

computing@computingonline.net www.computingonline.net ISSN 1727-6209 International Journal of Computing

# FOUNDATION FIELDBUS: FROM THEORY TO PRACTICE

Vítor Viegas <sup>1, 2)</sup>, J. M. Dias Pereira <sup>1, 2)</sup>

<sup>1)</sup> Instituto Politécnico de Setúbal, ESTSetúbal/LabIM, 2910-761 Setúbal, Portugal (vitor.viegas@estsetubal.ips.pt) <sup>2)</sup> Instituto de Telecomunicações, DEEC/IST/UTL, 1049-001 Lisboa, Portugal

**Abstract:** This paper describes the main characteristics of the Foundation Fieldbus (FF) technology considering both communication levels, namely H1 and H2, which have bit rates of 31.25 K and 100 Mbit/s, respectively. Several details about the physical layer, communication stack and user layer will be highlighted. Topics related with the configuration of instruments, as well as the design and implementation of supervision software, based on a LabVIEW interface, will be presented. A pilot plant that includes temperature, pressure, level and flow variables will be used to test and validate the capabilities of FF systems. Experimental results will be analyzed, their meaning discussed and the overall performance evaluated.

**Keywords:** Foundation Fieldbus, industrial networks, fieldbus control systems, Open Process Control, supervision, data acquisition.

### **1. INTRODUCTION**

The Foundation Fieldbus (FF) [1-3] is a communication technology intended to connect instruments in a process automation environment. At the physical level, communications are supported by a two-wire, multidrop bus that supplies power and ensures the flow of digital data. At the logic level, communications are supported by a protocol that guarantees message delivery in real-time [4]. On the top of the protocol layers, functional blocks hide communication details and make easier the development of control applications. FF is a broad technology that covers topics such as power over bus, real-time networking, visual programming, and information management.

The FF technology is supervised by the Fieldbus Foundation [5], a non-profit corporation composed by end-users, manufacturers and research organizations. The foundation promotes and regulates the use of the technology and provides guidelines for the future. The regulation work includes rigorous certification programs that guarantee interoperability between equipment from different manufacturers. The goal is to give endusers the ability to choose the best hardware and software at any time without being stuck to a specific vendor.

The FF technology distinguishes between lowspeed communications (H1 level) and high-speed communications (H2 level) (see figure 1). The H1 level acts as a digital replacement for 4-20 mA current loops widely used in common industrial plants. The H2 level aggregates data from H1 segments and adds support for discrete control. Together, H1 and H2 levels satisfy the automation needs of most systems whether they are continuous or discrete.

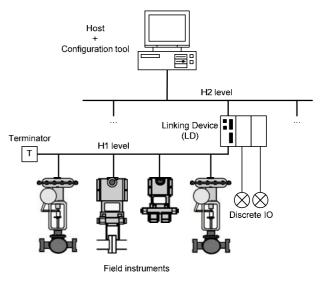


Fig. 1 – FF overview

#### 1.1. H1 LEVEL

The H1 level is a digital bus that implements a subset of the OSI (Open Systems Interconnection) model. The physical layer is fully implemented, while layers 2 to 7 are compressed in the so-called

"communication stack". The user layer (extra OSI) defines a library of functional blocks intended to build control applications. These three components (physical layer, communication stack and functional blocks) must all reside in every FF instrument.

The physical layer has the following characteristics:

- Power over bus: The bus is powered with 24 VDC and a current capability above 100 mA (typical). Each instrument can draw up to 20 mA from the bus.
- Data rate of 31.25 Kbit/s: The data is transmitted together with the clock, in base band, using Manchester coding. The digital signal is superimposed over the DC level. The relatively low data rate allows the reuse of 4-20 mA wiring.
- Free topology: Spurs are allowed anywhere along the bus. The maximum cable length (including spurs and considering high-quality wiring) is about 1900 m. This value can be extended to 7600 m by adding up to four repeaters. The bus must have a proper RC terminator to avoid signal reflections.
- 6, 12 or 32 instruments: The maximum number of instruments is six if bus powered with Intrinsic Safety (IS), 12 if bus powered without IS, and 32 if neither bus powered nor IS. These values are merely indicative since they depend on the actual power specifications of the devices.

The communication stack implements a masterslave protocol that guarantees message delivery in real-time. The master is called "Link Active Scheduler" (LAS) because it distributes "permissions to talk" (tokens) according a deterministic schedule. When a device receives the token, it publishes messages on the bus that are picked up and consumed by one or more subscribers. The LAS supports the following dialogues:

- Programmed dialogues: Periodically, according a programmed control strategy, the LAS sends tokens of type CD (Compel Data). The device owning the CD token publishes data immediately without waiting for the subscriber(s) to confirm the reception. If a data point is lost, the system relies on the previous value until a new one is transmitted. This dialogue is used to transfer output variables and status information between functional blocks.
- Unprogrammed dialogues: After executing the control strategy, the LAS reserves some time to send tokens of type PT (Pass Token). The device owning the PT token has a limited amount time to send messages by its own initiative. All messages have to be confirmed otherwise are repeated. This dialogue is used to report events (such as alarms and trends) and to perform

configuration tasks (such as set-point and tuning adjustments, program downloading, and remote diagnostics).

- Live list dialogue: The LAS maintains a list of active devices by sequentially sending tokens of type PN (Probe Node) to all possible addresses (0 to 255). The target device responds by returning its unique IDentifier (ID) and tag number. If a new device is found it is added to the list; if a device fails to respond three consecutive times it is removed from the list.
- Time distribution dialogue: The LAS distributes time by sending tokens of type TD (Time Distribution) to all devices. Each device compares its internal clock against the timestamp received and resets it to maintain accuracy within 1 ms.

Each H1 bus has one primary master. Other devices can be configured as redundant masters provided they have LAS capabilities. The master with lowest address takes control automatically and transparently.

As said before, the programming interface of FF devices is based on functional blocks. Each device contains:

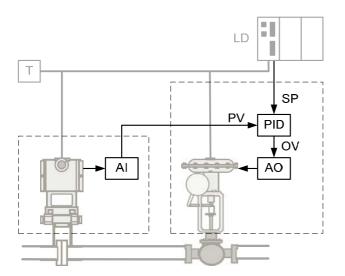
- One Resource Block (RB) that describes the general characteristics of the device (such as ID, tag number, manufacturer, model, serial number, firmware version and available features). This data, which is stored in a non-volatile memory, is very useful for maintenance and inventory purposes.
- One or more Transducer Blocks (TB) that describe the characteristics of primary transducers (such as transducer type, connection, compensation, and calibration data).
- One or more Function Blocks (FB) that implement data processing algorithms. There are dozens of predefined FBs covering the most common functionalities. Some examples are:
  - Analog Input (AI): Takes the data from the analog input signal and makes it available to other FBs. It implements scaling conversion, filtering, square root extraction, and alarm processing.
  - Analog Output (AO): Provides a real value to generate an analog output signal. It implements value limiting, scaling conversion, and fault-state handling.
  - Digital Input (DI): Takes the data from the discrete input signal and makes it available to other FBs. It implements value inversion, filtering and alarm processing.
  - Digital Output (DO): Provides an integer value to generate a discrete output signal. It implements value inversion and fault

state handling.

- Proportional, Integral, Derivative (PID): Implements the PID algorithm with a lot of valuable features such as set-point treatment (value and rate limiting), filtering, feed forward, anti-wind-up and alarm processing.
- Arithmetic (ARTH): Provides some predefined, ready-to-use equations such as flow compensation, hydrostatic tank gauging, ratio control and others.
- Integrator(INTG): Integrates a variable in function of the time.
- Set-Point Generator(SPG): Generates a setpoint following a profile in function of the time.
- TIMEr and logic(TIME): Implements combinational logic and timers.

The control strategy is defined by a FB diagram (see figure 2). The arrows establish data relations between FBs: if two interdependent FBs reside on the same device data is transferred internally; if they reside in different devices data is transferred across the bus. By dissecting the diagram it is possible to know who talks to whom and when; in other words, it is possible to schedule programmed dialogues. Each FB can also be configured individually to determine its behavior in terms of processing and event reporting. It should be noted that by enabling the transmission of alarms and trends the bus gets loaded with unprogrammed dialogues.

The use of predefined FBs promotes interoperability because devices can be replaced while the program maintains the same structure.



SP: Set-Point PV: Process Variable OV: Output Variable

Fig. 2 – Flow control loop (instruments and FB diagram)

### 1.2. H2 LEVEL

The H2 level aggregates data from the field including H1 segments, Programmable Logic Controllers (PLC), and sensor buses. Over the last years there has been an effort to apply internet technologies at this level: Ethernet for data transmission, Internet Protocol (IP) for data routing, and Transport Control Protocol (TCP) and User Datagram Protocol (UDP) for data transport. This approach provides high baud rates (100 Mbit/s typical) and allows the use of inexpensive, commercial off-the-shelf equipment. In return, it does not provide native support for real-time, power over bus or redundancy.

Each H1 segment is connected through a gateway called "Linking Device" (LD), which, most of the times, acts as the primary master and provides support for discrete control. When the host needs to access a particular H1 device, it sends TCP messages to the corresponding linking device which translates them into H1 dialogues. The reverse happens when the H1 device reports data to the host. UDP messages are used when the host needs to contact several linking devices simultaneously (to distribute time, for example). The process of translation is absolutely transparent so that configuration tools (residing on the host) can configure, diagnose and monitor H1 devices as if they were locally connected.

