITS_INDEX	%	.3	RW
DECIMAL		.4	RW
XD_SCALE		12	
EU_100	100	.1	RW
EU_0	0	.2	RW
UNITS_INDEX	%	.3	RW
DECIMAL		.4	RW

Figure 45 Off Line Characterization for Analog Output (FCV_AO)

The analog output block receives setpoint input from other function blocks and may process the value before passing it to the physical output over a hardware channel through a transducer block. At a minimum configuration, these parameters must be set; _SCALE; MODE_BLK and CHANNEL. The functions of CHANNEL and

SIMULATE parameters are just the same as the functions of the input block

The desired output value is normally received on the cascade input (CAS_IN), typically from the PID block. Therefore the AO mode block (MODE_BLK) is usually set in Cas mode. The demanded valve position, calculated from the PID thus becomes the setpoint, which is the most important parameter in the block. Figure 45 below shows the analog output characterization based on the design strategy in Table 4.

5.4.6 Input Selector

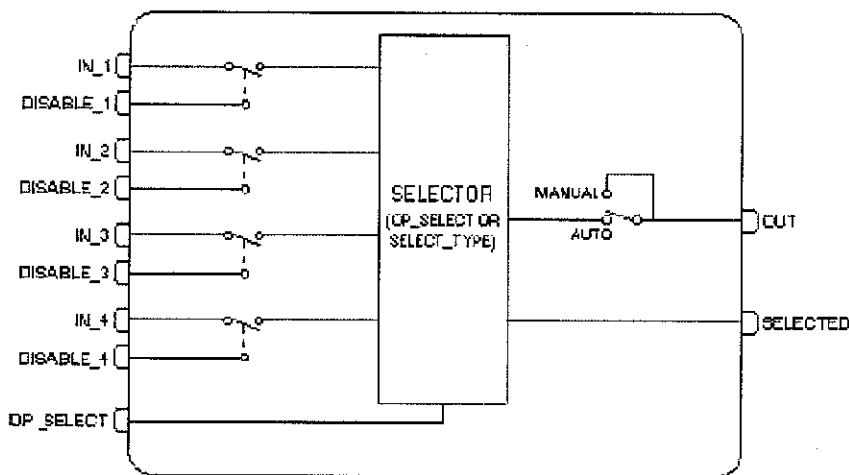


Figure 46 Input Selector Blocks Schematic

Off Line: Control Valve - Input Selector - FY100_SEL

Parameter	Value	Offset	Handling
MODE_BLK		5	
---TARGET	Auto	.1	RW
---ACTUAL		.2	RO
---PERMITTED		.3	RW
---NORMAL		.4	RW
---BLOCK_ERR		6	RO
OUT		7	
IN_1		11	
IN_2		12	
IN_3		13	
IN_4		14	
---SELECT_TYPE	Max	19	RW
OP_SELECT		22	
---STATUS	Good_NonCascade::NonSpecific:LowLimited	.1	RW
---VALUE	2	.2	RW

Buttons: Cancel Edit, Edit, Close, Help

Figure 47 Off Line Characterization for Input Selector (FY100_SEL)

The signal selector block provides selection of up to four inputs and generates an output based on the configured action. This block would normally receive its input from an AI or another block and not directly from a transducer. The block can perform max, min, mid, avg and first good selection in the selection type (SELECT_TYPE) parameter. If the operator selection (OP_SELECT) is non-zero, the OP_SELECT value will override the SELECT_TYPE selection. SELECTED is a parameter which will indicate which input has been selected by the algorithm.

5.4.7 Sensor Calibration and Configuration

The transducer block has an algorithm and a set of contained parameters. The algorithm describes the behavior of the transducer as the data transfer function between the I/O hardware and other function. Calibration is performed step-by-step by an established method by using SYSCON. The SYSCON identifies each method associated to the parameters and enables the interface to it.

The electronics of the devices, is very stable in time, not requiring further calibrations after manufacturer's calibration. However, should the user decide to use his/her reference to calibrate the devices (which is not recommendable by the manufacturer), this may be done by means of parameters CAL_POINT_LO and CAL_POINT_HI. When trim is performed, these two are always used as references.

Parameter	Value	Quality	Changed	Offset	Handling
PRIMARY_VALUE_RANGE				15	
CAL_POINT_HI	850	Good:Non Specific:t		16	RW
CAL_POINT_LO	-200	Good:Non Specific:t		17	RW
CAL_MIN_SPAN	10	Good:Non Specific:t		18	RW
CAL_UNIT	°C	Good:Non Specific:t		19	RW
SENSOR_TYPE	Pt 100 IEC	Good:Non Specific:t		20	RW
SENSOR_RANGE				21	
SENSOR_SN	0	Good:Non Specific:t		22	RW
SENSOR_CAL_METHOD	Factory trim standard calibration	Good:Non Specific:t		23	RW
SENSOR_CAL_LOC		Good:Non Specific:t		24	RW
SENSOR_CAL_DATE	<Unspecified>	Good:Non Specific:t		25	RW
SENSOR_CAL_WH0		Good:Non Specific:t		26	RW
SENSOR_CONNECTION	Two wires	Good:Non Specific:t		27	RW

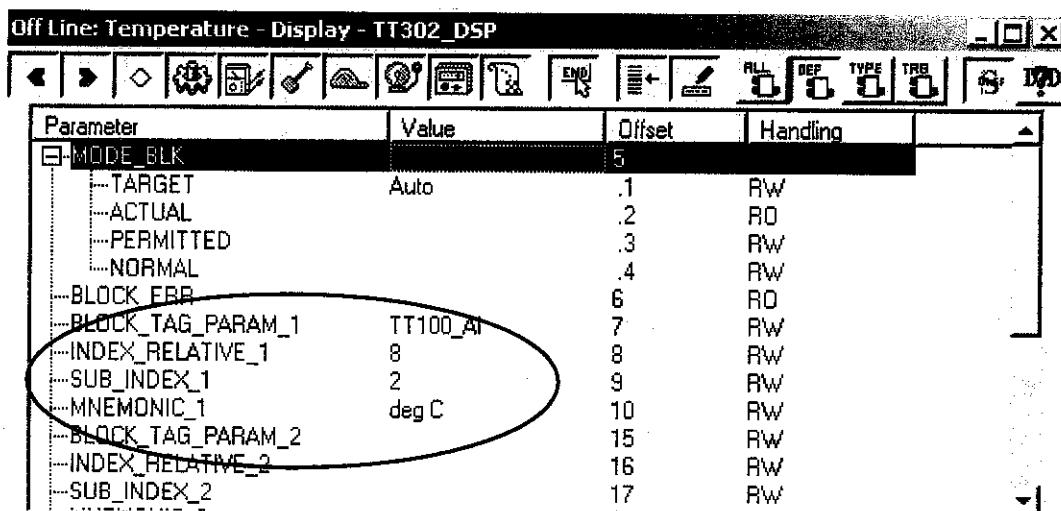
Figure 48 On Line Characterization for Transducer Block

5.5 IMPLEMENTATION

A tremendous amount of information is made available by the fieldbus technologies. However, to supervise the process the operators need to access some of this information. The process visualization software and operator interface should therefore be configured to show the information that is relevant for the operation of the process.

5.5.1 Display Setting

The local and remote operator interfaces also provide monitoring and actuation of variables, such as process variables and setpoint. Each fieldbus device has its own Display Block. The selection of display parameters should be seen as function block configuration. As shown below in Figure 49, these settings are necessary to configure the parameter to be displayed on the LCD display. The configured LCD display is shown in Figure 50.



Parameter	Value	Offset	Handling
MODE_BLK		5	
---TARGET	Auto	.1	RW
---ACTUAL		.2	RO
---PERMITTED		.3	RW
---NORMAL		.4	RW
---BLOCK_FBR		6	RO
---BLOCK_TAG_PARAM_1	TT100_A1	7	RW
---INDEX_RELATIVE_1	8	8	RW
---SUB_INDEX_1	2	9	RW
---MNEMONIC_1	deg C	10	RW
---BLOCK_TAG_PARAM_2		15	RW
---INDEX_RELATIVE_2		16	RW
---SUB_INDEX_2		17	RW

Figure 49 Off Line Characterization of Display Block (TT302_DSP)

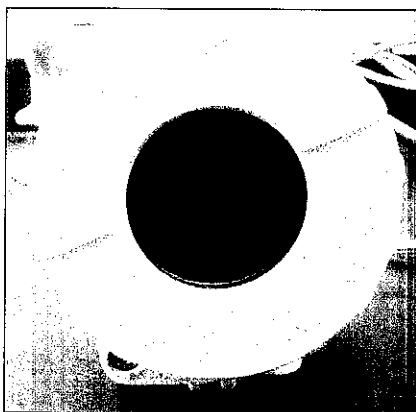


Figure 50 Temperature Transmitter with Configured Display

5.5.2 Simulation

The simulate parameter is used for diagnostics and checkout purposes. The simulation is activated by the ENABLE_DISABLE element in the simulate parameter. When enabled, the simulate parameter (SIMULATE) can be used to override the signal from the transducer for system test and troubleshooting purposes. Operators can manually writing the input values or status. In this case, simulate value and status will be the PV value.

Parameter	Value	Quality	Changed	Offset	Handling
---BLOCK_ERR	SimulationActive	Good:Non Specific:Not	6		RD
[-]PV			7		
---STATUS	Good_NonCascade::NonSpecific:NotLimited	Good:Non Specific:Not	.1		RD
---VALUE	50	Good:Non Specific:Not	.2		RD
[-]OUT			8		
---STATUS	Good_NonCascade::NonSpecific:NotLimited	Good:Non Specific:Not	.1		RW
---VALUE	50	Good:Non Specific:Not	.2		RW
[-]SIMULATE			9		
---SIMULATE_STATUS	Good_NonCascade::NonSpecific:NotLimited	Good:Non Specific:Not	.1		RW
---SIMULATE_VALUE	50	Good:Non Specific:Not V	.2		RW
---TRANSDUCER_STATUS	Good_NonCascade::NonSpecific:NotLimited	Good:Non Specific:Not	.3		RD
---TRANSDUCER_VALUE	22.416138	Good:Non Specific:Not	.4		RD
---ENABLE_DISABLE	Active	Good:Non Specific:Not V	.5		RW
[-]XD_SCALE			10		
[-]OUT_SCALE			11		

Figure 51 Simulation Parameter

5.5.3 Parameter Status

Input and output parameters have an associated status. Contained parameters, such as process variable (PV) and setpoint (SP) also have status. There are three conditions for the quality of the status element; “Good”, “Bad” and “Uncertain”. When a linked input is not updated within a certain time because of communication failure, its quality will be “Bad” or “Uncertain”.

