

E4: Exercise on Fieldbus Control System

OBJECTIVES: Before embarking on this hands-on session, the students should have been introduced to the concept of Fieldbus Control System (FCS) in the lectures. This hands-on experiment allows students to go through the configuration and operation procedure of a fieldbus control system via practice on the temperature control of a thermal chamber.

Background: Control system is the integration of hardware and software components, which support the implementation of control functions. Since 1920s, control systems have evolved from loop-localized to distributed, analog to digital, input/output transmitting to network communication. The FCS, the modern control architecture of today, has gained wide acceptance in process control industries. FCS makes possible data transfer between devices such as transmitters, valve positioners, controllers, workstations and servers via digital communication. A major advantage of digital communications is that a great deal of information (apart from simple I/O variables but also operational information such as setpoint and mode, alarms, and tuning) can be communicated on a single cable. To ease the problem of lack of interoperability for devices from different manufacturers, since every vendor developed his own protocol independently of others, industry experts have worked towards vendor-independent fieldbus standards since 1985. One of them is Foundation Fieldbus, which is supported by the setup that we will use for this experiment. The Foundation Fieldbus specification is uniquely different from other networking technologies in that it is not only a communication protocol, but also a programming language for building control strategies. One of the possibilities that a standard programming language and powerful communications features enable is the ability to perform control that is distributed into the field devices rather than a central controller. The rich library of function blocks provided by Foundation Fieldbus makes control implementation, process monitoring, fault diagnosis and others much easier.

This hands-on exercise will attempt to get the students exposed to a real FCS setup via temperature control of a thermal chamber. Step by step instructions are presented to guide the students go through configuration, operation and controller tuning procedures. At the end of this session, they will also gain some experience in PID controller tuning.

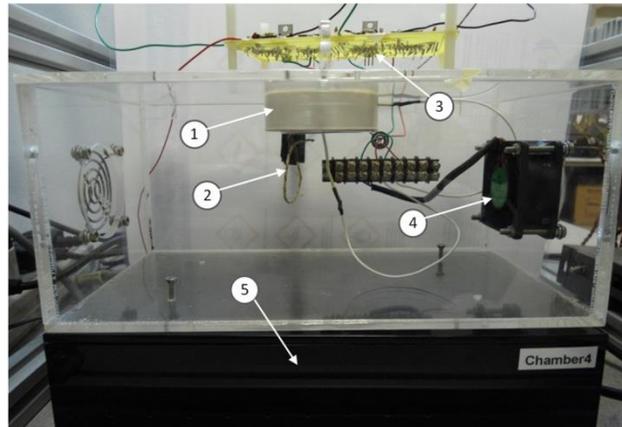
1. Thermal Chamber

Figure 1 shows the setup of the thermal chamber system. One J-type thermocouple is used as the temperature sensor to measure the air temperature in the chamber. The +13V power supply at the bottom of the chamber provides the power for both the bulb and fan, by being routed through the driver circuit located at the top of the chamber.

The air temperature can be controlled by adjusting the inputs to the bulb and fan. Real-time experiments can be easily implemented by connecting the setup with Fieldbus network. In this system, the controlled

variable of interest is the temperature of the chamber, with the electrical input to the bulb acting as the controlling variable. The fan serves as a disturbance source, and you may assume that the input to the fan is a disturbance signal which is measurable.

The thermal chamber can mimic as a thermal unit in a HVAC system or a temperature process and control unit in a large scale chemical process.



1. 12V Light with 20W halogen Bulb (draws 1.5A)
2. J-Type Thermocouple
3. Driver Circuit
4. 12V Fan (draws 0.15A)
5. PS-3 Power Supply (13V 4A)

Figure 1: SETUP OF THERMAL CHAMBER SYSTEM

2. Fieldbus Setup

A Fieldbus Control System, SYSTEM302 by SMAR (a supplier of FCS), has been set up in the laboratory. SYSTEM302 has gained prominence as an industrial automation solution. Figure 2 shows the schematic of the fieldbus control setup. Please inspect the setup and compare it with the illustrative scheme.

As shown in Figure 2, the whole network basically comprises of three FF-compliant devices, DFI302, TT302 and FI302. All the devices are connected together through twisted pairs, which form the Fieldbus network. A more detailed description of these devices is given below.

DFI302-Fieldbus Universal Bridge

This is a key-interfacing element in the distributed architecture of FCS. It comprises of Fieldbus power supplies (DF50, DF52), Controllers (DF62) and line impedance modules (DF53). It combines powerful communication features with direct I/O access and advanced control for discrete and continuous applications. In our application, it serves as a bridge between workstation and fieldbus networks.

TT302- Temperature Transmitter

This device converts a temperature analog signal into a FOUNDATION™ fieldbus digital signal.

It is intended for measurement of temperature using RTDs or thermocouples. However, it can also accept other sensors with resistance or mV output such as: pyrometers, load cells, resistance position indicators, etc. In our case, a J type thermocouple, as shown in Figure 3, is connected to TT302. Please check the wire connection to make sure it is similar to that depicted in Figure 3.

FI302 – FF to Current Converter

This device converts a FOUNDATION™ fieldbus digital signal into an analog 4 to 20 mA signal.