### 1.3. FIELDBUS CONTROL SYSTEMS

FF instruments are considered to be "smart" because they have processing power and can communicate with each other. This allows them to perform self-identification, self-diagnostics and self-calibration routines, and, more important, to collaborate in the execution of distributed control algorithms. The result is a "Fieldbus Control System" (FCS), so-called because the control strategy is decentralized across the bus. Compared to more conventional architectures, such as Distributed Control (DDC) systems [6], the FF technology provides the following advantages:

- Common to FCS systems:
  - Extended visibility and smartness: Visibility goes down to primary transducers as opposite to traditional systems where visibility is limited to input/output cards of PLCs and DCSs. Self-describing information and online diagnostics facilitate asset management and maintenance. Robust protocols allow the hot swapping of devices.
  - Reduction of cabling costs: The bus topology reduces cable length significantly. Analog

wiring can be reused in most cases.

- Improved robustness: If the primary master fails the secondary master takes control of the bus immediately.
- Specific to the FF technology:
  - Interoperability: Rigorous certification programs, supported by a strong community, guarantee interoperability between equipment from different manufacturers.
  - Productivity: The programming model based on standard functional blocks promotes software productivity and interoperability.

On the other hand, FF systems are generally more complex and difficult to configure and debug.

The paper describes the implementation of a FF pilot plant, covering aspects like the configuration of instruments, supervision software, and system operation. The text shall be interpreted as guide that explains the practical aspects of a concrete application. The goal is to share our experience with the community to help others in the implementation of their own projects. The paper is organized as follows: section 2 presents the physical process used as test bench, section 3 explains how FF instruments were configured, section 4 presents a proposal of supervision software, section 5 reports system operation, and section 6 extracts conclusions.

# 2. PHYSICAL PROCESS

The physical process was built to train undergraduate students in the principles of process control and FF instrumentation. The process contains all the equipment needed to run the following control loops (see figures 3 and 4):

- Level control loop: The water level inside the closed tank is measured by the transmitter LT1 and is controlled by operating the control valve FCV1. Information about water inflow, water temperature at the bottom of the tank, and air pressure at the top of the tank is provided by transmitters FT1, TT1 and PT1, respectively. The tank is equipped with an exhaust valve to prevent pressures above 3 bar.
- Flow control loop: The flow of water leaving the tank is measured by the transmitter FT2 and is controlled by operating the control valve FCV2.

The level control loop can be replaced by a pressure control loop by considering the signal from transmitter PT1 as the process variable. This was not the case in the current study.

Table 1 summarizes the main characteristics of the instruments installed on the physical process. The interface with analog transmitters (FT1, LT1 and FT2) was done using IF1, a triple channel current/FF converter. All converters, transmitters and control valves were properly verified and calibrated before experiments took place.

FF instruments were tied in a single H1 segment powered with 24 VDC and terminated by a 100  $\Omega$ resistor in series with a 100 nF capacitor. The H1 bus was connected directly to a computer (overcoming the H2 level) by means of an interface board that acts as linking device (model USB-8486 from National Instruments (NI) [7]). Finally, on the computer, it was installed all the software needed to configure and supervise the pilot plant, namely NI-FBUS Configurator version 4.0.1, and LabVIEW version 2009 SP1 plus Datalogging and Supervisory Control (DSC) module.



**Fig. 3** – **Picture of the physical process** 

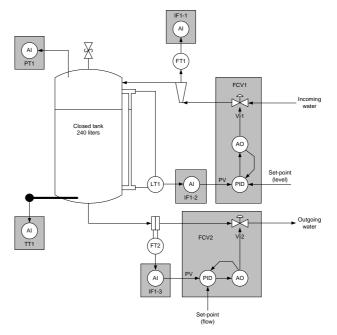


Fig. 4 – P&I diagram of the physical process

Tag	Manufacturer	Reference	Range	Signal	Brief description
FT1	Gebr. Muller	GEMU 830 + 1270 + 1275 (a)	5 to 50 l/min	4 to 20 mA	Variable area flowmeter.
LT1	Rosemount	D2A12A2S1B4	0 to 100% (b)	4 to 20 mA	Differential pressure transmitter.
FT2	Fischer Porter	F50DPF110-3	0 to 47.7 l/min	4 to 20 mA	Differential pressure transmitter coupled to a Venturi tube.
TT1	Smar	TT302	-200 to +850 °C	FF	Temperature transmitter.
PT1	Smar	LD302	0 to 25400 mmH <sub>2</sub> O (c)	FF	Pressure transmitter.
IF1	Smar	IF302	4 to 20 mA	FF	Triple channel current/FF converter.
FCV1	Smar + Sart von Rohr	FY302 + MA821E63SP0 (d)	0 to 100%	FF	Fieldbus positioner coupled to a pneumatic valve.
FCV2	Smar + Sart von Rohr	FY302 + MA821E63SP0	0 to 100%	FF	Fieldbus positioner coupled to a pneumatic valve.

#### Table 1. Field instruments.

Notes:

a) GEMU 830 refers to the variable area flowmeter, GEMU 1270 refers to the displacement/voltage converter, and GEMU 1275 refers to the voltage/current converter with local indicator.

b) The range in meters depends on the dimensions of the tank.

c) Gauge pressure.

d) FY302 refers to positioner from Smar, and MA821E63SP0 refers to the pneumatic valve from Sart von Rohr.

# 3. CONFIGURATION OF FF INSTRUMENTS

The configuration of FF instruments is very challenging because it takes into account the dynamics of the physical process and the multitude of options offered by functional blocks. The only way to deal with this level of complexity is by using powerful software configuration tools, as is the case of NI-FBUS Configurator [8].

The configuration was done online having all FF instruments powered up and remotely visible. This requires patience (because the H1 bus is slow) but gives the chance to fix errors incrementally. The job was done instrument by instrument walking through the following steps:

- 1. The instrument was reset to its factory defaults.
- 2. A unique address from 17 to 247 was assigned to the instrument (address 16 is automatically reserved by the interface board). This range is indicated for permanent instruments.
- 3. One or more FBs were instantiated to provide processing power for the instrument (according application needs).
- 4. Unique tags were assigned to the instrument and its functional blocks.
- 5. Each functional block was configured by editing its parameters according the desired behavior (see table 2). For this purpose it was essential to study the meaning of each parameter and the options it offers [9]. Helpful information was found in the operation manuals of the instruments [10-13].

The interface board was configured as the primary master by resetting all its parameters to the default values. No other (redundant) masters were implemented.

Having configured the H1 bus, it was time to build a control application for the pilot plant. The application, shown in figure 5, is composed by three main sections:

- 1. The top section instructs the instruments TT1, PT1 and IF1 (channel 1) to log their input values and pass them to the interface board. The log has a fixed capacity of 15 values. This data is non-critical, has low priority, and is passed through unprogrammed dialogues.
- 2. The middle section implements the level loop control. The loop is closed by a PID controller that receives the process variable from the level transmitter LT1 (via channel 2 of the converter IF1), and writes the output variable to the positioner of the control valve FCV1. The AO function block feeds back its state to increase the loop consistency: if the AO function block breaks the loop (by passing to Manual mode, for example) the controller stops working and follows the valve opening; if the loop is restored the controller resumes its operation automatically.
- 3. The bottom section is similar to the middle one, with the difference that it applies to the flow control loop. The process variable comes from the flow transmitter FT2 (via channel 3 of converter IF1), and the output variable goes to the positioner of the control valve FCV2.

The schedule of the control application is shown in figure 6. The configurator gives time for instruments to do internal processing (blue bars), as well as to exchange data across the H1 bus (red bars). The flow control loop has a period of 400 ms, while the (slower) level control loop allows a more "relaxed" period of about 800 ms.