“Good” status quality means that the value can be used for control. There are two forms of “Good” status element. Input and calculate class block use “Good (Noncascade)”. This status is only associated with variables that are not in cascade structure. The sub quality for “Good (Noncascade)” can be associated with “Nonspecific” subquality which means there is no alarm. Whereas control and output class block use “Good (Cascade)”, that serve as part of the automatic interlocks between the blocks. This status is only associated with variables that participate in a cascade structure.

In addition to that, the limit part of the status element indicates whether the associated value is limited or constant, or has no constraint. The following limit conditions may be seen:

- None – the value is not limited
- Limited High – the value has reached its upper limit and cannot go higher
- Limited Low – the value has reached its lower limit and cannot go any lower
- Constant – the value cannot go higher or lower

The following Figure 52 shows an example of parameter status appeared in the on line characterization of an Analog Output block.

Parameter	Value	Quality	Changed	Offset	Handling
ALERT_KEY	0	Good:Non Specific:Not l	4		RW
MODE_BLK			5		
BLOCK_ERR	<None>	Good:Non Specific:Not l	6		RO
PV			7		
STATUS	Good_NonCascade::NonSpecific:NotLimited	Good:Non Specific:Not l	.1		RO
VALUE	0.067063458	Good:Non Specific:Not l	.2		RO
SP			8		
STATUS	Good_Cascade::NonSpecific:LowLimited	Good:Non Specific:Not l	.1		RW
VALUE	0	Good:Non Specific:Not l	.2		RW
OUT			9		
STATUS	Good_Cascade::NonSpecific:NotLimited	Good:Non Specific:Not l	.1		RW
VALUE	0	Good:Non Specific:Not l	.2		RW
SIMULATE			10		
SIMULATE_STATUS	Good_NonCascade::NonSpecific:NotLimited	Good:Non Specific:Not l	.1		RW
SIMULATE_VALUE	0.067063458	Good:Non Specific:Not l V	.2		RW
TRANSDUCER_STATUS	Good_NonCascade::NonSpecific:NotLimited	Good:Non Specific:Not l	.3		RO
TRANSDUCER_VALUE	0.067063458	Good:Non Specific:Not l	.4		RO
ENABLE_DISABLE	Disabled	Good:Non Specific:Not l V	.5		RW

Figure 52 On Line Characterization Shows Parameter Status

5.5.4 Operator Interfaces

The operation and the diagnostics of the fieldbus control loop can be done remotely via Fieldbus System Configurator (SYSCON) or GraphworX32. GraphworX32 is process visualization applications software which allows screens to be totally customized to those found in traditional DCS.

The main window of the operator interface is illustrated in Figure 53 below. It shows the overview of the process plant with selection button to select the control loop strategy to be applied to the process. Note that several control loop strategy has been

designed for experimental purpose. In real processes these selections of control strategies may maximize the plant output as well as tight control over the processes.

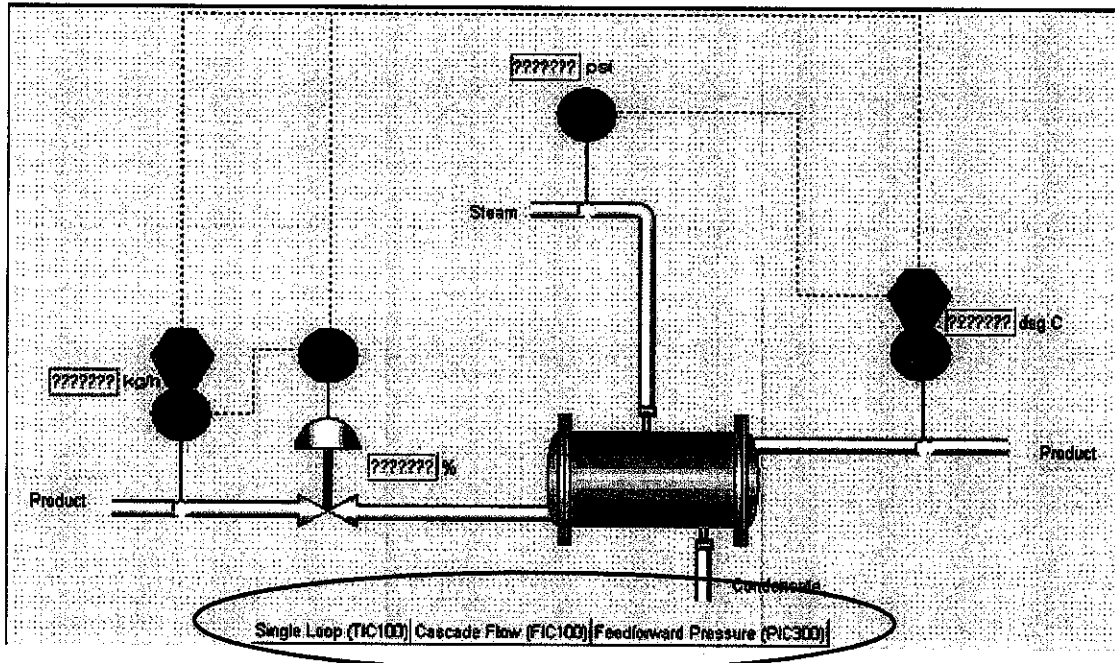


Figure 53 Overview of Heat Exchanger Plant Process

From Figure 53, the operator can be directed to other windows as shown in Figure 54. These windows show respective control strategy applied to the heat exchanger process; the Single Loop Feedback Control, the Cascade Control and the Feedback and Feedforward Control.

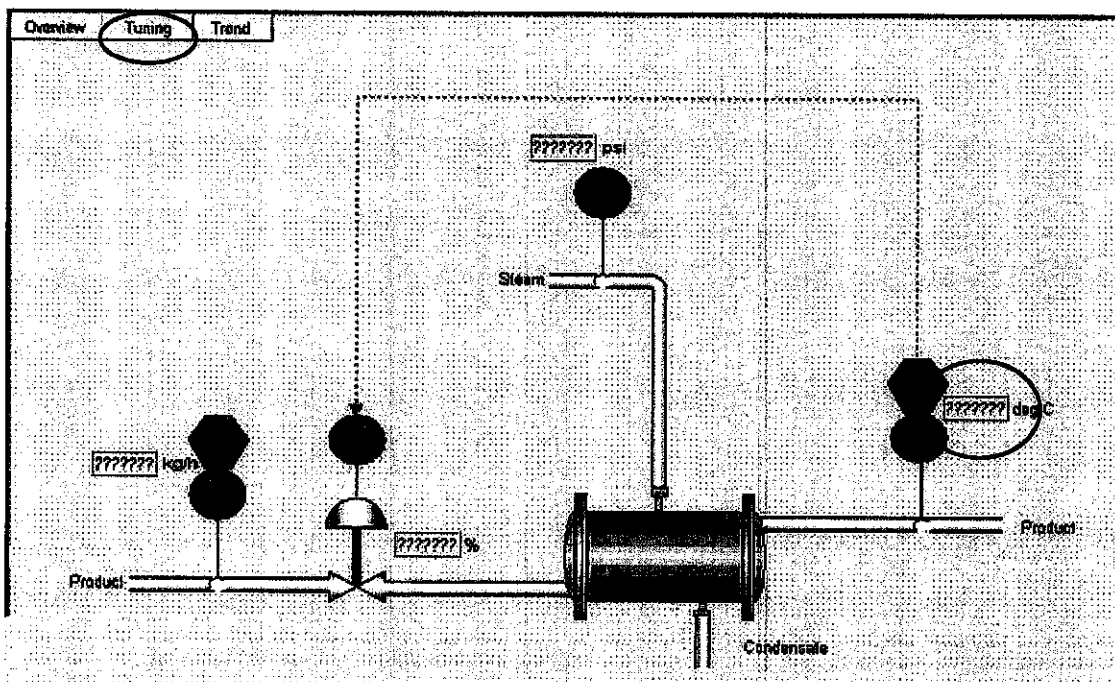


Figure 54 Single Loop Feedback Control Strategy

5.5.4.1 Configuring the Process Visualization

GraphWorX32 is a software solution of OPC based Client for operator interface. OPC is a standard-based approach for connecting controllers and I/O devices with HMI client application (e.g. graphics, trending). OPC technology is tag based. The desired data to be displayed uses the same tag that was entered previously in the configuration tool.

The red circle in Figure 54 is the process value which indicates the temperature reading from TT 100. The data source of that process value is linked to the field reading based on the OPC tags as shown below in Figure 55.