It produces a 4 -20 mA output proportional to the input received by the Fieldbus network. It serves as an actuation unit to output control signals. At most, it provides triple channels output. In our case, only two channels, connecting to the drive circuit, are used. One is to control the bulb, while another is to control the fan.

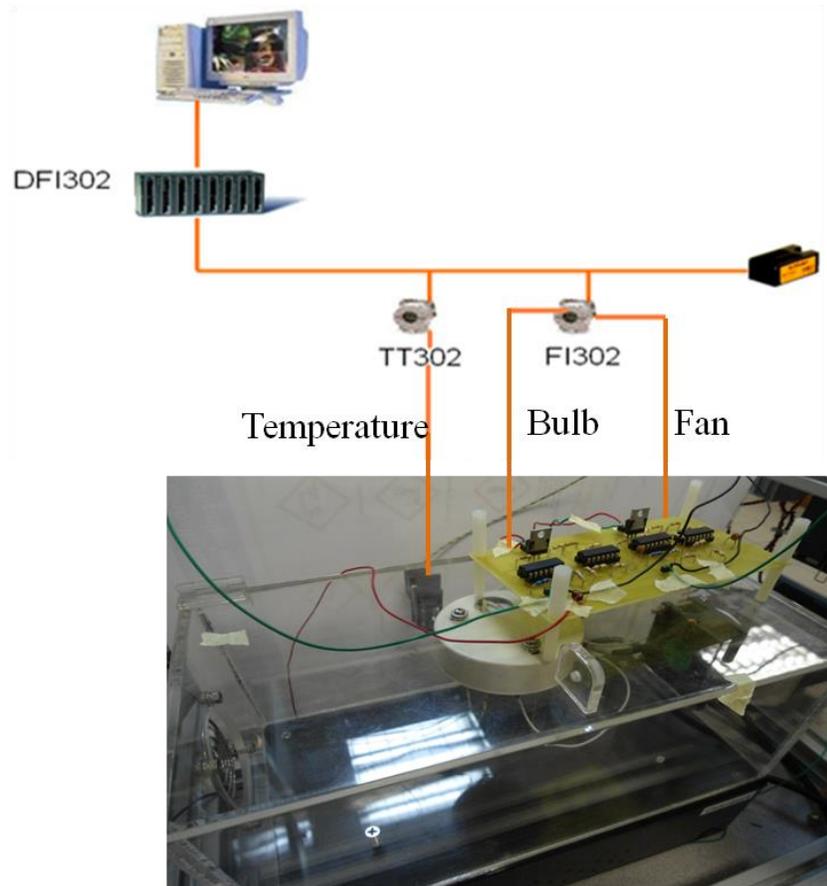


Figure 2: Setup for control of thermal chamber using of Fieldbus Control System

TT302 Terminals

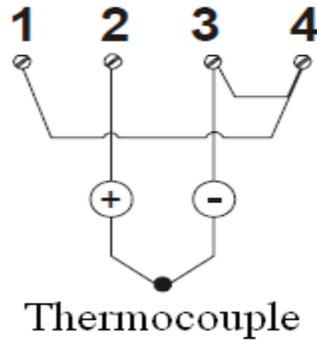


Figure 3: TT302 Connection (From TT302 Manual)

3. Configuration

Click **Start-> Studio302**, a welcome window will pop up. Click the option **Starting working with Studio now**. After system initialization, log in with:

Login: ee3302 Password: control

Click on the login button. The workspace window is shown in Figure 4. Before the system is switched on, it has to be connected virtually and logically. In order to work with it properly, the system configuration has to be consistent with the hardware connections. In this section, you will be guided to go through the configuration steps, which have been done in advance.

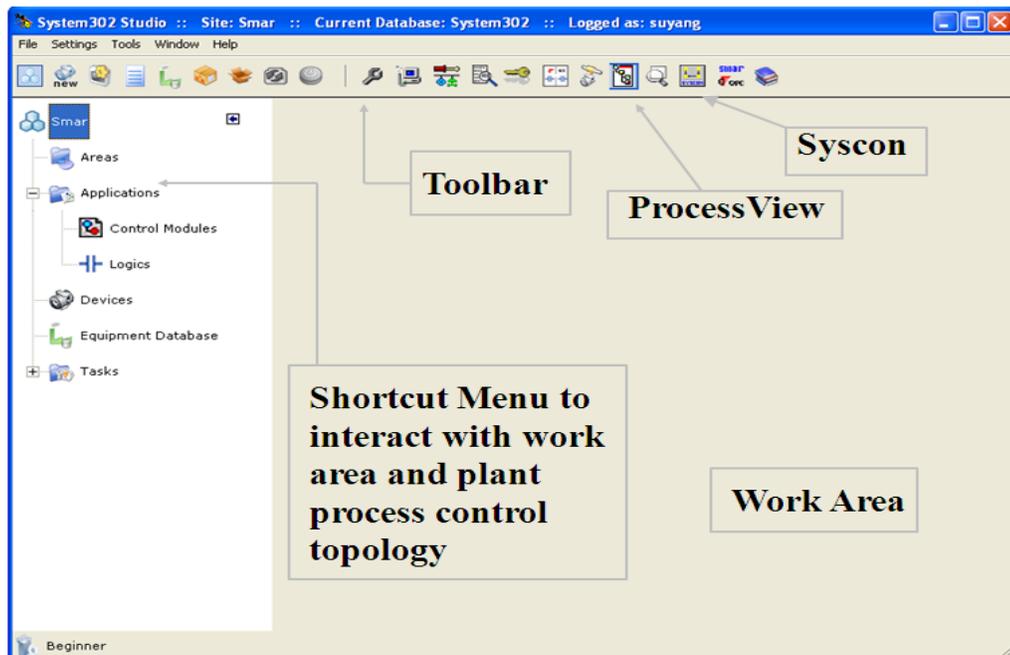


Figure 4. System302 studio window

Click the item SYSCON in the toolbar.