## Table 2. Configuration of FF instruments.

IF1_A/3 (Analog Input FB)     OUT_SCALE.ED_0     O       UT_SCALE.UNITS_INDEX     L/min       L_TYPE     Indirect Sq Root       The input range is converted to the output range by applying the square root operation. Useful for flow meters based on different pressure.			Temperature transmitter	TT1, address = 20	(a)
TT. JPI (Transburg Block)         I/O Carting         SERISOR COMMECTION         The units P110 IEC uses used as the messaure.           TT. JPI (Transburg Block)         Others         SERISOR TRANDUCER NUM         1         Series notes.         Series notes.           TT. JPI (Transburg Block)         Others         SERISOR TRANDUCER NUM         1         Series notes.         Series notes.           TT. JPI (JPI (Transburg Block)         Others         SERISOR TRANDUCER NUM         2         Series notes.         Series notes.           TTL JPI (JPI (Transburg Block)         Others         SERISOR TRANDUCER NUM         2         Series notes.         Series notes.           TTL JPI (Transburg Block)         Transb.         OUT         Transb.         DUT         Transb.         Series notes.         Se	Block	Category		1	
TT T8 (Transduce Block)         Dross         Process         SERISOL TRANSDUCER JUNK         Database         Transduce register and the metalance.           TT 2, 782 Transducer Block)         Oners         SERISOL TRANSDUCER JUNK         1         Series of transducer Block.           TT 1, 144         Transducer Block         Oners         Series of transducer Block.         2           TT 1, 144         Transducer Block         Transducer Block         2         Series res           TT 1, 144         Transducer Block         Common Series res         Series res         Series res           Transducer Block         Campory         Durit         Fronzel         Durit         Fronzel         Durit         Auson Series res           TT 1, 144         Transducer Block         Campory         Buarter transducer Block         Auson Series res         Auson Series res           PT 1, 81 (Transducer Block         Process         MODE_BK/TARGET         Auto         Activates res block.         Autor Series res           PT 2, 81 (Transducer Block)         Process         MODE_BK/TARGET         Auto         Activates res block.         Transducer Series         Autor Activates res block.           PT 2, 81 (Transducer Block)         Process         MODE BK/TARGET         Auto         Activates res block.         Transducer Series <td>TT1_RB (Resource Block)</td> <td>Process</td> <td>MODE_BLK.TARGET</td> <td>Auto</td> <td>Activates the block.</td>	TT1_RB (Resource Block)	Process	MODE_BLK.TARGET	Auto	Activates the block.
This II (Incardure Book)         Others         Binston Provide Life Manual II is an experimental in the incardiant of the incord.           TT1_TR1 (Incardure Biok)         Others         BERSON Provide III is Advised the book.           TT1_TR1 (Incardure Biok)         Others         SERSING Provide III is Advised the book.           TT1_TR1 (Incardure Biok)         Others         SERSING Provide III is Advised the book.           TT1_TR1 (Incardure Biok)         Others         SERSING Provide III is Advised the book.           PT1_TR1 (Incardure Biok)         Process         MODE_BICK TARGET         Advise the transformer block.           PT1_TR1 (Increasure Biock)         Process         MODE_BICK TARGET         Advise the transformer block.           PT1_TR1 (Increasure Biock)         Process         MODE_BICK TARGET         Advise the block.           PT1_TR1 (Increasure Biock)         Process         MODE_BICK TARGET         Advise the block.           PT1_TR1 (Increasure Biock)         Process         MODE_BICK TARGET         Advise the block.           PT1_R1 (Increasure Biock)         Process         MODE_BICK TARGET         Advise the block.           PT1_R1 (Increasure Biock)         Process         MODE_BICK TARGET         Advise the block.           PT1_R1 (Increasure Biock)         Process         MODE_BICK TARGET         Advise the block.		I/O Config	SENSOR_CONNECTION	Three wires	A three-wire PT100 IEC was used as the primary sensor.
Image: Control of the standard state in the sta	TT1 TB1 (Transducer Block)	Othora	TWO_WIRES_COMPENSATION	Disable	The three-wire connection compensates cable resistance.
Tri TR2 Transduor Bioco,         Omen         SERSIDE TRANSDUCR2 NUM         2         Senser index.           TTI_MI (Anilog Feal Feal         Tracks         OUT         Tracks         Durt         Tracks           TTI_MI (Anilog Feal Feal         Tracks         OUT         Tracks         Durt         Tracks           Process         MODE BLK TARGET         Aut         Links to the branducer block.         Tracks           PTI_RE (Resource Block)         Process         MODE BLK TARGET         Auto         Activates the block.           PTI_RE (Resource Block)         Process         MODE BLK TARGET         Auto         Activates the block.           PTI_RE (Resource Block)         Process         MODE BLK TARGET         Auto         Activates the block.           PTI_RE (Resource Block)         Process         MODE BLK TARGET         Auto         Activates the block.           PTI_RE (Resource Block)         Process         MODE BLK TARGET         Auto         Activates the block.           PTI_RE (Resource Block)         Process         MODE BLK TARGET         Auto         Activates the block.           PTI_RE (Resource Block)         Process         MODE BLK TARGET         Auto         Activates the block.           PTI_RE (Resource Block)         Process         MODE BLK TARGET </td <td></td> <td>Others</td> <td>SENSOR_TRANSDUCER_NUM</td> <td>1</td> <td>Sensor index.</td>		Others	SENSOR_TRANSDUCER_NUM	1	Sensor index.
Society         Society         L_TYPE         Dres         Wature from the transducer block was used directly (in *C).           (Analog lipol FB)         Trends         OUT         Trends         OUT         Trends         Control           Process         MODE Bick TARGET         Auro         Activates the block.         Trends         Control           Block         Category         Parameter         Value         Activates the block.         Comment           PTT_R8 (Resource Block)         Process         MODE Bick TARGET         Auro         Activates the block.           PTT_R8 (Resource Block)         Process         MODE Bick TARGET         Auro         Activates the block.           PTT_R8 (Resource Block)         Process         MODE Bick TARGET         Auro         Activates the block.           PTT_R8 (Resource Block)         Process         MODE Bick TARGET         Auro         Activates the block.           VD_SCALEEU.100         0         Transducer's input range (between 0 and 36.126) opp).         OUT SCALE EURO         0           OUT SCALE EURO         0         Transducer Block         Outer Scale EURO         0           PTT_ADT         Transducer Block         Transducer Block         Transducer Block         Transducer Block         Transducer Block		Process	MODE_BLK.TARGET	Auto	Activates the block.
Tri All (Analog liquel Fb)         Tinoda         OUT         Tinoda         OUT         Tinoda         Evables transmoter OUT.           Process         Process         OUT         F         Index to fix strandower block TT TB I.           MODE_BLK_TARGET         Auto         Activates the block.         Comment           PT_RB (Resource Block)         Process         MODE_BLK_TARGET         Auto         Activates the block.           PT_RB (Resource Block)         Process         MODE_BLK_TARGET         Auto         Activates the block.           PT_RB (Resource Block)         Process         MODE_BLK_TARGET         Auto         Activates the block.           PT_RB (Transduce Block)         Proces         MODE_BLK_TARGET         Auto         Activates the block.           PT_RB (Transduce Block)         Process         MODE_BLK_TARGET         Auto         Activates the block.           PT_RB (Resource Block)         Process         OUT_SCALEEU_0         0         Output trange timeshy converted to the output trange timeshy converted to	TT1_TB2 Transducer Block)	Others	SENSOR_TRANSDUCER_NUM	2	Sensor index.
(Availing (input FB)         CHANNEL         1         Lesks to the transacurer block TT1_TB1           Process         MODE_BLKTARGET         Auto         Activates the block.           PT1_R8 (Resource Block)         Process         MODE_BLKTARGET         Auto         Activates the block.           PT1_R8 (Resource Block)         Process         MODE_BLKTARGET         Auto         Activates the block.           PT1_R8 (Resource Block)         Process         MODE_BLKTARGET         Auto         Activates the block.           PT1_R1 (Transducer's Block)         Process         MODE_BLKTARGET         Auto         Activates the block.           VAD_SCALE_EU_0         0         Transducer's Input range (between 0 and 26.1283 psig).         OUT_SCALE_EU_0         0           OUT_SCALE_EU_0         0         OUT_SCALE_EU_0         0         OUT_SCALE_EU_0         0           Process         MODE_BLKTARGET         Auto         Activates the block.         Disput range (between 0 and 26.1283 psig).           OUT_SCALE_EU_0         0         OUT_SCALE_EU_0         0         OUT_SCALE_EU_0         Disput range (between 0 and 26.1283 psig).           FT_ER8 (Resource block)         Process         MODE_BLKTARGET         Auto         Activates the block.           FT_T3 (Transducer Block)         Process		Scaling	L_TYPE	Direct	Values from the transducer block are used directly (in °C).