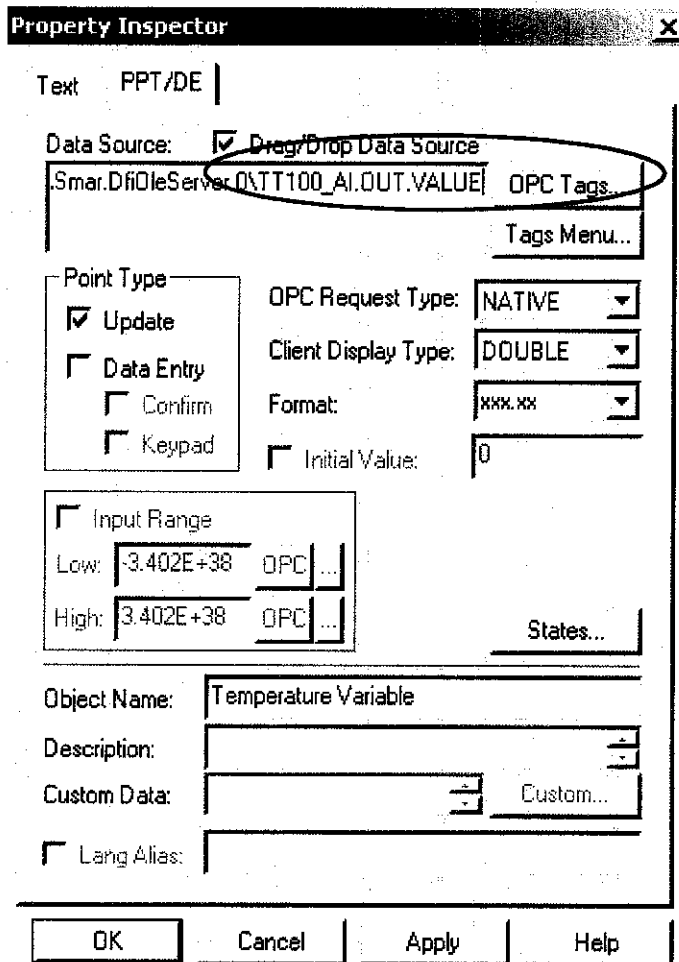


Figure 55 Property Inspector of Process Value to be Displayed

CHAPTER 6

FIELDBUS BENEFITS AND SAVINGS

6.1 LOWER COST OF PURCHASE

6.1.1 Hardware Reduction

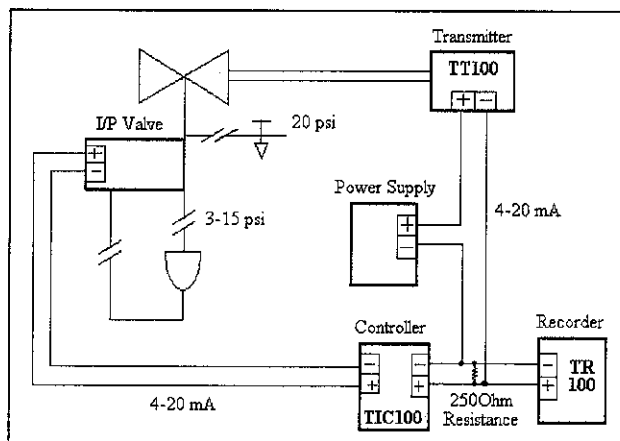


Figure 56 Conventional Control Loop

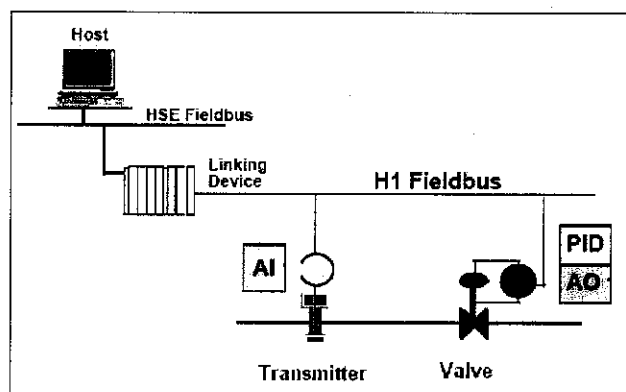


Figure 57 Fieldbus Control Loop

Figure 56 illustrates the conventional control loop where tuning and controller settings had to be done locally. Sensors and actuators were hardwired to the controllers using an individual dedicated pair of wires. With fieldbus technology,

reduction in hardware is seen at all levels of the system architecture, from field instruments to the workstations. Figure 57 points up the shift of control system functions to the field level. The proportional-integral-differential (PID), analog input and output (AI/AO) from the DCS controller card are now positioned at the sensors and actuators at the point of measurement and control of the fieldbus system. The control strategy is distributed along the field devices by having function blocks in the devices' microprocessor. Such implementation reduces the I/O and control equipment needed such as card files, cabinet and power supplies. Fewer, smaller and lighter components also mean reduced shipping cost.

6.1.2 Installation Savings

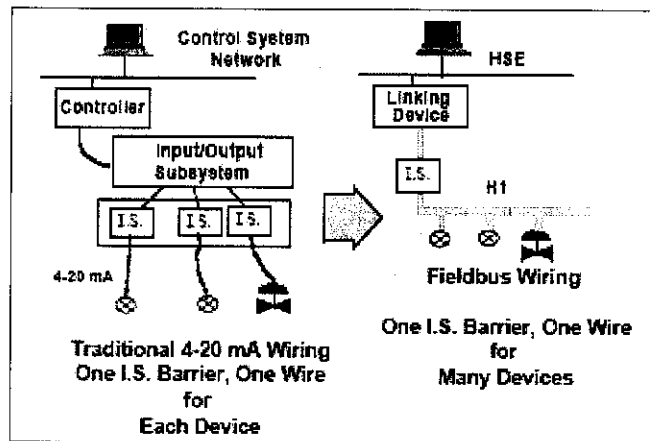


Figure 58 Installation Savings

Fieldbus concept can be summarized as a Local Area Network (LAN) for process control that uses shared wiring for powering devices and carrying signal between devices. As shown in Figure 58, a number of devices can be connected to a pair of wires. Since many devices can be multidropped on a single pair of wires, the amount of cable can be drastically reduced. The amount of cable reduction depends on the wiring scheme, the number of device installed on each network, the distances and whether or not the installation in the hazardous area. With having minimal numbers of hardware and wiring element, the man-hours spent to install all these elements is far smaller than what would be required for a conventional wiring scheme. Given simpler and faster installation task, this becomes a major cost reduction in comparison with a conventional system, especially in view of the large number of devices installation [1].

6.1.3 Cost Comparison

The ultimate process control scheme is one that provides the system most information possible, but to do this there is also a cost factor that must be evaluated. The more information being provided to the control scheme, the more cost for the field devices and the complex the controller, control strategy, wiring, and the like. Therefore the cost justification is important to identify the correct control strategy and also the control system architecture to be applied.

Based on Figure 56 and 57 above, it is clearly noted that fieldbus architecture reduce the equipment such as DCS controller and recorder because of the PID algorithms were executed in the fieldbus devices itself. Each transmitter can be remotely configured. Device parameters such as the high and low range values were changed without having a technician adjust the controller in the field. Labor costs were saved due to the simpler wiring configuration, remote device configuration and identification. Overall, the fieldbus system is expected to result in 29% savings in installation and commissioning costs.

Table 10 Cost Comparison

	Conventional (RM)	Fieldbus (RM)
Power Supply	200	120
Interface	280	640
Wiring and Fittings	5 600	1 160
Valve	2 260	4 100
Transmitter	2 200	2 500
Standalone PC	NA	3 000
Hub	NA	500
Terminator	NA	200
Controller	2 100	NA
Recorder	2 900	NA
Decade Box	1 500	NA
Labor Cost	2 040	1 400
TOTAL	19 080	13 620

6.2 GREATER SYSTEMS FUNCTIONALITY

6.2.1 Data Quantity and Quality

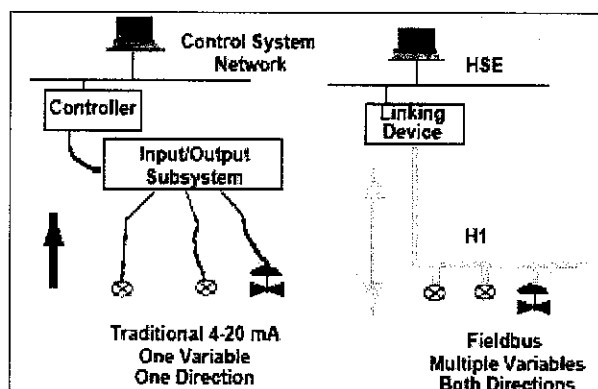


Figure 59 Data Quantity and Quality

In a 4-20mA analog system value is transmitted by infinite variation of current. A signal error just changes a valid signal into another valid signal. Fieldbus system with digital communications has the advantage of being a very robust signal with only two valid states (one and zero). It is transmitted directly or encoded in same form and is therefore less sensitive to distortion than an analog signal. Signal distortion cannot be detected in an analog signal because a distorted signal still looks like a valid process signal. High resolution and distortion-free characteristics of digital fieldbus communication enables improved control capability that increase products yield.

Figure 59 compares data availability between a DCS and a fieldbus system. As shown, the fieldbus data transmission carries information of multiple variables. Digital communication of fieldbus carries not only I/O like process and manipulated variables but also operational information such as setpoint and tuning from both directions to and from the control room. Fieldbus also enables distributed processing and diagnostic and configuration in field instruments such as transmitters and valve positioners. With fieldbus, field instruments now perform not only a basic measurement or actuation but also have function for control and asset management.

6.2.2 Expanded View of Process Instruments

The only means analog systems had to detect device fault was using discrepancy checking to compare the signal from two redundant transmitters. This is a costly solution for a few critical control loops. Devices using fieldbus technology detect their own fault and communicate their health. As a result one device can be used instead of two, reducing the costs by 50 percent for such loops.

As illustrated in Figure 60, fieldbus functionality enable operator from a single workstation to have extend view to the instruments condition in the field. This can be done by using the engineering and maintenance tool such as SYSCON and GraphworX32. The self-test and communication capabilities of microprocessor-based fieldbus devices help reduces downtime and improve plant safety. Upon detection of abnormal condition, plant operations and maintenance personnel can be notified. This allows corrective action to be initiated quickly and safely. Furthermore, fieldbus has the ability to operate multiple devices, from different independent manufacturers in a same system.