SYSCON, System Configurator, is the software tool that configures, maintains and operates the SMAR products line and communicates with the comprehensive new series of controllers.

Click project file menu->open to open the program Thermal_Chamber, located at C:\Program Files\Smar\ConfigurationWorkspace\Client\CWFiles\System302. The window will be like below.

As we can see, the program Thermal_Chamber includes two parts: Application and Fieldbus Networks. Roughly speaking, these two correspond to control strategy configuration, and network and devices configuration, respectively. All the configurations have been done for you in advance, thus only explanations on what have been configured are given in the following parts.

3.1 Network configuration

We discuss network configuration first. As far as the user is concerned, network configuration is a matter of defining the network hierarchy.

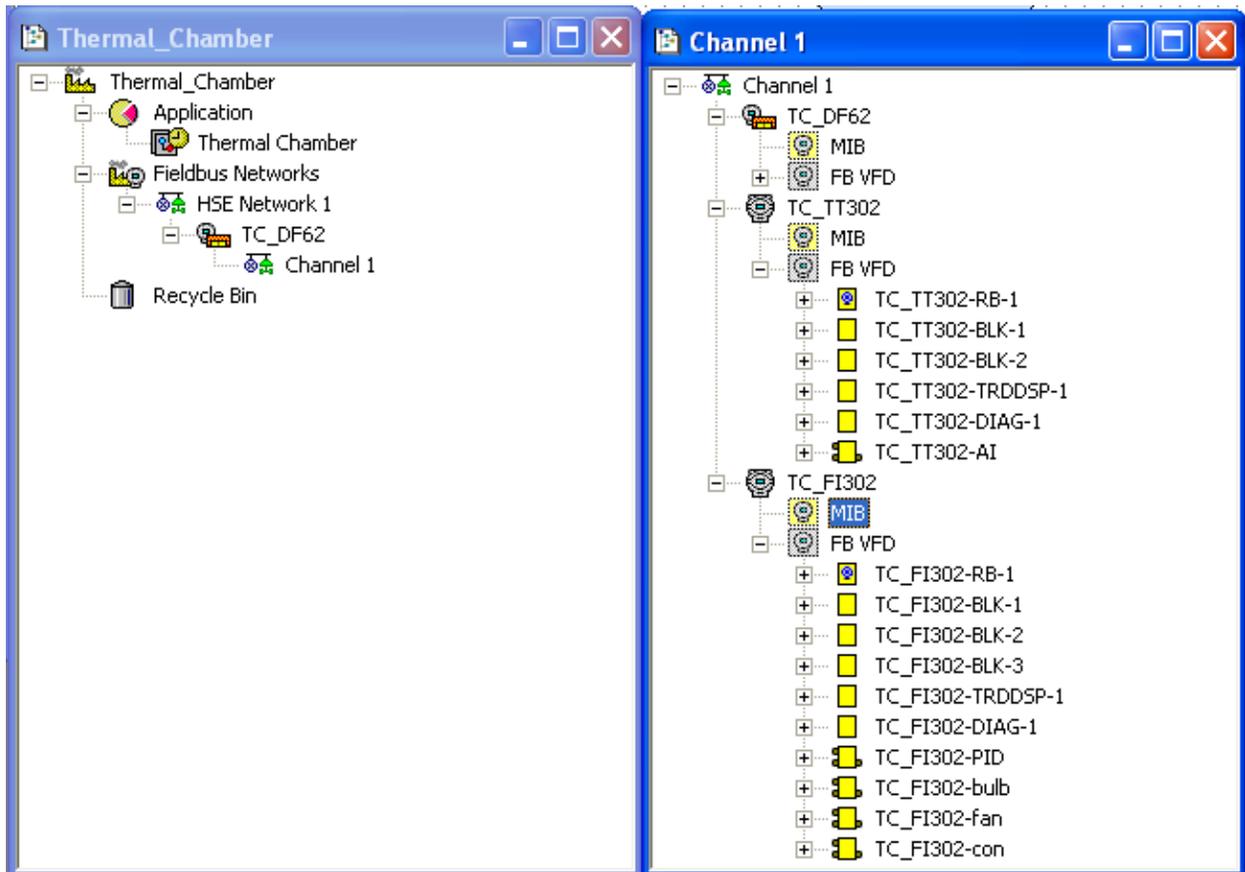


Figure 5. Fieldbus configuration

As shown in the left half of Figure 5, 'Channel 1' is defined. Double click on it; its structure is presented in the right half of Figure 5. As can be seen, three devices are appended on 'Channel 1', including

TC_DF62, TC_TT302 and TC_FI302. The Fieldbus network definition is consistent with the wiring connections in Section 2.