Process         MODE_BLKTARGET         Auto         Activates the block.           Process         MODE_BLKTARGET         Auto         Activates the block.           PTI_R8 (Resource Block)         Process         MODE_BLKTARGET         Auto         Activates the block.           PTI_R8 (Resource Block)         Process         MODE_BLKTARGET         Auto         Activates the block.           PTI_R8 (Resource Block)         Process         MODE_BLKTARGET         Auto         Activates the block.           PTI_F8 (Transducer Block)         Process         MODE_BLKTARGET         Auto         Activates the block.           PTI_F8 (Transducer Block)         Process         MODE_BLKTARGET         Auto         Activates the block.           (Anatog Input F9)         Freeds         OUT_SCALE_U.100         36 (22)         Output range (between 0 and 36 (22) Spig).           OUT_SCALE_U.ND_NDEX         pag         LTMPE         Indirect ange 1 linearity converted to the output range (in pig           Trends         OUT_SCALE_U.100         36 (22)         Output range (between 0 and 36 (22) Spig).           Process         MODE_BLKTARGET         Auto         Activates the block.           Current to FF output range (between 0 and 36 (22) Spig).           Current to FF output range (between 0 and 36 (2		Trends	OUT	Trend⊠	Enables trending for parameter OUT.
MODE BLK PAGET         Auto         Activates the black.           Pressure transmitter PTr, address = 21(a)           Block         Convent         Convent           PTT_R8 (Resource Block)         Process         MODE, BLK TARGET         Auto         Activates the black.           PTT_R1 (Transducer Block)         Process         MODE, BLK TARGET         Auto         Activates the black.           PTT_A11 (Anatog Input FB)         Process         MODE, BLK TARGET         Auto         Activates the black.           If Transducer Block         Process         MODE, BLK TARGET         Auto         Activates the black.           (Anatog Input FB)         If Transducer's input range (between 0 and 25:400 mmHZO.         Transducer's input range (between 0 and 25:400 mmHZO.           (Anatog Input FB)         If Transducer's input range in Insety converted to the output range (in page insety converted to the output range (in page insety)           (Process         MODE, BLK TARGET         Auto         Activates the black.           (Process         MODE, BLK TARGET         <	(Analog Input FB)	Process	CHANNEL	1	Links to the transducer block TT1_TB1.
Bick         Category         Percess         MODE BIX TARGET         Auto         Comment           PTI_TB (fransducer Block)         Process         MODE BIX TARGET         Auto         Activates the block.           PTI_TB (fransducer Block)         Process         MODE BIX TARGET         Auto         Activates the block.           PTI_TB (fransducer's input range (between 0 and 25:400 mmH2O.         Z5:400         Transducer's input range (between 0 and 35:1253 paig).           QUT_SCALE_EU_100         30:1263         Qutput range (between 0 and 35:1253 paig).           QUT_SCALE_EU_100         30:1263           Process         MODE_BLKTARGET         Auto           Activates the block.         Comment           Process         MODE_BLKTARGET         Auto           Activates the block.         Process         MODE_BLKTARGET         Auto           Process         MODE_BLKTARGET         Auto         Activates the block. <t< td=""><td></td><td>MODE_BLK.TARGET</td><td>Auto</td><td>Activates the block.</td></t<>			MODE_BLK.TARGET	Auto	Activates the block.
Bick         Category         Personal         MODE BIX TARGET         Auto         Comment           PT1: 7B (frameducer Block)         Process         MODE BIX TARGET         Auto         Activates the block.           PT1: 7B (frameducer Block)         Process         MODE BIX TARGET         Auto         Activates the block.           PT1: 7B (frameducer Block)         Process         MODE BIX TARGET         Auto         Activates the block.           PT1: All (frameducer Block)         Process         MODE BIX TARGET         Auto         Activates the block.           Value         Category         Process         MODE BIX TARGET         Auto         Transducer's input range (between 0 and 36; 1283 paig).           OUT.SCALE.EU.100         36: 1283         OUT.SCALE.EU.100         36: 1283         Process           MODE_BIX TARGET         Auto         Activates theranducer block P17: T61.         Activates theranducer block.           Trends         OUT.SCALE.EU.100         28: 00         Activates the block.           FT: 783 (frameducer Block)         Process         MODE_BIX TARGET         Auto         Activates the block.           IFT.781 (frameducer Block)         Process         MODE_BIX TARGET         Auto         Activates the block.           IFT_7173 (frameducer Block)         Process			Proceuro transmittor P	T1 addross - 21(a	
IPT. FB (Resource Block)         Process         MODE BLK TARGET         Auto         Activates the block.           PT1. TB (Transducer Block)         Process         MODE BLK TARGET         Auto         Activates the block.           PT1. TB (Transducer Block)         Process         MODE BLK TARGET         Auto         Activates the block.           PT1. ATI (Analog input FB)         Process         MODE BLK TARGET         Auto         Activates the block.           PT1. ATI (Analog input FB)         Process         MODE BLK TARGET         Auto         Activates the block.           PT1. ATI (Analog input FB)         Process         MODE BLK TARGET         Auto         Activates the block.           Process         MODE BLK TARGET         Auto         Activates the block.         Process           Block         Category         Parameter         Value         Activates the block.         Process           FT1. 78 (Transducer Block)         Process         MODE BLK TARGET         Auto         Activates the block.           FF1. 78 (Transducer Block)         Process         MODE BLK TARGET         Auto         Activates the block.           FF1. 78 (Transducer Block)         Process         MODE BLK TARGET         Auto         Activates the block.           FF1. 78 (Transducer Block)         Process </td <td>Block</td> <td>Category</td> <td></td> <td></td> <td></td>	Block	Category			
PT1_TB1 (Transducer Block)         Process         MODE BLX TARGET         Auto         Achivates the block.           PT1_TB1 (Transducer Block)         VD_SCALE_EU_100         25600         Transducer's input range (between 0 and 25400 mmH20.           PT1_AT1 (Analog linput FB)         Scaling         VD_SCALE_EU_0         0         Transducer's input range (between 0 and 36.1283 psi).           VD_SCALE_EU_0         0         VD_SCALE_EU_0         0         VD_SCALE_EU_0         0           VD_SCALE_EU_0         0         VD_SCALE_EU_0         0         Advalues the block.         0           VD_SCALE_EU_0         VD_SCALE_EU_0         Advalues the block.         0         0         0           VD_SCALE_EU_10         2         Advalues the block.         0         0         0         0         0         0         0         0         0					
PTI_AIT (Analog Input FB)         XD_SCALE FU_100         22400 XD_SCALE FU_100         Transducer's input range (between 0 and 25400 mmH20.           Scaling         Scaling         OUT_SCALE FU_100         36.1263         Output range (between 0 and 36.1263 psig).           OUT_SCALE FU_100         36.1263         Output range (between 0 and 36.1263 psig).         Output range (between 0 and 36.1263 psig).           IFI_AIT         Tends         OUT_SCALE FU_100         36.1263         Output range (between 0 and 36.1263 psig).           IFI_TER         Tends         OUT_SCALE FU_100         36.1263         Output range (between 0 and 36.1263 psig).           IFI_TER         Tends         OUT_T_TendsT         Enables trending for parameter OUT.         Ich so the transducer block PT2_TB1.           IFI_TB3 (Transducer Block)         Process         MODE_BLXTARGET         Auto         Activates the block.           IFI_TB3 (Transducer Block)         Process         MODE_BLXTARGET         Auto         Activates the block.           IFI_TB3 (Transducer Block)         Process         MODE_BLXTARGET         Auto         Activates the block.           IFI_TB3 (Transducer Block)         Process         MODE_BLXTARGET         Auto         Activates the block.           IFI_TB3 (Transducer Block)         Process         MODE_BLXTARGET         Auto         Activates the	, <i>, ,</i>				
Pr1_At1 (Analog input PB)         XD_SCALE_EU_10         0         Transducer's input range (between 0 and 25400 mmH20.           VD_SCALE_EU_100         36.1283         Output range (between 0 and 36.1283 paig).         Output range (between 0 and 36.1283 paig).           Image: Comparison of the comparison of th		FIDCESS			
PF1_A11 (Analog Inpul FB)         XD_SCALE UNITS_INDEX         nmH20 (69P)           Sealing         XD_SCALE UNITS_INDEX         psig           UT_SCALE EU_0         0         0           UT_SCALE EUNTS_INDEX         psig           Tends         0UT         Trends         Freidater           NODE_BLKTARGET         Auto         Activates the block.           FL7B (Transducer Block)         Process         MODE_BLKTARGET         Auto           FL7B (Transducer Block)         Process         MODE_BLKTARGET         Auto           FL7B (Transducer Block)         Process         MODE_BLKTARGET         Auto           FL7B (Transducer Block)         Process         MODE_BLKTARGET         Auto         Activates the block.           IF1_TB (Transducer Block)         Process         MODE_BLKTARGET         Auto         Activates the block.         Activates the block.           IF1_TB (Transducer Block)         Process         MODE_BLKTARGET         Auto         Activates the block.         Activates the block.         Activates the block. <td< td=""><td></td><td></td><td></td><td></td><td>Transducer's input range (between 0 and 25400 mmH20</td></td<>					Transducer's input range (between 0 and 25400 mmH20
Bits         OUT_SCALE EU_100         36.1263         Output range (between 0 and 36.1263 peig).           Image: Construction of the second se				-	