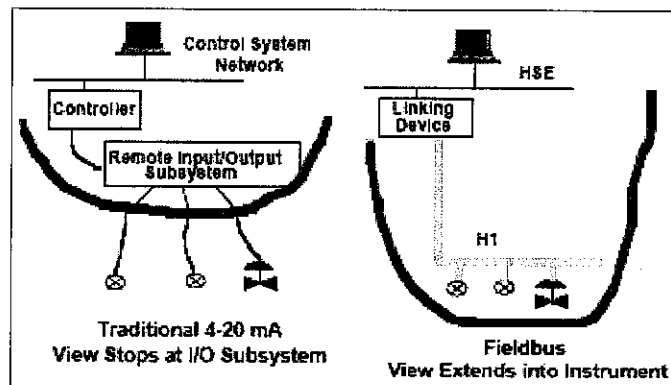


Figure 60 Expanded Views of Process Instruments

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

The system design for fieldbus is very similar to a Distributed Control System (DCS) design with the following differences:

- The physical wiring due to change from 4-20mA analog point-to-point wiring to a digital bus wiring where many devices can be connected in a wire.
- Each device on the fieldbus must have a unique physical device tag and a corresponding network address
- The ability to distribute the control input and output (I/O) subsystem functions from the control system to the fieldbus devices. This may reduce the number of rack mounted controllers and remote mounted I/O equipment needed for the system design.
- The function blocks programming and device configuration to enable control strategy to be implemented in the fieldbus network.

Fieldbus technology is already changing the way systems perform control and will have greater impact on system architecture. Definitely, fieldbus is the next technology that will be broadly used in advanced process control. It has been stipulated that the fieldbus has credibility over DCS on the hardware implementation, installation, wiring, communication speed, data quantity and quality, maintenance and devices interoperability. The study and the implementation of the fieldbus network for controlling process loop in laboratory is an intriguing project which anticipated the benefits of using fieldbus in order to increase plant control performances.

The aim of this work has been to design, configure and implement a fieldbus test rig using fieldbus devices, controller and actuator. In particular it has been organized to

answer questions such as;

- How to design, configure and build a fieldbus test rig,
- How to specify problem and scenarios to be analyzed (different control loops),
- How to extract useful information for the implementation of a control loops, and
- What scope of research area pertaining to fieldbus that would be important to be studied.

The main contribution of this work is:

- As a relatively new technology in the area of process and industrial instrumentation, this work demonstrate the steps taken in the designing, configuring and implementing a fieldbus test rig, incorporating the real fieldbus field devices, controllers and actuators and the software development tool.

7.2 DIRECTIONS FOR FUTURE WORK

Further analysis, test and enhancement can be done to have in-depth understanding on the fieldbus system technology. There are further problems to be considered both in the configuration of the devices in the control loops and the hardware interfacing and integration issues of the fieldbus devices.

- One of the fieldbus benefits is the availability of fieldbus device to work together with other devices or the interoperability. This enables easy and tighter integration of devices from different manufacturers than what was previously been happened when substitution of a device by other manufacturer could not be done when protocols are proprietary. Thus, the issue on fieldbus interoperability is a research scope that would need to be explored.
- For many years now, DCS has been the most preferable control system architecture for controlling a process plant. Thus it is not desirable decisions to convert all conventional system all the way to fieldbus system. Some might have wanted to apply fieldbus system in only a part of the process plant. Thus, integration between conventional and fieldbus system may be required. There

are two basic ways that conventional devices can be integrated with fieldbus devices within the same system. One way is to have a traditional I/O subsystem for conventional signal (4-20mA) situated at a central location within the system. Another way is to use field-mounted converters that are connected to the fieldbus network and interfacing the conventional device. Since the I/O subsystem and the field-mounted converters are available in the fieldbus test rig, further enhancement to the existing control scheme can be done with the integration of conventional devices to the fieldbus network.

- Improvement can be made to the existing project which deals with open loop process. When the process is in open loop, the process response to PID control and the setpoint value can not be monitored and further analyzed. Thus the system reliability to control the process plant is incapable to be investigated. Hence, the system can be improved by applying the fieldbus control in the closed loop processes so that the reliability and efficiency of the fieldbus control can be further examined.

The work presented in this dissertation has contributed to an improved understanding of the procedure for configuring and implementing a fieldbus system. The work presented here offers some promising tools in terms of hardware and software handling of a fieldbus system and provides avenues for other research scope to address different aspects of issues pertaining to the fieldbus.

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APPENDIX A
FUNCTION BLOCK LIBRARY

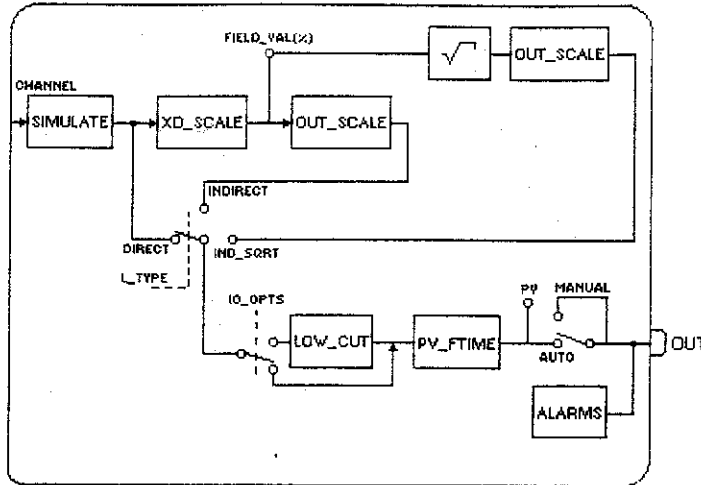
.6 - INPUT FUNCTION BLOCKS

I - Analog Input

Overview

The Analog Input block takes the input data from the Transducer block, selected by channel number, and makes it available to other function blocks at its output.

Schematic



Description

The AI block is connected to the transducer block through the CHANNEL parameter that must match with the following parameter in the transducer block:

SENSOR_TRANSDUCER_NUMBER parameter for the TT302

TERMINAL_NUMBER parameter for the IF302

The CHANNEL parameter must be set to 1 (one) if the AI block is running in the LD302, and no configuration is necessary in the transducer block to connect it to the AI block.

Transducer scaling (XD_SCALE) is applied to the value from the channel to produce the FIELD_VAL in percent. The XD_SCALE engineering units code and range must be suitable to the sensor of transducer block connected to the AI block, otherwise a block alarm indicating configuration error will be generated.

The L_TYPE parameter determines how the values passed by the transducer block will be used into the block. The options are:

Direct - the transducer value is passed directly to the PV. Therefore OUT_SCALE is useless.

Indirect - the PV value is the FIELD_VAL value converted to the OUT_SCALE.

Indirect with Square Root - the PV value is square root of the FIELD_VAL converted to the OUT_SCALE.

PV and OUT always have identical scaling based on OUT_SCALE.

The LOW_CUT parameter is an optional characteristic that may be used to eliminate noise near zero for a flow sensor. The LOW_CUT parameter has a corresponding "Low cutoff" option in the IO_OPTS bit string. If the option bit is true, any calculated output below the low cutoff value (LOW_CUT) will be changed to zero.

BLOCK_ERR

The BLOCK_ERR of the AI block will reflect the following causes:

Block Configuration Error – the configuration error occurs when one or more of the following situations occur:

When the CHANNEL or L_TYPE parameters have an invalid value;

Index	Parameter	Data Type (length)	Valid Range/ Options	Default Value	Units	Store / Mode	Description
12	GRANT_DENY	DS-70		0	na	D	
13	IO_OPTS	Bitstring(2)	See Block Options	0	na	S / O/S	See Block Options
14	STATUS_OPTS	Bitstring(2)	See Block Options	0	Na	S / O/S	See Block Options
15	CHANNEL	Unsigned16		0	None	S / O/S	The number of the logical hardware channel to the transducer that is connected to this I/O block.
16	L_TYPE	Unsigned8	1: Direct 2: Indirect 3: Indirect Square Root	0	E	S / Man	Determines how the values passed by the transducer block may be used: Directly (Direct) ; with a percent (Indirect) ; or with a percent and with square root (Ind Sqr Root).
17	LOW_CUT	Float	Non-Negative	0	OUT	S	A value of zero percent of scale is used in block processing if the transducer value falls below this limit, in % of scale. This feature may be used to eliminate noise near zero for a flow sensor.
19	PV_FTIME	Float	Non-Negative	0	Sec	S	Time constant of a single exponential filter for the PV, in seconds.
19	FIELD_VAL	DS-65			%	D / RO	Raw value of the field device in percent of the PV range, with a status reflecting the Transducer condition, before signal characterization (L_TYPE) or filtering (PV_FTIME).
20	UPDATE_EVT	DS-73			Na	D	This alert is generated by any change to the static data.
21	BLOCK_ALM	DS-72			Na	D	The block alarm is used for all configuration, hardware, connection failure or system problems in the block. The cause of the alert is entered in the subcode field. The first alert to become active will set the Active status in the Status attribute. As soon as the Unreported status is cleared by the alert reporting task, another block alert may be reported without clearing the Active status, if the subcode has changed.
22	ALARM_SUM	DS-74	See Block Options		Na	S	The current alert status, unacknowledged states, unreported states, and disabled states of the alarms associated with the function block.
23	ACK_OPTION	Bitstring(2)	0: Auto ACK Disable 1: Auto ACK Enable	0	Na	S	Selection of whether alarms associated with the block will be automatically acknowledged

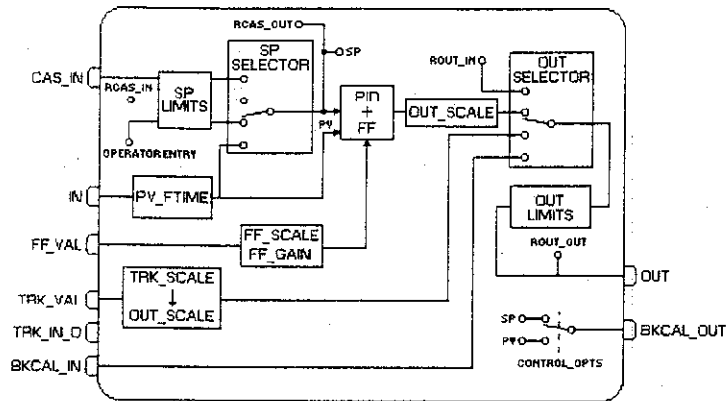
7 - CONTROL AND CALCULATION FUNCTION BLOCKS

)/EPID - PID Control/Enhanced PID Control

Overview

The PID block offers a lot of control algorithms that use the Proportional, integral and derivative terms.