3.2 Device configuration

Each device is assigned a physical device tag to identify it. To customize the devices and fit their functions to the intended application; we need to configure the functionalities of all devices. This can be done via Function Block Parameterization. As shown in Fig 6, the characteristics and functions of each device are defined by its function blocks. Each block should be given a block tag to identify it. Take TC_TT302 for example. It has 6 blocks, TCTT302-RB-1, BLK-1, BLK-2, -TRDDSP-1, -DIAG-1, and -AI. Parameterization is necessary for each function block. TC_TT302-AI block is shown in Figure 6. The block function is decided by the specification in the value column. For example, value for the item 'channel' is 1, which corresponds to a particular sensor connection to TC_TT302. The specification has to be consistent with the real hardware connections. The value for items XD-scale and output-scale specify the input/ output relations.

Each device must be configured with one resource block, and all input and output devices can be configured with at least one transducer block, essentially one per measurement or actuation.

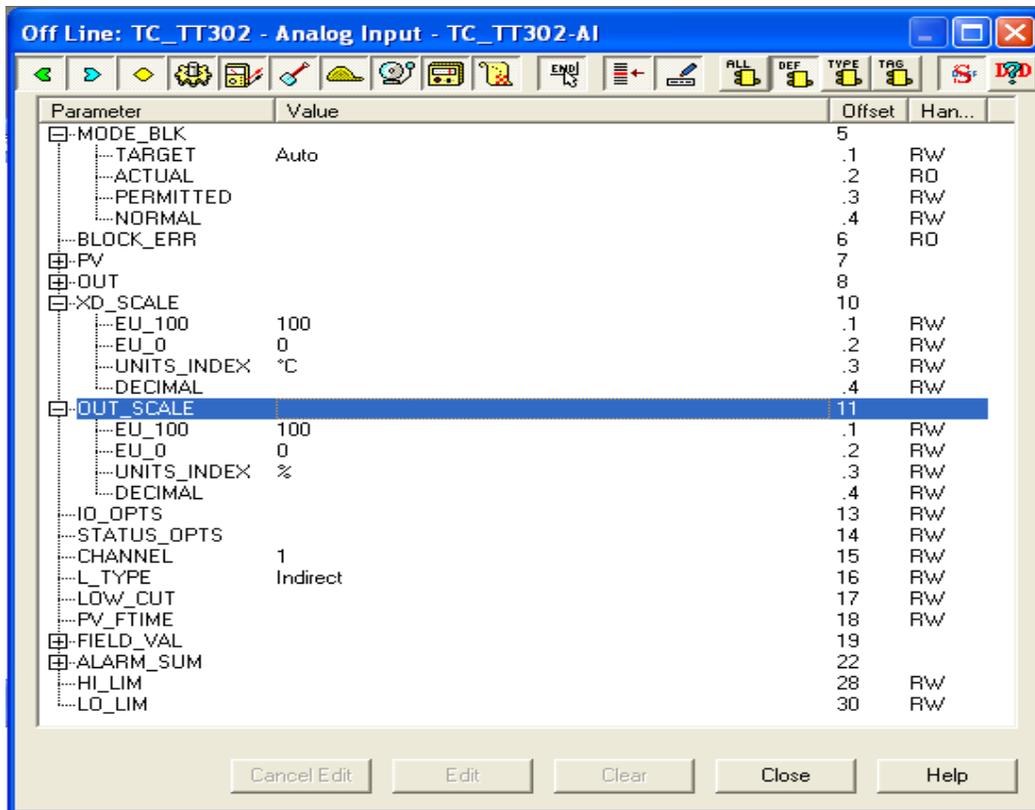


Figure 6. TC_TT302-AI function block

You may wish to check some important function blocks, whose configuration are list in Table

1.

Table 1 Function block parameterization

Devices	Block	Parameters	Value
TC_TT302	TC_TT302-BLK-1	MODE_BLK	Auto
		SENSOR_TYPE	T/C Type J NBS
		SENSOR_CONNECTION	Two wires
	TC_TT302-AI	MODE_BLK	Auto
		CHANNEL	1
		L_TYPE	Indirect
		XD_SCALE	EU_100: 100
			EU_0 : 0
			UNITS_INDEX: °C
		OUT_SCALE	EU_100: 100
			EU_0 : 0
UNITS_INDEX: %			
CHANNEL	2		
TC_FI302	TC_FI302-RB-1	MODE_BLK	Auto
	TC_FI302-BLK-1	MODE_BLK	Auto
	TC_FI302-BLK-2	MODE_BLK	Auto
	TC_FI302-PID	MODE_BLK	Auto
		GAIN	To Be Decided
		RESET	To Be Decided
		PV_SCALE	EU_100: 100
			EU_0 : 0
			UNITS_INDEX: %
		OUT_SCALE	EU_100: 100
			EU_0 : 0
	UNITS_INDEX: %		
	TC_FI302-bulb	MODE_BLK	Cas:Auto
		PV_SCALE	EU_100: 100
			EU_0 : 0
			UNITS_INDEX: %
		XD_SCALE	EU_100: 20
			EU_0 : 4
	UNITS_INDEX: mA		
	CHANNEL	1	
	TC_FI302-fan	MODE_BLK	Cas:Auto
		PV_SCALE	EU_100: 100
			EU_0 : 0
UNITS_INDEX: %			
XD_SCALE		EU_100: 20	
		EU_0 : 4	
	UNITS_INDEX: mA		
CHANNEL	2		
TC_DF62	DF62-RB-1	MODE_BLK	Auto

3.3 Control strategy configuration

The above two subsections explain how the fieldbus network is configured. The next step is the implementation of PID controller for temperature control of the thermal chamber. The controller strategy configuration is presented in this subsection.