PT_ATI (Analog hput FB)         OUT         SCALE EU         0         Output range (between 0 and 36.1263 psig).           Image: Construct and the image of the imput range (between 0 and 36.1263 psig).         OUT_SCALE UNTS. INDEX         paig           Image: Construct and the image of the imput range is linearly converted to the output range (in psigned in the imput range) is linearly converted to the output range (in psigned in the imput range) is linearly converted to the output range (in psigned in the imput range) is linearly converted to the output range (in psigned in the imput range) is linearly converted to the output range (in psigned in the imput range) is linearly converted to the output range (in psigned in the imput range) is linearly converted to the output range (in psigned in the imput range (in psigned in the imput range) is linearly converted to the output range (in psigned in the imput range) is linearly converted to the output range (in psigned in the imput range) is linearly converted to the output range (in psigned in the imput range (in psigned in the imput range) is linearly converted to the output range (in the imput range in the imput range (in the imput range in psigned in the imput range (in the imput range in psigned in the imput range (in the imput range in psigned in the imput range (in the imput range in psigned in the imput range in the imput range in the imput range in the imput range in psigned in the imput range (in the imput range in the imput r		Quality :		. ,	
(Anaiog input FB)         Image: Control of the c		Scaling			Output range (between 0 and 36 1263 psig)
Image: Instant of the second					Output lange (between 0 and 30.1203 psig).
Trends         OUT         Trends?         Enables trending for parameter OUT.           Process         CHANNEL         1         Links to the transducer block.PT2_TB1.           MODE_BLK_TARGET         Auto         Activates the block.           IFI_BR (Resource block)         Process         MODE_BLK_TARGET         Auto         Activates the block.           IFI_TB1 (Transducer Block)         Process         MODE_BLK_TARGET         Auto         Activates the block.           IFI_TB2 (Transducer Block)         Process         MODE_BLK_TARGET         Auto         Activates the block.           IFI_TB2 (Transducer Block)         Process         MODE_BLK_TARGET         Auto         Activates the block.           IFI_TB3 (Transducer Block)         Process         MODE_BLK_TARGET         Auto         Activates the block.           IFI_TB3 (Transducer Block)         Process         MODE_BLK_TARGET         Auto         Activates the block.           IFI_TB3 (Transducer Block)         Process         MODE_BLK_TARGET         Auto         Activates the block.           IFI_TB3 (Transducer Block)         Process         MODE_BLK_TARGET         Auto         Activates the block.           IFI_TB3 (Transducer Block)         D.SCALE_EU_100         20         D.SCALE_EU_100         20           OUT_SCALE_UNT	(, indiag input i b)				The input range is linearly converted to the output range (in psig)
$\left  \begin{array}{c c c c c c c c c c c c c c c c c c c $		Tranda			
Process         MODE_BLK TARGET         Auto         Activates the block.           Block         Category         Parameter         Value         Comment           IF1_RB (Resource block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_RB (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB1 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_AIT         (Analog Input FB)         Scaling         OUT_SCALE.EU_0         4         Transducer's input range (4 to 20 mA).           VD_SCALE.LUNTS_INDEX         L/min         ULTYPE         Indirect         The input range is linearly converted to the output range.           IF1_AIZ         OUT_SCALE.EU_0         0		Trends			
Block         Category         Parameter         Value         Comment           IF1_RB (Resource block)         Process         MODE_BLKTARGET         Auto         Activates the block.           IF1_RB (Transducer Block)         Process         MODE_BLKTARGET         Auto         Activates the block.           IF1_TB2 (Transducer Block)         Process         MODE_BLKTARGET         Auto         Activates the block.           IF1_TB2 (Transducer Block)         Process         MODE_BLKTARGET         Auto         Activates the block.           IF1_TB2 (Transducer Block)         Process         MODE_BLKTARGET         Auto         Activates the block.           IF1_TB2 (Transducer Block)         Process         MODE_BLKTARGET         Auto         Activates the block.           IF1_TB2 (Transducer Block)         Process         MODE_BLKTARGET         Auto         Activates the block.           IF1_RB1 (Analog Input FB)         Scaling         OUT_SCALE.EU_0         4         Transducer's input range (0 to 50 Vmin). This range applies to the incoming oUT_SCALE.EU_100         0           IF1_AD2 (Analog Input FB)         Frends         OUT_SCALE.EU_10         0         Activates the block.           IF1_AD2 (Analog Input FB)         Scaling         OUT_SCALE.EU_10         1         Linkiva to the transducer block IF1_TB1.		Process			
Block         Category         Parameter         Value         Comment           IF1_RB (Resource block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB1 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_AUT         Out         Scaling         VD_S SCALE.EU_100         4         Transducer's input range (4 to 20 mA).           Scaling         OUT_SCALE.UNTO         0         Out         water flow.         Water flow.           IF1_AUT         (Analog Input FB)         ITrends         OUT         Trends?         L/min           IF1_AUT         CHANNEL         1         Links to the transducer block IF1_TB1.           MODE_BLK TARGET         Auto         Activates the block.         XD_SCALE.EU_1			MODE_BER.TARGET	Auto	Activates the block.
Block         Category         Parameter         Value         Comment           IF1_RB (Resource block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB1 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_AUT         Out         Scaling         VD_S SCALE.EU_100         4         Transducer's input range (4 to 20 mA).           Scaling         OUT_SCALE.UNTO         0         Out         water flow.         Water flow.           IF1_AUT         (Analog Input FB)         ITrends         OUT         Trends?         L/min           IF1_AUT         CHANNEL         1         Links to the transducer block IF1_TB1.           MODE_BLK TARGET         Auto         Activates the block.         XD_SCALE.EU_1			Current to FF converter	IF1, address = 23(	a)
IF1_RB (Resource block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB1 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB2 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_AB1         Scaling         VD_SCALE.EU_100         20         YD_SCALE.EU_0         0           OUT_SCALE.EU_100         0         Output range (0 to 50 /min). This range applies to the incoming water flow.         0UT_SCALE.EU_0         0           OUT_SCALE.EU_100         1         Links to the transducer block IF1_TB1.         1           IF1_AB2         MODE_BLK TARGET         Auto         Activates the block.         1           IF1_AB2         MODE_BLK TARGET         Auto	Block	Category	Parameter	Value	Comment
IF1_TB1 (Transducer Block)         Process         MODE_BLK.TARGET         Auto         Activates the block.           IF1_TB2 (Transducer Block)         Process         MODE_BLK.TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK.TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK.TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK.TARGET         Auto         Activates the block.           IF1_AI1         Process         MODE_BLK.TARGET         Auto         Activates the block.           IF1_AI1         Value         Activates the block.         Transducer's input range (4 to 20 mA).           Value         OUT_SCALE.EU_0         0         water flow.           OUT_SCALE.UNITS_INDEX         L/min         Links to the transducer block IF1_TB1.           Activates the block.         Activates the block.         Activates the block.           IF1_AI2         Frends         OUT_SCALE.U_ION         20           MODE_BLK.TARGET         Auto         Activates the block.         Activates the block.           IF1_AI2         CHANNEL         1         Links to the transducer block IF1_TB1.	IF1 RB (Resource block)		MODE BLK.TARGET	Auto	Activates the block.
IF1_TB2 (Transducer Block)         Process         MODE_BLK.TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK.TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK.TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         Process         MODE_BLK.TARGET         Auto         Activates the block.           IF1_AI1 (Analog Input FB)         Scaling         OUT_SCALE_U.0         4         Transducer's input range (4 to 20 mA).           IF1_AI1 (Analog Input FB)         Enables tending for parameter QUT.         The input range is linearly converted to the output range.           IF1_AI2 (Analog Input FB)         Trends         OUT         Trends/T         Enables tending for parameter QUT.           IF1_AI2 (Analog Input FB)         Scaling         OUT_SCALE_UNITS_INDEX         Infinect         Transducer's input range (4 to 20 mA).           IF1_AI2 (Analog Input FB)         Scaling         OUT_SCALE_U_100         20         Transducer's input range (4 to 20 mA).           IF1_AI2 (Analog Input FB)         Scaling         OUT_SCALE_U_10D         20         Transducer's input range (4 to 20 mA).           IF1_AI2 (Analog Input FB)         Scaling         OUT_SCALE_U_10D         100         0000		Process		Auto	Activates the block.
IF1_TB3 (Transducer Block)         Process         MODE_BLK TARGET         Auto         Activates the block.           IF1_TB3 (Transducer Block)         XD_SCALE_EU_100         20         Transducer's input range (4 to 20 mA).           XD_SCALE_EU_0         4         Transducer's input range (4 to 20 mA).         XD_SCALE_EU_0         0           XD_SCALE_EU_100         50         Output range (0 to 50 l/min). This range applies to the incoming water flow.         Output range (0 to 50 l/min). This range applies to the incoming water flow.           IF1_AI1 (Analog Input FB)         Trends         OUT         Trends         Output range is linearly converted to the output range.           IF1_AI2 (Analog Input FB)         Trends         OUT         Trends         Output range is linearly converted to the output range.           IF1_AI2 (Analog Input FB)         Scaling         CHANNEL         1         Links to the transducer's input range (4 to 20 mA).           IF1_AI2 (Analog Input FB)         Scaling         XD_SCALE_EU_100         20         Transducer's input range (4 to 20 mA).           IF1_AI2 (Analog Input FB)         Scaling         OUT_SCALE_EU_100         20         Transducer's input range (4 to 20 mA).           IF1_AI2 (Analog Input FB)         Scaling         OUT_SCALE_EU_100         4         Transducer's input range is linearly converted to the output range.           IF1_AI2 (	· · · · ·				