Schematic



Description

The algorithm of the PID is the non-iterative or ISA. In this algorithm, the GAIN is applied to all terms of the PID, and the Proportional and the Integral actuate over the error, and the derivative actuates over the PV value. Therefore user changes of SP will not cause bump in the output due to the derivative term when the block is in Auto.

As long as an error exists, the PID function will integrate the error, which moves the output in a direction to correct the error. PID blocks may be cascaded when the difference in process time constants of a primary and secondary process measurement makes it necessary or desirable.

See the PV calculation and SP calculation section for details.

Direct and Reverse Acting

It is possible to choose the direct or reverse action of control that is made through the "Direct Acting" bit in the CONTROL_OPTS parameter:

If the "Direct acting" bit is true then the error is obtained subtracting the SP from the PV:

$$\text{Error} = (\text{PV} - \text{SP})$$

If the "Direct acting" bit is false (clear), the choice is "Reverse acting" then the error is obtained subtracting the PV from the SP:

$$\text{Error} = (\text{SP} - \text{PV})$$

The Default value of the "Direct acting" bit is false, it means "reverse action".

- Step 2 - the target mode is changed to Man in order to write BYPASS
- Step 3 - the user sets BYPASS to ON, and OUT is transferred to SP with scaling conversion
- Step 4 - the user changes the target mode to Cas
- Step 5 - the PID block reaches the Cas mode, despite of IN.Status.
- Step 7 - the status of IN becomes good
- Step 8 - the target mode is changed to Man in order to write BYPASS
- Step 9 - the user sets BYPASS to OFF, and PV is transferred to SP

CONTROL_OPTS = "Bypass Enable"

Steps	1	2	3	4	5	6	7	8	9	10	11
Target	Cas	Man		Cas				Man		Cas	
Bypass	Off		On						Off		
IN	Bad	Bad	Bad	Bad	Bad	Bad	GNC 80	GNC 80	GNC 80	GNC 80	GNC 80
SP	GC 50	GC 50	GC 20	GC 20	GC 20	GC 20	GC 20	GC 20	GC 80	GC 80	GC 80
Actual	Man	Man	Man	Man	Cas	Cas	Cas	Man	Man	Man	Cas
KCAL_OUT	NI	NI	NI	IR	GC	GC	GC	NI	NI	IR	GC
OUT	GC 20	GC 20	GC 20	GC 20	GC 20	GC 20	GC 20	GC 20	GC 20	GC 20	GC 20

Legend: GNC-Good Non Cascade status; GC-Good Cascade status

Output Tracking

The PID block supports the output track algorithm, which allows the output to be forced to a tracking value when the tracking switch is on.

In order to activate the output tracking, the block should attend the following conditions:

The "Track Enable" bit in the CONTROL_OPTS must be true.

The target mode is an "automatic" mode (Auto, Cas and Rcas) or Rout.

The TRK_VAL and TRK_IN_D status are usable, it means that the status is good or uncertain with the STATUS_OPTS."Use Uncertain as good" bit true.

The TRK_IN_D value is active.

If the target mode is Man, it is necessary besides the above conditions:

The "Track in Manual" bit in CONTROL_OPTS must be true.

When the output tracking is active, the output OUT will be replaced by the TRK_VAL converted to OUT_SCALE. The output limit status becomes constant and the actual mode goes to LO.

If the TRK_IN_D or TRK_VAL status is unusable, the Output tracking will be off and the PID will return to the normal operation.

Additional features for the Enhanced PID block (EPID)

The EPID function block provides the following additional features:

1- Different type of transfer from a "manual" mode to an "automatic" mode.

The BUMPLESS_TYPE parameter provides four types of transfer from a "manual" mode to an "automatic" mode:

a.bumpless : This is the default value and the behavior of the standard PID block. The block starts to calculate from the last value in the "manual " mode.

Situation	PID_OPTS	Mode		Algorithm Action
		Target	Actual	
TRK_IN_D is not usable	0x00		"auto"	. Output tracking is not active. . The algorithm continues the normal calculation.
	IFS if Bad TRK_IN_D		"auto" -> lman	. Output tracking is not active. . The algorithm continues the normal calculation. . OUT.Status is GoodC-IFS. . When the output block goes to fault state, the upper blocks go to lman.
	Man if Bad TRK_IN_D		Man	. Output tracking is not active. . The algorithm stops the calculation.
	"Target to Man if Bad TRK_IN_D"; "Man if Bad TRK_IN_D"	Man	Man	. Output tracking is not active. The target mode is changed to Man.
TRK_VAL is not usable	0x00		"auto"	. Output tracking is not active. . The algorithm continues the normal calculation.
	IFS if Bad TRK_VAL		"auto" -> lman	. Output tracking is not active. . The algorithm continues the normal calculation. OUT.Status is GoodC-IFS. . When the output block goes to fault state, the upper blocks go to lman.
	Man if Bad TRK_VAL		Man	. Output tracking is not active. . The algorithm stops the calculation.
	"Target to Man if Bad TRK_VAL"; "Man if Bad TRK_VAL"	Man	Man	. Output tracking is not active. the target mode is changed to Man.
TRK_IN_D and TRK_VAL is usable, TRK_IN_D is active, output tracking is enabled			LO	Output Tracking is active.

If the additional parameters of EPID block is configured with the default values, the block works as the standard PID block.

BLOCK_ERR

The BLOCK_ERR of the PID block will reflect the following causes:
 Block Configuration Error – the configuration error occurs when the BYPASS and SHED_OPT parameters have an invalid value;
 Out of Service – it occurs when the block is in O/S mode.

Supported Modes

O/S, IMAN, LO, MAN, AUTO, CAS, RCAS and ROUT.

Control Algorithm

$$OUT = GAIN * \left[E + \frac{RATE * S}{1 + \alpha * RATE * S} * PV + \frac{E}{RESET * S} \right] + BIAS_A/M + FEEDFORWARD$$

NOTE: ① BIAS_A/M: Internal BIAS Calculated on changing to automatic modes (RCAS, CAS, AUTO).
 • α: Pseudo - Derivative Gain Equals to 0.13

Index	Parameter	Data Type (length)	Valid Range/Options	Default Value	Units	Store / Mode	Description
21	SP_HI_LIM	Float	PV_SCALE +/- 10%	100	PV	S	The setpoint high limit is the highest setpoint operator entry that can be used for the block.
22	SP_LO_LIM	Float	PV_SCALE +/- 10%	0	PV	S	The setpoint low limit is the lowest setpoint operator entry that can be used for the block.
23	GAIN	Float		0	None	S	Proportional term of the PID. It is the Kp value.
24	RESET	Float	Positive	+INF	sec	S	Integral term of the PID. It is the Tr value.
25	BAL_TIME	Float	Positive	0	sec	S	This specifies the time for the internal working value of bias or ratio to return to the operator set bias or ratio, in seconds. In the PID block, it may be used to specify the time constant at which the integral term will move to obtain balance when the output is limited and the mode is Auto, Cas, or Rcas.
26	RATE	Float	Positive	0	sec	S	Derivative term of the PID. It is the Td value.
27	BKCAL_IN	DS-65			OUT	N	The value and status from a lower block's BKCAL_OUT that is used to prevent reset windup and to initialize the control loop.
28	OUT_HI_LIM	Float	OUT_SCALE +/- 10%	100	OUT	S	Limits the maximum output value.
29	OUT_LO_LIM	Float	OUT_SCALE +/- 10%	0	OUT	S	Limits the minimum output value.
30	BKCAL_HYS	Float	0 to 50%	0.5%	%	S	The amount that the output must change away from its output limit before the limit status is turned off, expressed as a percent of the span of the output.
31	BKCAL_OUT	DS-65			PV	D/RO	The value and status required by an upper block's BKCAL_IN so that the upper block may prevent reset windup and provide bumpless transfer to closed loop control.
32	RCAS_IN	DS-65			PV	D	Target setpoint and status provided by a supervisory Host to a analog control or output block.
33	ROUT_IN	DS-65			OUT	D	Target output and status provided by a Host to the control block for use as the output (Rout mode).

I - Input Selector**Description**

The signal selector block provides selection of up to four inputs and generates an output based on the configured action. This block would normally receive its input from an AI or another block and not directly from a transducer. In addition to signal selection the block can also perform max, min, mid, avg and first good selection. With the combination of parameter configuration options the block can function as a rotary position switch, or a validated priority selection based on the use of the first good parameter and the DISABLE_n parameter. As a switch the block can receive switch toggle information from both the connected inputs or from an operator input. The block also supports the concept of a middle selection. Logic is provided for handling of dubious and bad signals in conjunction with configured actions. The intended application of this block is to provide control signal selection in the forward path only and is not intended to receive signals from the output of a controller, therefore, no back calculation support is provided.

The algorithm has the following actions, choose by the SELECT_TYPE parameter:

Max = select the max from all the connected and good inputs

Min = select the min from all the connected and good inputs

Mid = select the middle value from all the connected and good inputs, if less than MIN_GOOD inputs are connected then an error code is generated. An error code is also generated if less than MIN_GOOD values have good status. Not intended for use with 2 or 4 inputs. Although the normal configuration for this feature would be with three signals the block will generate an average of the middle two if four signals are configured or the average of two if three are configured and a bad status is passed on one of the inputs.

First Good = determine the first good input encountered based on ascending evaluation of the inputs, see text for further discussion

Avg = compute the average for all the connected and good inputs, if less than two inputs are connected then set the output equal to the input and generate an error code. An error code is also generated if less than MIN_GOOD inputs have good status.

The processing of the block is as follows:

If DISABLE_n is true then the respective input IN_n is not used.

Inputs whose status is bad are ignored. Process the dubious option.

MIN_GOOD specifies the minimum available signals for OUT status to be good. If there are no inputs left, or fewer than MIN_GOOD inputs then set the status of OUT to Bad and the value of SELECTED to zero. Do not do selection processing.