As shown in Figure 5, a process cell ‘Thermal Chamber’ was created under the category ‘Application’, with a structure as shown in Figure 7. There are five function blocks; TC_TT302-AI, TC_FI302-bulb, TC_FI302-fan, TC_FI302-PID and TC_FI302-con are attached to the controller module ‘Temperature_PID’. Double click on ‘Temperature_PID’ to open the Strategy window at the right. The controller logic is represented and implemented by linking these function blocks graphically, which is shown in Figure 7.

TC_TT302-AI measures the temperature and transmits to TC_FI302-PID; TC_FI302-PID calculates the control action, as defined in Section 3.2; then TC_FI302-PID transmits the output to TC_FI302-bulb via fieldbus network; TC_FI302-bulb outputs a corresponding 4-20 mA current signal, which is routed through the driver circuit. The reverse connection from TC_FI302-bulb to TC_FI302-PID is for back calculation, which may be used for anti-windup.

The block TC_FI302-con defines a constant variable, which is passed to TC_FI302-fan as the input to the fan.

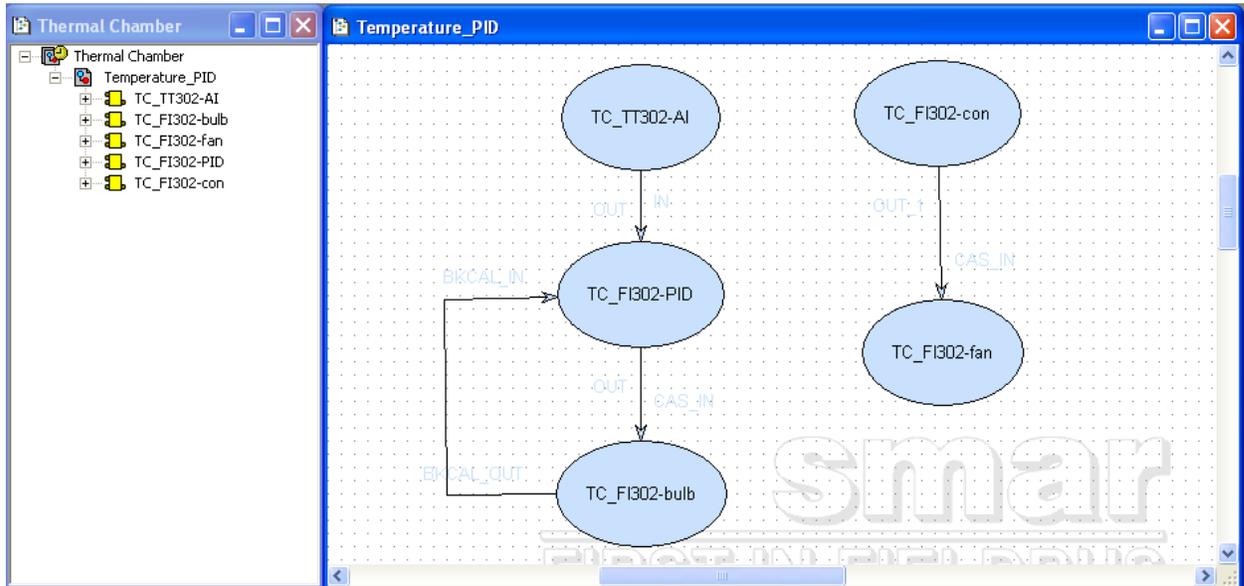


Figure 7. Control module and Strategy Window

The controller module ‘Temperature_PID’ is a very common implementation since PID is widely used in industry. It is also the easiest one. The function block library includes a large amount of function blocks, making it greatly convenient and powerful to solve various engineering problems. Some representative blocks are presented in Table 2.

Table 2 Representative function blocks

Input	Control and Calculation	Logic function	Output
Analog input; Discrete Input; Multiple input; Pulse input...	PID control; Arithmetic; Input Selector; Lead lag; Smith Predictor; Transfer Function...	Ladder logic...	Analog output; Discrete output; Multiple output; Step output PID...

T

The offline configuration is done. A summary of the configuration is given in Figure 8. Please make sure you understand what has been done by inspecting the five windows in Fig. 9. To enable the fieldbus system to behave as designed, the configuration information has to be passed to field devices. This is achieved by online communication and downloading, which will be explained in following sections.