IF1_Al1 (Analog Input FB)         XD_SCALE_EU_100         20 XD_SCALE_EU_100         4 XD_SCALE_U_100         Transducer's input range (4 to 20 mA).           IF1_Al1 (Analog Input FB)         Scaling         OUT_SCALE_EU_100         50 OUT_SCALE_EU_100         OUT_SCALE_U_010         50 OUT_SCALE_U_010         Output range (0 to 50 l/min). This range applies to the incoming water flow.           IF1_Al2 (Analog Input FB)         Trends         OUT         Trends         Unim         The input range is linearly converted to the output range.           IF1_Al2 (Analog Input FB)         Scaling         OUT_SCALE_EU_100         20 OUT_SCALE_EU_100         Trends/ OUT         Trends/ Trends/ OUT_SCALE_EU_100         Transducer's input range (4 to 20 mA).           IF1_Al2 (Analog Input FB)         Scaling         OUT_SCALE_EU_100         20 AD_SCALE_EU_10         Transducer's input range (4 to 20 mA).           IF1_Al2 (Analog Input FB)         Scaling         OUT_SCALE_EU_100         100 OUT_SCALE_EU_10         OUT_SCALE_EU_10           IF1_Al3 (Analog Input FB)         Scaling         OUT_SCALE_EU_100         100 OUT_SCALE_EU_100         OUT_SCALE_EU_10           IF1_Al3 (Analog Input FB)         Scaling         CHANNEL         2         Links to the transducer block.           XD_SCALE_EU_0         4         XD_SCALE_EU_0         4         Transducer's input range (4 to 20 mA).           VD_SCALE_E	, ,	Process		Auto	Activates the block.
IF1_Al1 (Analog Input FB)     XD_SCALE_EU_101     Scaling     XD_SCALE_EU_100     SO       OUT_SCALE_EU_0     0     Output range (0 to 50 l/min). This range applies to the incoming water flow.       OUT_SCALE_EU_0     0     Output range (0 to 50 l/min). This range applies to the incoming water flow.       IF1_AL2 (Analog Input FB)     Trends     OUT     Trends?       IF1_AL2 (Analog Input FB)     CHAINNEL     1     Links to the transducer block IF1_TB1.       IF1_AL2 (Analog Input FB)     Scaling     MODE_BLK TARGET     Auto       ACLE_U_100     20     XD_SCALE_EU_100     100       VD_SCALE_EU_100     100     Output range (0 to 100%). This range applies to the water level inside the tank.       IF1_AL2 (Analog Input FB)     Scaling     OUT_SCALE_EU_100     100       IF1_AL3 (Analog Input FB)     CHAINNEL     2     Links to the transducer block IF1_TB2.       IF1_AL3 (Analog Input FB)     NODE_BLK TARGET     Auto     Activates the block.       IF1_AL3 (Analog Input FB)     NODE_BLK TARGET     Auto     Activates the block.       IF1_AL3 (Analog Input FB)     Scaling     OUT_SCALE_EU_100     20       IF1_AL3 (Analog Input FB)     Scaling     OUT_SCALE_EU_100     4       IF1_AL3 (Analog Input FB)     Scaling     OUT_SCALE_EU_100     4       IF1_AL3 (Analog Input FB)     Scaling	, ,		XD_SCALE.EU_100	20	
IF1_Al1 (Analog Input FB)     XD_SCALE_EU_101     Scaling     XD_SCALE_EU_100     SO       OUT_SCALE_EU_0     0     Output range (0 to 50 l/min). This range applies to the incoming water flow.       OUT_SCALE_EU_0     0     Output range (0 to 50 l/min). This range applies to the incoming water flow.       IF1_AL2 (Analog Input FB)     Trends     OUT     Trends?       IF1_AL2 (Analog Input FB)     CHAINNEL     1     Links to the transducer block IF1_TB1.       IF1_AL2 (Analog Input FB)     Scaling     MODE_BLK TARGET     Auto       ACLE_U_100     20     XD_SCALE_EU_100     100       VD_SCALE_EU_100     100     Output range (0 to 100%). This range applies to the water level inside the tank.       IF1_AL2 (Analog Input FB)     Scaling     OUT_SCALE_EU_100     100       IF1_AL3 (Analog Input FB)     CHAINNEL     2     Links to the transducer block IF1_TB2.       IF1_AL3 (Analog Input FB)     NODE_BLK TARGET     Auto     Activates the block.       IF1_AL3 (Analog Input FB)     NODE_BLK TARGET     Auto     Activates the block.       IF1_AL3 (Analog Input FB)     Scaling     OUT_SCALE_EU_100     20       IF1_AL3 (Analog Input FB)     Scaling     OUT_SCALE_EU_100     4       IF1_AL3 (Analog Input FB)     Scaling     OUT_SCALE_EU_100     4       IF1_AL3 (Analog Input FB)     Scaling			XD SCALE.EU 0	4	Transducer's input range (4 to 20 mA).
IF1_Al1 (Analog Input FB)          OUT_SCALE.EU_0         O         OUT_SCALE.UNITS_INDEX         L/min         Indirect         Indirect         Trends         OUT_TPE         Indirect         Indirect         The input range is linearly converted to the output range.         Enables trending for parameter OUT.         Trends         OUT_TPE         Indirect         I         L_TYPE         Indirect         The input range is linearly converted to the output range.         Enables trending for parameter OUT.         Internels         MODE_BLK.TARGET         Auto         Activates the block.         XD_SCALE.EU_100         20         XD_SCALE.EU_0         4         Transducer's input range (4 to 20 mA).         XD_SCALE.EU_100         OUT_SCALE.EU_100         OUT_SCALE.EU_0			XD_SCALE.UNITS_INDEX	mA	
IF1_AI1 (Analog Input FB)       Image: Constraint of the const		Scaling		-	
(Analog Input FB)     OUT_SCALE_UNITS_INDEX     L/min     Writer Indw.       Image: Input FB)     Trends     OUT_     Trend/2     Enables trending for parameter OUT.       Image: Input FB)     Process     CHANNEL     1     Links to the transducer block IF1_TB1.       Image: Input FB)     Process     MODE_BLK.TARGET     Auto     Activates the block.       Image: Input FB)     Scaling     XD_SCALE.EU_100     20     Transducer's input range (4 to 20 mA).       Image: Input FB)     Scaling     OUT_SCALE.EU_100     100     Output range (0 to 100%). This range applies to the water level inside the tank.       Image: Input FB)     OUT_SCALE.INITS_INDEX     mA     Output range (0 to 100%). This range applies to the water level inside the tank.       Image: Input FB)     Process     CHANNEL     2     Links to the transducer block IF1_TB2.       Image: Input FB)     Process     CHANNEL     2     Links to the transducer block IF1_TB2.       Image: Input FB)     Process     CHANNEL     2     Links to the transducer block IF1_TB2.       Image:	IE1 AI1	-	OUT_SCALE.EU_0	0	
			OUT_SCALE.UNITS_INDEX	L/min	
			L TYPE	Indirect	The input range is linearly converted to the output range.
IF1_AI2 (Analog Input FB)         CHANNEL         1         Links to the transducer block <i>IF1_TB1</i> .           MODE_BLK.TARGET         Auto         Activates the block.           XD_SCALE.EU_100         20           XD_SCALE.EU_0         4           Transducer's input range (4 to 20 mA).           XD_SCALE.EU_100         100           OUT_SCALE.EU_100         100           OUT_SCALE.EU_100         0           OUT_SCALE.EU_100         00           OUT_SCALE.EU_0         0           OUT_SCALE.EU_100         00           OUT_SCALE.EU_0         0           OUT_SCALE.EU_0         0           OUT_SCALE.EU_0         0           OUT_SCALE.EU_0         0           OUT_SCALE.EU_100         100           OUT_SCALE.EU_100         2           L_TYPE         Indirect           The input range is linearly converted to the output range.           XD_SCALE.EU_100         20           XD_SCALE.EU_100         20           XD_SCALE.EU_0         4           VD_SCALE.EU_0         4           VD_SCALE.EU_0         4           VD_SCALE.EU_0         0           VD_SCALE.EU_0         0           VD_SCALE.EU_0 <td></td> <td>Trends</td> <td>OUT</td> <td>Trend⊠</td> <td></td>		Trends	OUT	Trend⊠	
IF1_Al2 (Analog Input FB)         MODE_BLK.TARGET         Auto         Activates the block.           IF1_Al2 (Analog Input FB)         XD_SCALE.EU_100         20         Transducer's input range (4 to 20 mA).           IF1_Al2 (Analog Input FB)         Scaling         XD_SCALE.EU_100         100         Output range (0 to 100%). This range applies to the water level inside the tank.           IF1_Al2 (Analog Input FB)         0UT_SCALE.EU_0         0         Output range (0 to 100%). This range applies to the water level inside the tank.           IF1_Al3 (Analog Input FB)         CHANNEL         2         Links to the transducer block IF1_TB2.           MODE_BLK.TARGET         Auto         Activates the block.         Indirect           Scaling         XD_SCALE.EU_100         20         Transducer's input range (4 to 20 mA).           IF1_Al3 (Analog Input FB)         Scaling         XD_SCALE.EU_100         4         Transducer's input range (4 to 20 mA).           IF1_Al3 (Analog Input FB)         OUT_SCALE.EU_100         47.7         Output range (0 to 47.7 l/min). This range applies to the outgoin water flow.           IF1_Al3 (Analog Input FB)         OUT_SCALE.EU_100         47.7         Output range (0 to 47.7 l/min). This range applies to the outgoin water flow.           IF1_Al3 (Analog Input FB)         OUT_SCALE.EU_100         47.7         Output range is converted to the output range by applying the square root		_	CHANNEL	1	
IF1_AI2 (Analog Input FB)     XD_SCALE.EU_100     20       IF1_AI2 (Analog Input FB)     Scaling     XD_SCALE.EU_100     100       OUT_SCALE.EU_100     100     Output range (0 to 100%). This range applies to the water level inside the tank.       OUT_SCALE.EU_0     0       OUT_SCALE.EU_100     100       OUT_SCALE.EU_0     0       OUT_SCALE.EU_0     0       OUT_SCALE.EU_0     0       OUT_SCALE.EU_0     0       OUT_SCALE.EU_0     0       OUT_SCALE.UNITS_INDEX     %       IL_TYPE     Indirect       The input range is linearly converted to the output range.       IF1_AI3     MODE_BLK.TARGET       Auto     Activates the block.       XD_SCALE.EU_100     20       XD_SCALE.EU_100     20       XD_SCALE.EU_100     20       XD_SCALE.EU_100     4       Transducer's input range (4 to 20 mA).       XD_SCALE.EU_100     4       Transducer's input range (0 to 47.7 l/min). This range applies to the outgoin water flow.       OUT_SCALE.EU_100     47.7       OUT_SCALE.EU_100     47.7       OUT_SCALE.EU_100     47.7       OUT_SCALE.EU_100     47.7       OUT_SCALE.EU_100     0       OUT_SCALE.EU_100     47.7       OUT_SCALE.EU_100     0 <td></td> <td>Process</td> <td>MODE_BLK.TARGET</td> <td>Auto</td> <td></td>		Process	MODE_BLK.TARGET	Auto	