For Average ("Avg") the status of OUT is set to worst of inputs considered, then average of the useable inputs is calculated, if none are useable then the output status is bad.

When SELECT_TYPE is "Mid", "First Good", "Max", or "Min", set the status of OUT to the status of the selected input. The "First Good" option starts at the first input then the second until it encounters an input whose DISABLE_n is not set and its status is Good, and then transfers this value to the output of the block.

If OP_SELECT is non-zero, the OP_SELECT value will override the SELECT_TYPE selection.

SELECTED is a second output which will indicate which input has been selected by the algorithm for all SELECT_TYPE except "Avg", when it reflects the number of inputs used in the average. The SELECTED output always has a good status, unless the block is out of service.

BLOCK_ERR

The BLOCK_ERR of the ISEL block will reflect the following causes:

Block Configuration Error – the configuration error occurs when the SELECT_TYPE parameter has an invalid value;

Out of Service – it occurs when the block is in O/S mode.

Supported Modes

O/S, MAN and AUTO.

Index	Parameter	Data Type (length)	Valid Range/Options	Default Value	Units	Store / Mode	Description
19	SELECT_TYPE	Unsigned8	1=First good 2=MIN 3=MAX 4=MID 5=AVG	0	E	S	<p>selector action</p> <p>max = select the max from all the connected and good inputs</p> <p>min = select the min from all the connected and good inputs</p> <p>mid = select the mid value from all the connected and good inputs, if less than min_good inputs are connected then an error code is generated. An error code is also generated if less than min_good values have good status. Not intended for use with 2 or 4 inputs.</p> <p>First Good = determine the first good input encountered based on ascending evaluation of the inputs, see text for further discussion</p> <p>avg = compute the average for all the connected and good inputs, if less than two inputs are connected then set the output equal to the input and generate an error code. An error code is also generated if less than min_good inputs have good status.</p>
20	MIN_GOOD	Unsigned8	0 through 4	0		S	<p>If the number of inputs which are good is less than the value of MIN_GOOD then set the out status to bad.</p>
21	SELECTED	DS-66	None, 1= 1 2= 2 3= 3 4= 4			D / RO	<p>An integer indicating which input has been selected.</p>
22	OP_SELECT	DS-66	0 = Normal Operation 1= Selects IN1 2= Selects IN2 3= Selects IN3 4= Selects IN4		None	D	<p>An operator adjustable parameter to force a given input to be used. Selecting 0 will indicate normal operation while choosing 1 to 4 will indicate the input to be used.</p>
23	UPDATE_EVT	DS-73			na	D	<p>This alert is generated by any change to the static data.</p>
24	BLOCK_ALM	DS-72			na	D	<p>The block alarm is used for all configuration, hardware, connection failure or system problems in the block. The cause of the alert is entered in the subcode field. The first alert to become active will set the Active status in the Status attribute. As soon as the Unreported status is cleared by the alert reporting task, another block alert may be reported without clearing the Active status, if the subcode has changed.</p>

Legend: E – Enumerated parameter; na – Adimensional parameter; RO – Read only; D – dynamic; N – non-volatile; S - static

Gray Background Line: Custom Parameters

If BEHAVIOR parameter is “Adapted”:

The default value of SELECT_TYPE is First good.

Simulate

The SIMULATE parameter is used for the diagnostics and checkout purposes. When it is active, the transducer value and status will be overridden by the simulate value and status. The SIMULATE can be disabled either by software in the SIMULATE parameter or hardware through the jumper.

The SIMULATE structure is composed by the following attributes:

Simulate Value and Status

Transducer Value and Status

Simulate Enable/Disable

The Transducer Value/Status attributes of SIMULATE parameter are always showing the value that the AO block receives from the corresponding transducer block.

There is a hardware jumper to disable the SIMULATE parameter. If this jumper is placed Off, then the simulation will be disabled. In this case, the user cannot change the ENABLE/DISABLE attribute. This jumper prevents simulation from accidentally being enabled during plant operations. When the jumper is placed ON, it will cause "Simulate Active" attribute in the BLOCK_ERR of Resource block to be true.

The simulate is active if the following conditions exist:

The simulate hardware jumper is not placed Off;

The SIMULATE.ENABLE/DISABLE parameter is "Active".

When simulation is active, the READBACK and PV parameters will be calculated based on the attribute Simulate Value/Status of the SIMULATE parameter. Otherwise it will be that one supplied by the transducer block in the Transducer Value/Status attribute of the SIMULATE parameter.

Readback parameter

If the hardware supports a readback value, such as valve position, then the value will be read by the transducer block and it will be provided to the corresponding AO block through the Transducer Value/Status attribute of the SIMULATE parameter. If not supported, the Transducer Value/Status attribute of the SIMULATE parameter is generated from AO.OUT by the transducer block.

The READBACK parameter has a copy of the Transducer Value/Status attribute of the SIMULATE parameter if the simulation is disabled, otherwise it is a copy of the Simulate Value/Status attribute of the SIMULATE parameter

The PV is the READBACK parameter converted to the PV_SCALE, therefore the PV can be simulated through the SIMULATE parameter.

In addition, the block admits safe action as described early in the fault state processing. The AO block supports the mode-shedding feature as described early in the mode parameter.

BLOCK_ERR

The BLOCK_ERR of the AO block will reflect the following causes:

Block Configuration Error – the configuration error occurs when one or more of the following situations occur:

When the CHANNEL or SHED_OPT parameters have an invalid value;

When the XD_SCALE does not have a supported engineering unit and/or range for the respective the transducer block.

When the transducer block is in O/S mode.

When it is not compatible the CHANNEL parameter and HC configuration (DFI302).

Simulate Active – When the Simulate is active.

Local Override – When the block is in LO mode because the fault state is active.

Output Failure – I/O module failure (DFI302)

Out of Service – Occur when the block is in O/S mode.

Index	Parameter	Data Type (length)	Valid Range/Options	Default Value	Units	Store / Mode	Description
13	GRANT_DENY	DS-70		0	Na	D	
14	IO_OPTS	Bitstring(2)	See Block Options	0	Na	S / O/S	See Block Options
15	STATUS_OPTS	Bitstring(2)	See Block Options	0	Na	S / O/S	See Block Options
16	READBACK	DS-65			XD	D / RO	Indicate the readback of the actual position of the transducer, in transducer units.
17	CAS_IN	DS-65				D	This parameter is the remote setpoint value, which must come from another Fieldbus block, or a DCS block through a defined link.
18	SP_RATE_DN	Float	Positive	+INF	PV/Sec	S	Ramp rate at which upward setpoint changes in PV units per second. It is disable if is zero or +INF. Rate limiting will apply in AUTO, CAS and RCAS modes.
19	SP_RATE_UP	Float	Positive	+INF	PV/Sec	S	Ramp rate at which downward setpoint changes in PV units per second. It is disable if is zero or +INF. Rate limiting will apply in AUTO, CAS and RCAS modes.
20	SP_HI_LIM	Float	PV_SCALE +/- 10%	100	PV	S	The setpoint high limit is the highest setpoint operator entry that can be used for the block.
21	SP_LO_LIM	Float	PV_SCALE +/- 10%	0	PV	S	The setpoint low limit is the lowest setpoint operator entry that can be used for the block.
22	CHANNEL	Unsigned16		0	None	S / O/S	The number of the logical hardware channel to the transducer that is connected to this I/O block.
23	FSTATE_TIME	Float	Positive	0	Sec	S	The time in seconds to ignore the existence of a new fault state condition. If the fault state condition does not persist for FSTATE_TIME seconds and while this time does not elapse, the block will execute in the last actual mode.
24	FSTATE_VAL	Float	PV_SCALE +/- 10%	0	PV	S	The preset analog SP value to use when fault occurs. This value be used if the I/O option fault state to value is selected.
25	BKCAL_OUT	DS-65			PV	D / RO	The value and status required by an upper block's BKCAL_IN so that the upper block may prevent reset windup and provide bumpless transfer to closed loop control.
26	RCAS_IN	DS-65			PV	D	Target setpoint and status provided by a supervisory Host to a analog control or output block.