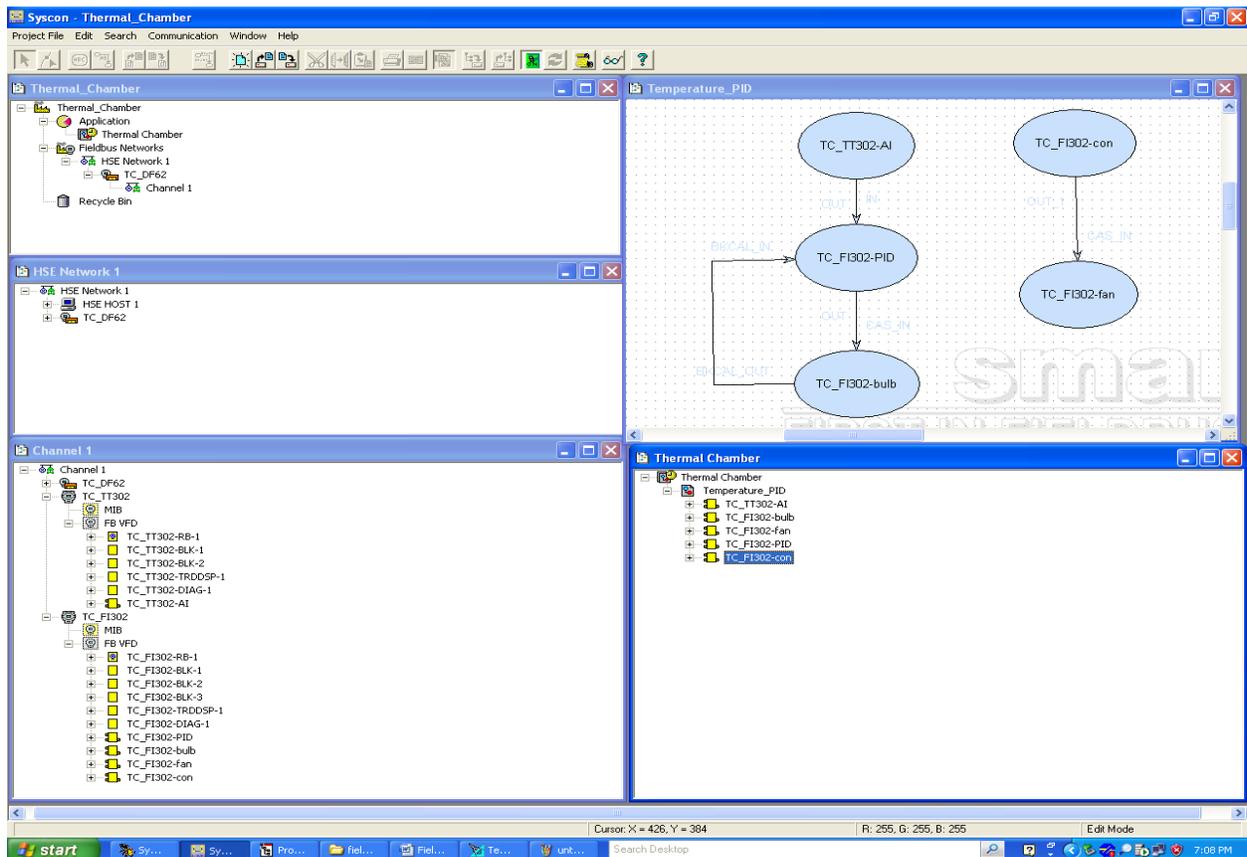


Figure 8. Configuration summary

4. Operations

Below is the procedure to switch on the fieldbus system.

- **Init Communication**
- Live List Access
- Devices Commissioning
- Download Configuration
- Save the Configuration
- **Export Tag**
- **Syscon On Line Monitoring**

Some are done in advance; please follow to perform the steps underlined above.

Click on the **Operations Mode** button  on the toolbar to initialize communications. Proceed the Field devices Commissioning (omit this step if all devices are commissioned.) Now, you are ready to put the FCS in operation by downloading all the configurations into the field devices. Right-click on the fieldbus segment and choose the option Download as in Figure 9. It may take a few minutes to complete the downloading.

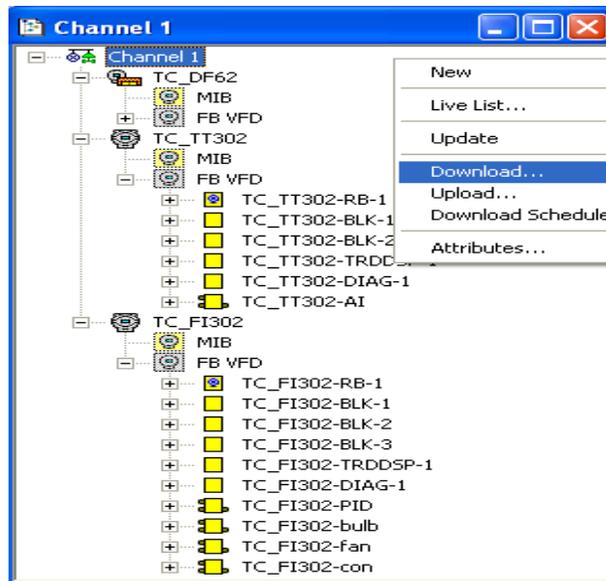


Figure 9. Configuration download

Once the Download procedure is concluded successfully, save the configuration. One final procedure is required to enable the on-line communication with the parameters of the function blocks. This command is called Export Tags. It generates a file (Taginfo.ini) containing all tags (devices and function blocks)

present in the configuration. This file is used by the *OPC* (OLE for Process Control) interface for supervision purposes.