$ \begin{array}{c} IF1\_AI2 \\ (Analog Input FB) \end{array} \left\{ \begin{array}{c} XD\_SCALE\_EU\_0 & 4 \\ XD\_SCALE\_EU\_100 & 100 \\ OUT\_SCALE\_EU\_100 & 100 \\ OUT\_SCALE\_EU\_0 & 0 \\ OUT\_SCALE\_EU\_0 & 1 \\ OUT\_SCALE\_EU\_0 & 0 \\ Scaling \\ IF1\_AI3 \\ (Analog Input FB) \end{array} \left. \begin{array}{c} XD\_SCALE\_EU\_0 & 0 \\ Scaling \\ OUT\_SCALE\_EU\_100 & 20 \\ XD\_SCALE\_EU\_100 & 20 \\ XD\_SCALE\_EU\_100 & 20 \\ XD\_SCALE\_EU\_0 & 4 \\ SCALE\_EU\_0 & 4 \\ OUT\_SCALE\_EU\_0 & 4 \\ Scaling \\ OUT\_SCALE\_EU\_0 & 0 \\ OUT\_SCALE\_EU\_0$				20	
$ \begin{array}{c} IF1\_AI2\\ (Analog Input FB) \end{array} \left( \begin{array}{c} XD\_SCALE.UNITS\_INDEX & mA \\ \hline & OUT\_SCALE.EU\_100 & 100 \\ OUT\_SCALE.EU\_0 & 0 \\ \hline & OUT\_SCALE.EU\_0 & 0 \\ \hline & OUT\_SCALE.UNITS\_INDEX & \% \end{array} \right) \\ \hline & OUT\_SCALE.UNITS\_INDEX & \% \end{array} \right) \\ \hline & OUT\_SCALE.UNITS\_INDEX & \% \end{array} \right) \\ \hline & Process & \hline & CHANNEL & 2 \\ \hline & Process & MODE\_BLK.TARGET & Auto & Activates the block. \end{array} \\ \hline & & XD\_SCALE.EU\_100 & 20 \\ \hline & & XD\_SCALE.EU\_100 & 20 \\ \hline & & XD\_SCALE.EU\_0 & 4 \\ \hline & & XD\_SCALE.EU\_0 & 4 \\ \hline & & XD\_SCALE.EU\_100 & 4 \\ \hline & & XD\_SCALE.EU\_100 & 47.7 \\ \hline & & OUT\_SCALE.EU\_0 & 4 \\ \hline & & OUT\_SCALE.EU\_0 & 0 \\ \hline & & OUT\_SCALE.EU\_0 & OUT\_SCALE.EU\_0 & 0 \\ \hline & & OUT\_SCALE.EU\_0 & OUT\_SCALE.EU\_0 & 0 \\ \hline & & OUT\_SCALE.EU\_0 & OUT\_SCALE.EU\_0 & 0 \\ \hline & & OUT\_SCALE.EU\_0 & OUT\_SCALE.EU\_0 & OUT\_SCALE.EU\_0 & OUT\_SCALE.EU\_0 & OUT\_SCALE.EU\_0 & OUT\_SCALE.EU\_0 & OUT\_SCALE.EU\_$				4	
IF1_Al2 (Analog Input FB)       Scaling          OUT_SCALE.EU_100         OUT_SCALE.EU_0         O         OUT_SCALE.EU_0         OUT_SCALE.EU_0         OUT_SCALE.UNITS_INDEX         Vector          Output range (0 to 100%). This range applies to the water level inside the tank.             OUT_SCALE.UNITS_INDEX           OUT_SCALE.UNITS_INDEX         Vector          Output range (0 to 100%). This range applies to the water level inside the tank.             Process           CHANNEL           2         Links to the transducer block <i>IF1_TB2</i> .             Process           CHANNEL           2         Links to the transducer block.             Process           MODE_BLK.TARGET           Auto         Activates the block.             XD_SCALE.EU_100           20           Transducer's input range (4 to 20 mA).             XD_SCALE.EU_100           4           OUT_SCALE.EU_0           Auto             (Analog Input FB)           Scaling           OUT_SCALE.EU_0           Output range (0 to 47.7 l/min). This range applies to the outgoin         water flow.             (Analog Input FB)           OUT_SCALE.UNITS_INDEX           L/min             L_TYPE           Indirect Sq Root           Deutrange is					
IF1_Al2 (Analog Input FB)       OUT_SCALE.EU_0       Output range (0 to 100%). This range applies to the water level inside the tank.         OUT_SCALE.UNITS_INDEX       %         IL_TYPE       Indirect         Process       CHANNEL       2         MODE_BLK.TARGET       Auto         Activates the block.       XD_SCALE.EU_100         XD_SCALE.EU_100       20         XD_SCALE.EU_0       4         Transducer's input range (4 to 20 mA).         XD_SCALE.EU_100       47.7         OUT_SCALE.EU_0       0         VD_SCALE.EU_0       47.7         OUT_SCALE.EU_0       0         VD_SCALE.EU_0       0         VD_SCALE.EU_0       47.7         OUT_SCALE.EU_0       0         VD_SCALE.EU_0       0         VD_SCALE.EU_0       0         VD_SCALE.EU_0       0         VD_SCALE.EU_0       0         VD_SCALE.EU_0       0         VD_SCALE.EU_NITS_INDEX       MA         OUT_SCALE.EU_0       0         VUT_SCALE.EU_NITS_INDEX       Urmin         UT_SCALE.UNITS_INDEX       Urmin         L_TYPE       Indirect Sq Root         Square root operation. Useful for flow meters based on different pressure.		Scaling			
Inside the tank.       OUT_SCALE.UNITS_INDEX     %       Indirect     The input range is linearly converted to the output range.       Process     CHANNEL     2       Indirect     Links to the transducer block <i>IF1_TB2</i> .       MODE_BLK.TARGET     Auto       Activates the block.       XD_SCALE.EU_100     20       XD_SCALE.EU_0     4       Transducer's input range (4 to 20 mA).       XD_SCALE.EU_100     47.7       OUT_SCALE.EU_100     47.7       OUT_SCALE.EU_0     0       OUT_SCALE.EU_0     0       OUT_SCALE.EU_0     0       UT_SCALE.EU_0     0       VI_SCALE.EU_100     47.7       OUT_SCALE.EU_0     0       UT_SCALE.EU_0     0       UT_SCALE.EU_0     0       UT_SCALE.EU_100     47.7       OUT_SCALE.EU_0     0       UT_SCALE.EU_100     47.7       OUT_SCALE.EU_0     0       UT_SCALE.EUNITS_INDEX     U/min       UT_SCALE.UNITS_INDEX     L/min       L_TYPE     Indirect Sq Root       Square root operation. Useful for flow meters based on different pressure.				0	
Indirect         The input range is linearly converted to the output range.           Process         CHANNEL         2         Links to the transducer block <i>IF1_TB2</i> .           MODE_BLK.TARGET         Auto         Activates the block.           XD_SCALE.EU_100         20           XD_SCALE.EU_0         4           Transducer's input range (4 to 20 mA).           XD_SCALE.EU_100         47.7           OUT_SCALE.EU_0         47.7           OUT_SCALE.EU_0         0           OUT_SCALE.EU_0         0           OUT_SCALE.EU_0         0           VERTION         100           VERTION         100           OUT_SCALE.EU_0         47.7           OUT_SCALE.EU_0         0           VERTION         0           UT_SCALE.EU_NITS_INDEX         100           UT_SCALE.EU_NITS_INDEX         100           UT_SCALE.EU_NITS_INDEX         100           UT_SCALE.EUNITS_INDEX         100           UT_SCALE.EUNITS_INDEX         100           UT_SCALE.EUNITS_INDEX         100           UT_SCALE.EU_NITS_INDEX         100           UT_SCALE.EU_NITS_INDEX         100           UT_SCALE.EU_NITS_INDEX         100           UT_SCALE.EU_NITS_I	(Analog Input FB)				Inside the tark.
IF1_A/3 (Analog Input FB)         CHANNEL         2         Links to the transducer block //F1_TB2.           MODE_BLK.TARGET         Auto         Activates the block.           XD_SCALE.EU_100         20           XD_SCALE.EU_0         4           Transducer's input range (4 to 20 mA).           XD_SCALE.EU_100         47.7           OUT_SCALE.EU_0         0           OUT_SCALE.EU_0         0           OUT_SCALE.EU_0         0           Water flow.         Output range (0 to 47.7 l/min). This range applies to the outgoin water flow.           OUT_SCALE.EU_100         47.7           Image: Content of the output range is converted to the output range by applying the square root operation. Useful for flow meters based on different pressure.					The input range is linearly converted to the output range.
IF1_A/3 (Analog Input FB)         Scaling         MODE_BLK.TARGET         Auto         Activates the block.           IF1_A/3 (Analog Input FB)         Scaling         XD_SCALE.EU_100         20 XD_SCALE.EU_0         Transducer's input range (4 to 20 mA).           IF1_A/3 (Analog Input FB)         Scaling         OUT_SCALE.EU_100         47.7 0UT_SCALE.EU_0         Output range (0 to 47.7 l/min). This range applies to the outgoin water flow.           IF1_A/3 (Analog Input FB)         OUT_SCALE.EU_100         10.7 Indirect Sq Root         The input range is converted to the output range by applying the square root operation. Useful for flow meters based on different pressure.					
IF1_AI3 (Analog Input FB)     Scaling     XD_SCALE.EU_100     20 XD_SCALE.EU_0     4 Transducer's input range (4 to 20 mA).       IF1_AI3 (Analog Input FB)     Scaling     OUT_SCALE.EU_100     47.7 OUT_SCALE.EU_0     0 Water flow.       IF1_AI3 (Analog Input FB)     OUT_SCALE.EU_100     47.7 OUT_SCALE.EU_0     0 Water flow.       IF1_AI3 (Analog Input FB)     OUT_SCALE.EU_100     47.7 Indirect Sq Root       IF1_AI3 (Analog Input FB)     Indirect Sq Root     Output range is converted to the output range by applying the square root operation. Useful for flow meters based on different pressure.		Process			
IF1_A/3 (Analog Input FB)     Scaling     XD_SCALE.EU_0     4 XD_SCALE.UNITS_INDEX     Transducer's input range (4 to 20 mA).       IF1_A/3 (Analog Input FB)     OUT_SCALE.EU_100     47.7       OUT_SCALE.EU_0     0 UUT_SCALE.EU_0     0 UUT_SCALE.UNITS_INDEX       L_TYPE     Indirect Sq Root       Sequere root operation. Useful for flow meters based on different pressure.					
IF1_A/3 (Analog Input FB)     Scaling     XD_SCALE.UNITS_INDEX     mA       OUT_SCALE.EU_100     47.7       OUT_SCALE.EU_0     0       OUT_SCALE.EU_0     0       OUT_SCALE.EU_NITS_INDEX     L/min       L_TYPE     Indirect Sq Root       Square root operation. Useful for flow meters based on different pressure.					Transducer's input range (4 to 20 mA).
IF1_A/3 (Analog Input FB)     Scaling     OUT_SCALE.EU_100     47.7       OUT_SCALE.EU_0     0       OUT_SCALE.EU_0     0       OUT_SCALE.EU_NITS_INDEX     L/min       L_TYPE     Indirect Sq Root       Square root operation. Useful for flow meters based on different pressure.		Scaling			
IF1_A/3 (Analog Input FB)     Scaling     OUT_SCALE.EU_0     Output range (0 to 47.7 l/min). This range applies to the outgoin water flow.       UT_SCALE.UNITS_INDEX     L/min       L_TYPE     Indirect Sq Root       square root operation. Useful for flow meters based on different pressure.					
(Analog Input FB) (Analog Input FB) UT_SCALE.UNITS_INDEX L/min L_TYPE Indirect Sq Root square root operation. Useful for flow meters based on different pressure.				-	Output range (0 to 47.7 l/min). This range applies to the outgoing water flow.
L_TYPE         Indirect Sq Root         The input range is converted to the output range by applying the square root operation. Useful for flow meters based on different pressure.				-	
	(				The input range is converted to the output range by applying the square root operation. Useful for flow meters based on differential pressure.
CHANNEL 3 ILinks to the transducer block IF1 TB3			CHANNEL	3	Links to the transducer block <i>IF1_TB3</i> .
Process MODE_BLK.TARGET Auto Activates the block.		Process			