APPENDIX B
FIELD DEVICES SPECIFICATION

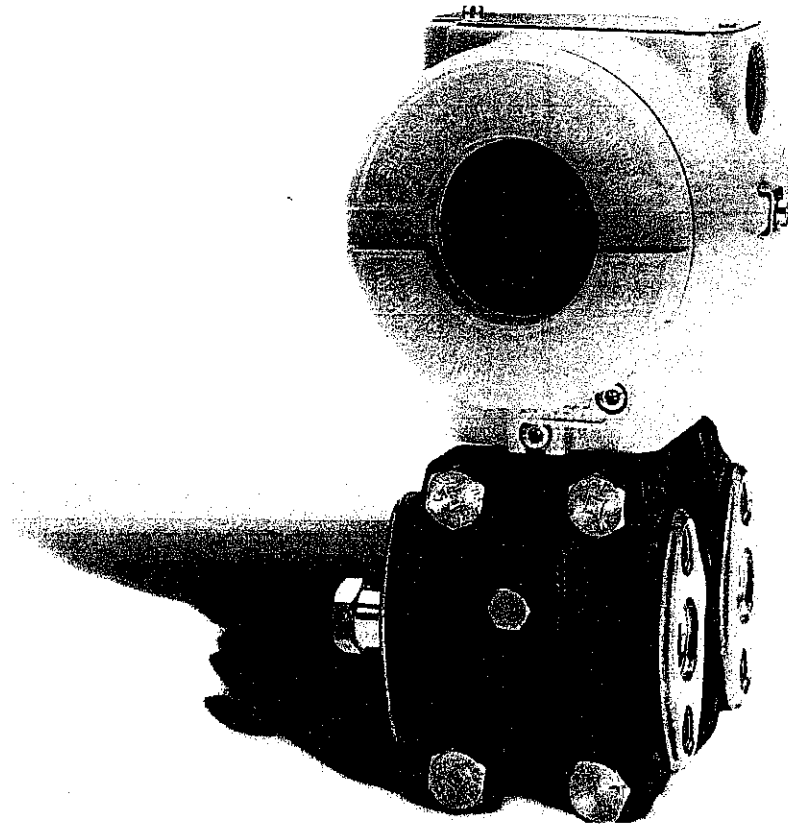
LD302 Series

FIELD BUS PRESSURE TRANSMITTERS

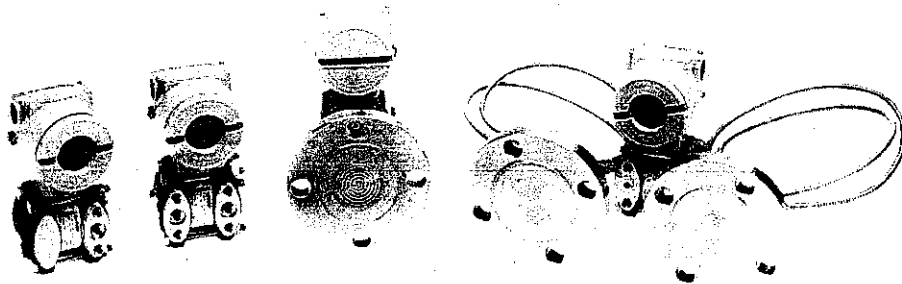


Features

- 0 ~ 125 Pa to 0 ~ 40 MPa.
- (0 ~ 0.5 inH₂O to 0 ~ 5800 psi).
- 0.075% accuracy of the calibrated range.
- Accepts calibration from URL to URL/40.
- Wetted parts in 316 SS, Hastelloy, Tantalum.
- Digital LCD display (optional).
- Configuration through FIELD BUS communication from a PC or by the local adjustment switches (should be used the display).
- Instantiation and deletion of function blocks.
- Totally digital; sensor, electronics and communication.
- Self diagnostics.
- Weather proof, explosion proof and intrinsically safe.
- Network master capability.



APID	ADVANCED PID – It has all the standard features plus: bumpless or hard transfer from a "manual" mode to an "automatic" mode, bias, Adaptive gain, PI sampling, dead-band for error, special treatment for error, ISA or parallel algorithm.
ARTH	ARITHMETIC – This calculation block provides some pre-defined equations ready for use in applications as flow compensation, HTG, ratio control and others.
INTG	INTEGRATOR – It integrates a variable in function of the time. There is a second flow input that may be used for the following applications: net flow totalization, volume/mass variation in vessels and precise flow ratio control.
ISEL	INPUT SELECTOR – This block has four analog inputs that may be selected by an input parameter or according to a criterion as first good, maximum, minimum, middle and average.
CHAR	SIGNAL CHARACTERIZER – It has capability for two signal characterization based on the same curve. The second input has an option for swapping "x" to "y", providing an easy way to use the inverse function, that may be used in signal characterization of read-back variables.
AALM	ANALOG ALARM – This alarm block has dynamic or static alarm limits, hysteresis, temporary expansion of alarm limits on step setpoint changes to avoid nuisance alarms, two levels of alarm limits and delay for alarm detection.
TIME	TIMER – This block has four discrete inputs that are processed by combination logic. The selected timer processing type operates on the combined input signal to produce a measurement, delay, extension, and pulse or debounce.
LLAG	LEAD-LAG – This block provides dynamic compensation of a variable. It is used normally in a feed-forward control.
OSDL	OUTPUT SELECTOR / DYNAMIC LIMITER – It has two algorithms: <ul style="list-style-type: none"> - Output selector – selection of output by a discrete input. - Dynamic limiter – this algorithm was developed specially for double cross limit in combustion control.
CT	CONSTANT – It provides analog and discrete output parameters with constant values.
DENS	DENSITY – This block has a special algorithm to calculate the density in different types of engineering units: Plato degree, INPM and others.



Temperature Effect $\pm(0.02\% \times \text{URL} + 0.1\% \times \text{span})$ per 20 °C (36 °F) for ranges 2, 3, 4 & 5.
 $\pm(0.05\% \times \text{URL} + 0.15\% \times \text{span})$ per 20 °C (36 °F) for range 1 and level models.

Static Pressure Effect

Zero error:
 $\pm 0.1\%$ URL per 7 MPa (1000 psi) for ranges 2, 3, 4 & 5 or 3.5 MPa (500 psi) for L models.
 $\pm 0.1\%$ URL per 1.7 MPa (250 psi) for range 1.

This is a systematic error that can be eliminated by calibrating at the operating static pressure.

Span error:
Correctable to $\pm 0.2\%$ of reading per 7 MPa (1000 psi) for ranges 2, 3, 4 and 5, and 3.5 MPa (500 psi) for range 1 and level models.

Power Supply Effect $\pm 0.005\%$ of calibrated span per volt.

Mounting Position Zero shift of up to 250 Pa (1 inH₂O) which can be calibrated out.
No span effect.

Electro-Magnetic Interference Effect Designed to comply with IEC 801.

Physical Specifications

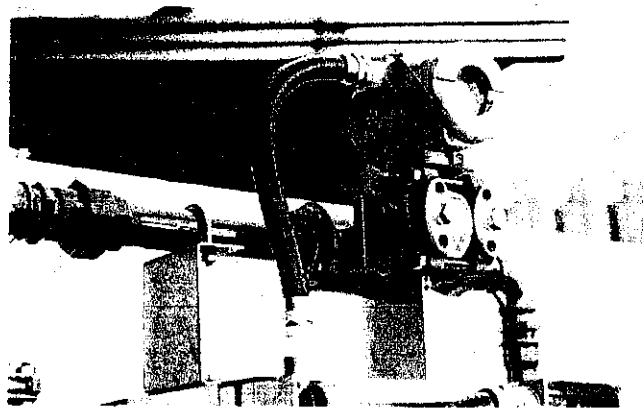
Electrical Connection $\frac{1}{2}$ -14 NPT, Pg 13,5 or M20 x 1,5 metric. Other connections on request.

Process Connection $\frac{1}{4}$ -18 NPT or $\frac{1}{2}$ -14 NPT (with adapter).
For L models see Ordering Code.

Wetted Parts

- Isolating Diaphragms
316L SST, Hastelloy C276, Monel 400 or Tantalum.
- Drain/Vent Valves and Blind Plug
316 SST, Hastelloy C276 or Monel 400.
- Flanges
Plated carbon steel, 316 SST, Hastelloy C276 or Monel 400.
- Wetted O-Rings (For Flanges and Adapters)
Buna N, Viton™ or PTFE. Ethylene-Propylene on request.
The LD302 is available in materials conforming to NACE MR-01-75.

	<ul style="list-style-type: none"> - Electronic Housing Injected aluminum with polyester painting or 316 SST (NEMA 4X, IP67). - Blank Flange Plated carbon steel, when the wetted flange is made of this same material, and 316 SST in the other cases. - Level Flange (LD302L) Material 316 SST. - Fill Fluid Silicone or Fluorolube Oil. - Cover O-Rings Buna N. - Mounting Bracket Plated carbon steel with polyester painting or 316 SST. Accessories (bolts, nuts, washers and U-clamp) in carbon steel or 316 SST. - Flange Screws, Bolts and nuts Plated carbon steel, Grade 7 or 316 SST. - Identification Plate 316 SST.
Mounting	<ul style="list-style-type: none"> a) Flange mounted for models LD302L. b) Optional universal mounting bracket for surface or vertical/horizontal 2"-pipe (DN 50). c) Via bracket on manifold valve (Optional). d) Directly on piping for closely coupled transmitter/ orifice flange combinations.
Approximate Weights	<p>3.15 kg (7 lb): all models, except level transmitters. 5.85 to 9.0 kg (13 lb. to 20 lb): level transmitter depending on the flanges, extension and materials.</p>



Description

The TT302 is from the first generation of Fieldbus devices. It is a transmitter mainly intended for measurement of temperature using RTDs or thermocouples, but can also accept other sensors with resistance or mV output such as: pyrometers, load cells, resistance position indicators, etc. The digital technology used in the TT302 enables a single model to accept several types of sensors, wide ranges, single-ended or different measurement and an easy interface between the field and the control room and several interesting features that reduce considerably the installation, operation and maintenance costs. The transmitter accepts two channels, i.e., two measurements. This reduces the cost per channel.

The TT302 is part of Smar's complete 302 series of Fieldbus devices. Fieldbus is a complete system enabling distribution of the control function to equipment in the field.

Using Fieldbus technology, with its capability to interconnect several devices, very large control schemes can be constructed. In order to be a user friendly, the function block concept was introduced. The user may now easily build and overview complex control strategies. Another advantage is adding flexibility, the control strategy may be edited without having to rewire or change any hardware.

The need for Fieldbus implementation in small as well as large systems was considered when developing the entire 302 series of Fieldbus devices. They have the common features of being able to act as a master on the network and be locally configured using a magnetic tool, eliminating the need for a configurator or console in many basic applications.

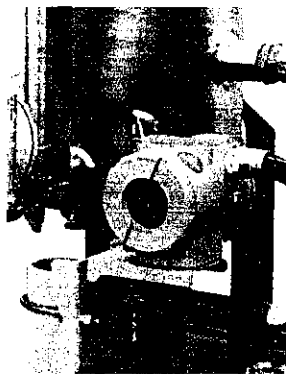
**Function
Blocks Table**

BLOCK	
RES	RESOURCE – This block contains data that is specific to the hardware that is associated with the resource.
TRD	TRANSDUCER BLOCK – This block converts the primary variables of the physical I/O devices into the proper engineering
DSP	DISPLAY TRANSDUCER – This block configures what process variables of the function blocks will be displayed in the device LCD panel.
DIAG	DIAGNOSTICS TRANSDUCER – It provides online measurement of block execution time, check of links between blocks and other features.
AI	ANALOG INPUT – This block takes the input data from the transducer block and makes it available to other function blocks. It has scaling conversion, filtering, square root and low cut.
PID	PID CONTROL – This standard block has a lot of valuable features as setpoint treatment (value and rate limiting), filtering and alarm on PV, feed-forward, output tracking and others.