Right-click on the Project icon and choose Export Tags as in Figure 10. A dialog box will appear. Choose Taginfo.ini and click Save. Repeat the Export Tag procedure every time a tag changing is done. Otherwise, a parameter supervision error can be introduced.

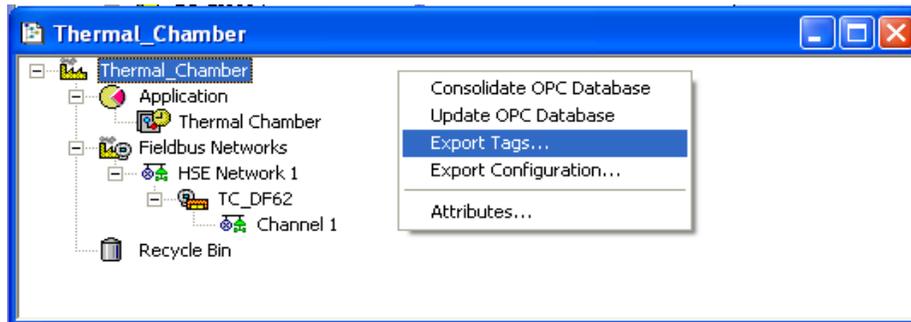


Figure 10. Export Tags

Now, the control system is commissioned. To monitor the process, click on the Online Monitoring button , when Strategy window is active. The Online strategy will appear, similar to the picture shown here:

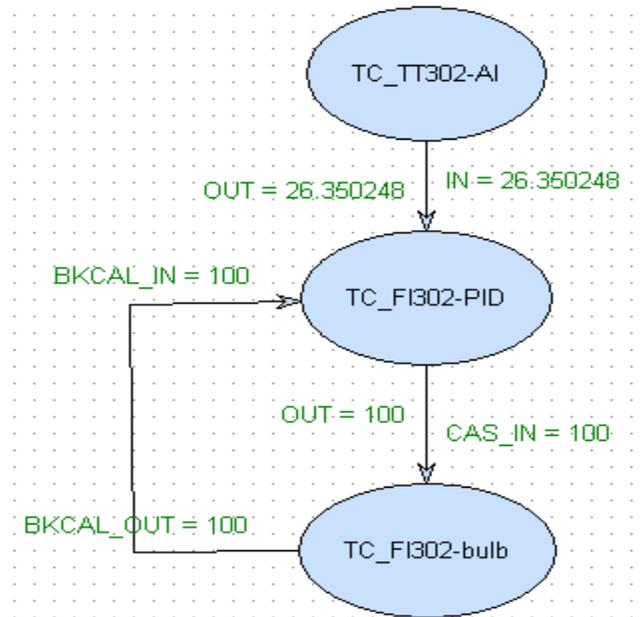


Figure 11. Online strategy

The data flow will be presented and updated in real time. A green color means the communication is normal and the data is of good quality. There may be some problems if the color of the data turns red.

5. User interface — ProcessView

In Section 4, you may experience the inconvenience to carry out the online monitoring and/or online operations. This is where the application programs come in useful. Various application programs, including alarm monitoring, data log, plot display and the normal process operation, can be developed on the top of fieldbus network and OPC (OLE for Process Control) technology. In this section, a temperature control application is presented.

Go to System302 studio window and click the ProcessView button in the toolbar to open the project console window. Expand the Projects console->Thermal Chamber->Applications->GraphworX->Displays >Temperature_PID.gdf

A pre-designed user interface window appears as shown in Figure 12. Click on ‘Runtime’ to start the program. There are several variables on the interface, such as Setpoint and Temperature, which are linked to the tags defined in Section 3:

Setpoint-> TC_FI302-PID.SP, P Gain-> TC_FI302-PID.GAIN, I Gain-> TC_FI302-PID.RESET, TC_TT302-AI.OUT ->Temperature, TC_FI302-PID.OUT->Control.

The process output, temperature, is displayed in the plot on the left; the control input is displayed in the plot on the right. Therefore, instead of operating the process as in Section 4, operators can monitor and operate the process in a much more friendly manner.