*Technical
Characteristics*

Functional Specifications

Inputs Signal	See following table for options.
Output Signal	Digital only. FOUNDATION™, 31.25 kbit/s voltage mode with bus power.
Power Supply	Bus powered: 9 - 32 Vdc. Current consumption quiescent 12 mA.
Indicator	Optional 4½-digit numerical and 5-character alphanumeric LCD indicator.
Hazardous Area Certifications	Explosion proof, weather proof and intrinsically safe (CENELEC and FM standards).
Temperature Limits	Ambient: -40 to 85 °C (-40 to 185 °F). Storage: -40 to 100 °C (-40 to 212 °F). Display: -10 to 60 °C (14 to 140 °F) operation. -40 to 85 °C (-40 to 185 °F) without damage.
Humidity Limits	10 to 60% RH.
Turn-on Time	Approximately 10 seconds.
Update Time	Approximately 0.2 second.
Configuration	Basic configuration may be done using local adjustment magnetic tool if device is fitted with display. Complete configuration is possible using remote configurator.



Physical Specifications

Electrical Connection 1/2-14 NPT, Pg 13,5 or M20 x 1,5 metric.

Material of Construction Injected low copper aluminum with polyester painting or 316 Stainless Steel housing, with Buna N O-rings on covers (NEMA 4X, IP67).

Mounting Can be attached directly to the sensor. With an optional bracket can be installed on a 2" pipe or fixed on a wall or panel.

Weight Without display and mounting bracket: 0.80 kg.
Add for digital display: 0.13 kg.
Add for mounting bracket: 0.60 kg.

2, 3 or 4 WIRES

DIFFERENTIAL

SENSOR	TYPE	2, 3 or 4 WIRES				DIFFERENTIAL			
		RANGE (°C)	RANGE (°F)	MINIMUM SPAN (°C)	ACCURACY (°C)	RANGE (°C)	MINIMUM SPAN (°C)	RANGE (°F)	ACCURACY (°C)
RTD	Cu10 GE	-20 to 250	-4 to 482	50	±1.0	-270 to 270	-454 to 518	50	±2.0
	Ni 120 DIN	-50 to 270	-58 to 518	5	±0.1	-320 to 320	-544 to 608	5	±0.5
	Pt50 IEC	-200 to 850	-328 to 1562	10	±0.25	-1050 to 1050	-1858 to 1922	10	±1.0
	Pt100 IEC	-200 to 850	-328 to 1562	10	±0.2	-1050 to 1050	-1858 to 1922	10	±1.0
	Pt500 IEC	-200 to 450	-328 to 842	10	±0.25	NA	NA	NA	NA
	Pt50 JIS	-200 to 600	-328 to 1112	10	±0.25	-850 to 850	-1498 to 1562	10	±1.0
	Pt100 JIS	-200 to 600	-328 to 1112	10	±0.25	-800 to 800	-1408 to 1472	10	±1.5
THERMO-COUPLE	B NBS	+100 to 1800	+212 to 3272	50	±0.5*	-1600 to 1600	-2848 to 2912	60	±1.0*
	E NBS	-100 to 1000	-148 to 1832	20	±0.2	-1100 to 1100	-1948 to 2012	20	±1.0
	J NBS	-150 to 750	-238 to 1382	30	±0.3	-900 to 900	-1588 to 1652	30	±0.6
	K NBS	-200 to 1350	-328 to 2462	60	±0.6	-1550 to 1550	-2758 to 2822	60	±1.2
	N NBS	-100 to 1300	-148 to 2372	50	±0.5	-1400 to 1400	-2488 to 2552	50	±1.0
	R NBS	0 to 1750	32 to 3182	40	±0.4	-1750 to 1750	-3118 to 3182	40	±2.0
	S NBS	0 to 1750	32 to 3182	40	±0.4	-1750 to 1750	-3118 to 3182	40	±2.0
	T NBS	-200 to 400	-328 to 752	15	±0.15	-600 to 600	-1048 to 1112	15	±0.8
	L DIN	-200 to 900	-328 to 1652	35	±0.35	-1100 to 1100	-1948 to 2012	35	±0.7
	U DIN	-200 to 600	-328 to 1112	50	±0.5	-800 to 800	-1408 to 1472	50	±2.5

* Not applicable below 440°C
NA Not applicable.

Reliable and flexible

Elimination of many mechanical parts seen in other positioners has a number of advantages. Higher reliability as there are fewer parts that wear, safer as there are less moving parts, more accurate as there is less dead-band from mechanical imprecision.

Position sensing is done without any mechanical contact virtually eliminating wear and tear and subsequent degradation. FY302 directly senses longitudinal or rotary movement based on the Hall effect. The position signal may also be used in advanced control schemes.

Valve characteristics, action, absolute and rate-of-change limits, etc. are altered in software instead of a mechanical cam and spring, changing, action or characteristics between linear, equal percentage, hyperbolic (quick opening) or a freely configurable table may be done remotely by the click of a button. These and other software capabilities make the FY302 extremely flexible.

Self diagnostics

The continuous self diagnostics of the positioner issues alerts for a range of hardware and software failures and problems with the positioner or valve immediately, enabling maintenance personnel to pinpoint errors instantly or even before they can cause any harm. The diagnostic data may also be accessed on demand.

The benefit for the operator to get this information without having to bring the valve or positioner in to a workshop for testing is obvious. The time that can be saved by not having to test only a few units is enormous.

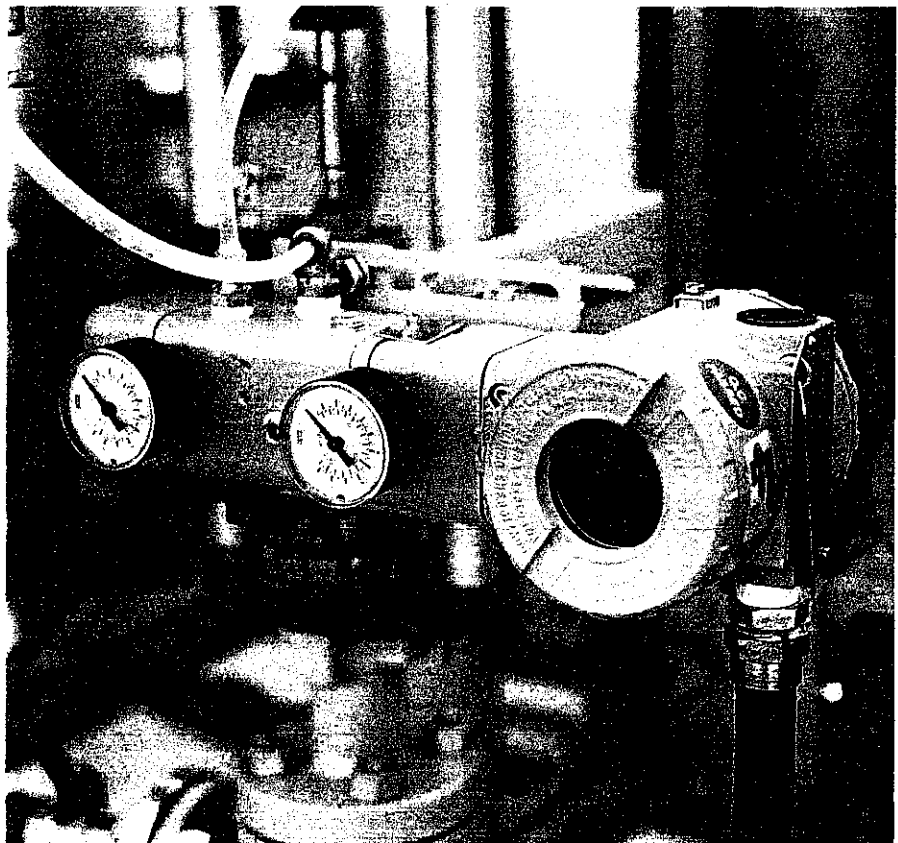
Diagnostics enables you to quickly determine if a process problem is due to the valve/positioner or not, without having to do several field visits. Production can get back in operation in minutes.

The diagnostics functions are also suitable for preventive maintenance such as detection of increasing valve dead-band and "stick-slip" operation.

There is also software limit switches for travel, which automatically alerts the operator.



TIME	TIMER - This block has four discrete inputs that are processed by combination logic. The selected timer processing type operates on the combined input signal to produce a measurement, delay, extension, and pulse or debounce.
LLAG	LEAD-LAG - This block provides dynamic compensation of a variable. It is used normally in a feed-forward control.
OSDL	OUTPUT SELECTOR / DYNAMIC LIMITER - It has two algorithms: <ul style="list-style-type: none"> - Output selector - selection of output by a discrete input. - Dynamic limiter - this algorithm was developed specially for double cross limit in combustion control.
CT	CONSTANT - It provides analog and discrete output parameters with constant values.



Performance Specifications

Resolution	≤ 0.1% F.S.
Repeatability	≤ 0.1% F.S.
Hysteresis	≤ 0.2% F.S.
Consumption	0.25 Nm ³ /h (0.15 scfm) at 1.4 bar (20 psi) supply. 0.70 Nm ³ /h (0.40 scfm) at 5.6 bar (80 psi) supply.
Output Capacity	46.7 Nm ³ /h (28 scfm) at 5.6 (80 psi) supply.
Ambient Temperature Effect	0.8%/20°C do span.
Supply Pressure Effect	Negligible.
Vibration Effect	15-150 Hz at 2 g. 150-2000 Hz at 1g. Reference SAMA PMC 31.1 - 1980, Sec. 5.3, Condition 3, Steady State.
Electro-Magnetic Interference Effect	Designed to comply with IEC 801 and European Standards EN50081 and EN50082.

Physical Specifications

Electrical Connection	1/2 -14 NPT, Pg 13,5 or M20 x 1,5.
Pneumatic Connections	Supply and output: 1/4 - 18 NPT. Gage: 1/8 - 27 NPT.
Material of Construction	Injected low copper aluminum with polyester painting or 316 Stainless Steel housing, with Buna-N O-rings on cover (NEMA 4X, IP67).
Weight	Without display and mounting bracket: 2.7 kg. Add for digital display: 0.1 kg.