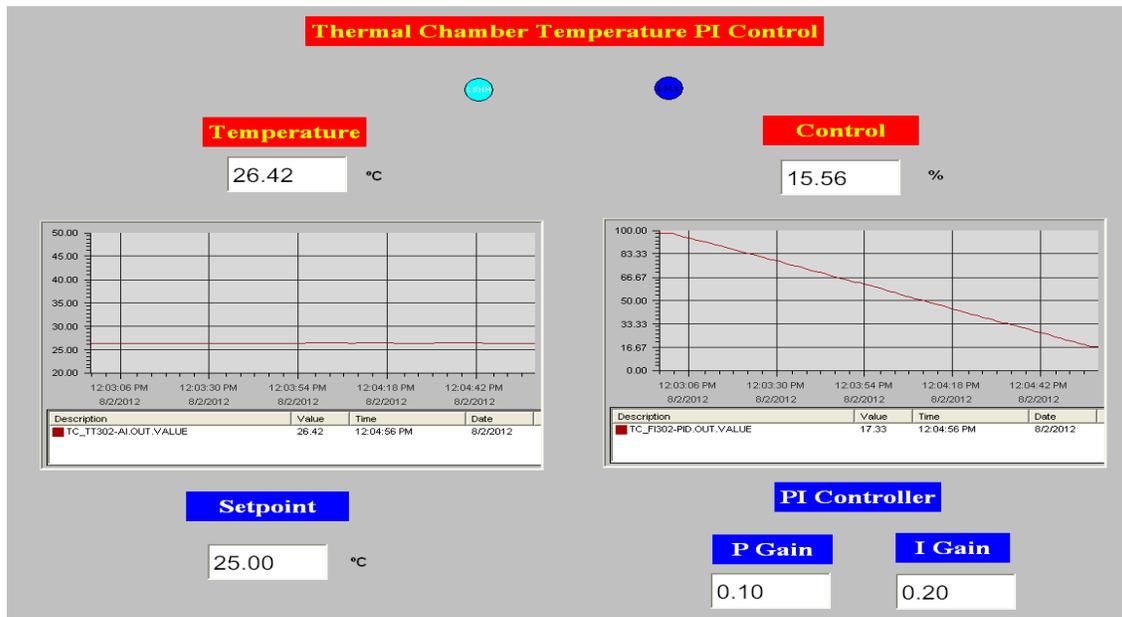


Figure 12. Temperature_PID User interface

For example, type in a new value in the Setpoint box. The new setpoint value will be passed down to the fieldbus network and change the temperature of the chamber. Similarly, the PID controller parameters, P and I, can also be changed.

6. Temperature control

The controller commissioned is a PI controller. Adjust the PI control to achieve an overshoot of not more than 10% to a step change in the temperature set-point. (e. g. set-point changed from 35°C to 36°C, with an overshoot of under 0.1°C). Specify your final PI parameters.

Gain (P): _____.

Reset (I): _____.

References:

Jonas Berge. Fieldbuses for Process Control: Engineering, Operation, and Maintenance. ISA, 2002.

SYSTEM302 User's manual, SMAR Enterprise Automation, www.smar.com.

E1: Advanced Control Systems, EE3302/3302E lab Manual, ECE, NUS.

APPENDIX Plant Monitoring: Boiler Plant Simulator

Prior to the experiment, you may want to look at this application of a boiler plant monitoring. The teaching assistant may also use this to carry out a demonstration to you. Go to System302 studio window and click the ProcessView button in the toolbar to open the project console window. Expand the Projects console->Demo Plant01_NUS->Applications->GraphworX->Displays >Temperature_PID.gdf and click 'Runtime' to run the application.

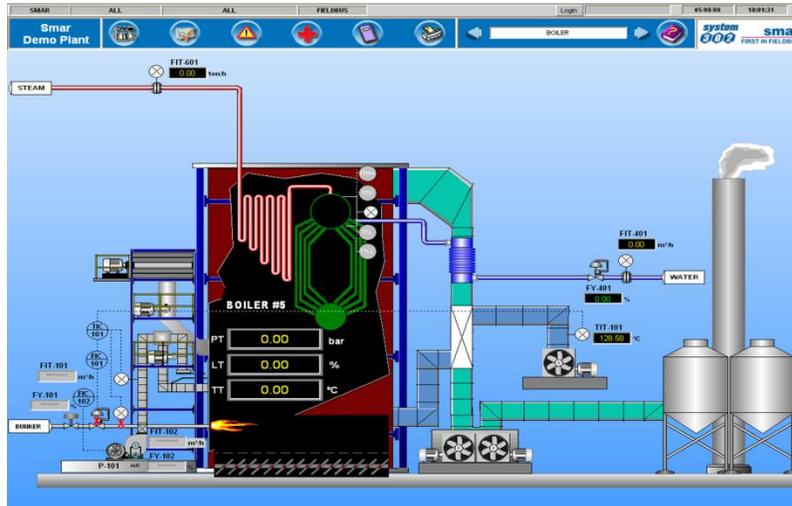


Figure 13. Boiler Plant Simulator

The setup mimics a subset of an industrial boiler as shown in Figure 13. The temperature and pressure of the furnace are continuously monitored and updated in the display. For real application, the temperature and pressure readings come from temperature and pressure transmitters (TT302 and LD302 for example). Here these two signals are replaced by simulated signals. One important requirement of plant management is monitoring and triggering of alarms. Commonly, the plant's states are compared with prescribed safety limits. Alarms can be triggered if the monitored states exceed or drop below a threshold. For the case of boiler monitoring, alarms will be triggered at different temperature levels:

- TTHH alarm will trigger once the temperature above 450°C.
- TTH alarm will trigger once the temperature above 300°C.
- TTL alarm will trigger once the temperature below 200°C and
- TTLL alarm will trigger once the temperature below 100°C.

Alarms call for the plant operators to take necessary actions to prevent disastrous consequences. In addition, a burner will be turned on to heat up the temperature once TTL alarm is triggered. On the display, the ON/OFF state of the burner is animated. This application provides a user-friendly interface to monitor the industrial boiler.