		Control valve FCV1	, address = $25(a)$	
Block	Category	Parameter	Value	Comment
FCV1_RB (Resource Block)	Process	MODE BLK.TARGET	Auto	Activates the block.
FCV1_TB1 (Transducer Block)	Process	MODE_BLK.TARGET	Auto	Activates the block.
	FIUCESS		100	Activates the block.
		PV_SCALE.EU_100	-	Range of the Process Variable (PV) (0 to 100%). In the
		PV_SCALE.EU_0	0	present case, the PV is the water level inside the tank.
	Scaling	PV_SCALE.UNITS_INDEX	%	
	-	OUT_SCALE.EU_100	100	Range of the Output Variable (OV) (0 to 100%). In the presen
		OUT_SCALE.EU_0	0	case, the OVsets the valve opening.
FCV1_PID1		OUT_SCALE.UNITS_INDEX	%	· · · ·
(PID FB)		GAIN	6	Proportional gain (Kp) of the PID controller.
	Tuning	RESET	4 Sec	Reset time (Ti) of the PID controller.
		RATE	4 Sec	Derivative time (Td) of the PID controller.
	Options	STATUS_OPTS	IFS if bad IN	If the block input goes bad (due to a communications failure, for example), initiate fault state in the cascaded block.
	_	SP.VALUE	ххх	Level set-point.
	Process	MODE_BLK.TARGET	Auto	Activates the block.
		PV_SCALE.EU_100	100	
		PV_SCALE.EU_0	0	Input range (0 to 100%).
	-	PV SCALE.UNITS INDEX	%	······································
	Scaling	XD_SCALE.EU_100	100	
	-	XD_SCALE.EU_0	0	Actuator's output range (0 to 100%). The input range is linearly
				converted to the output range.
FCV1_AO1		XD_SCALE.UNITS_INDEX	%	
(Analog Output FB)		IO_OPTS	Fault state to value	The fault state is activated if the block input has a status of
	Options	FSTATE_TIME	2 Sec	BAD for more than two seconds. If this happens, the valve is closed (output value = 0) for safety reasons.
		FSTATE_VAL	0	
		CHANNEL	1	Links to the transducer block FCV1_TB1.
	Process	MODE_BLK.TARGET	Cascade	The block follows the set-point given by the upstream controller (block <i>FCV1_PID1</i> in this case). Meanwhile, it applies scaling and checks the fault state condition.
Block	Category	Control valve FCV2 Parameter	1	Comment
Block ECV2_RB (Resource Block)	Category	Parameter	Value	Comment Activates the block
FCV2_RB (Resource Block)	Process	Parameter MODE_BLK.TARGET	Value Auto	Activates the block.
		Parameter MODE_BLK.TARGET MODE_BLK.TARGET	Value Auto Auto	
FCV2_RB (Resource Block)	Process	Parameter MODE_BLK.TARGET MODE_BLK.TARGET PV_SCALE.EU_100	Value Auto Auto 47.7	Activates the block.
FCV2_RB (Resource Block)	Process	Parameter MODE_BLK.TARGET MODE_BLK.TARGET PV_SCALE.EU_100 PV_SCALE.EU_0	Value Auto Auto 47.7 0	Activates the block. Activates the block.
FCV2_RB (Resource Block)	Process	Parameter MODE_BLK.TARGET MODE_BLK.TARGET PV_SCALE.EU_100 PV_SCALE.EU_0 PV_SCALE.UNITS_INDEX	Value Auto Auto 47.7 0 L/min	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the
FCV2_RB (Resource Block)	Process Process	Parameter         MODE_BLK.TARGET         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.UNITS_INDEX         OUT_SCALE.EU_100	Value Auto Auto 47.7 0 L/min 100	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow.
FCV2_RB (Resource Block)	Process Process	Parameter         MODE_BLK.TARGET         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.UNITS_INDEX         OUT_SCALE.EU_100         OUT_SCALE.EU_0	Value Auto 47.7 0 L/min 100 0	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow.
FCV2_RB (Resource Block)	Process Process	Parameter         MODE_BLK.TARGET         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.UNITS_INDEX         OUT_SCALE.EU_0         OUT_SCALE.EU_0         OUT_SCALE.UNITS_INDEX	Value           Auto           417.7           0           L/min           100           0           %	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow. Range of the Output Variable (OV) (0 to 100%). In the present case, the OVsets the valve opening.
FCV2_RB (Resource Block) FCV2_TB1 (Transducer Block)	Process Process	Parameter         MODE_BLK.TARGET         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.UNITS_INDEX         OUT_SCALE.EU_100         OUT_SCALE.EU_0	Value Auto 47.7 0 L/min 100 0	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow. Range of the Output Variable (OV) (0 to 100%). In the present
FCV2_RB (Resource Block) FCV2_TB1 (Transducer Block)	Process Process	Parameter         MODE_BLK.TARGET         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.UNITS_INDEX         OUT_SCALE.EU_0         OUT_SCALE.EU_0         OUT_SCALE.UNITS_INDEX	Value           Auto           417.7           0           L/min           100           0           %	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow. Range of the Output Variable (OV) (0 to 100%). In the present case, the OVsets the valve opening.
FCV2_RB (Resource Block) FCV2_TB1 (Transducer Block)	Process Process Scaling	Parameter MODE_BLK.TARGET MODE_BLK.TARGET PV_SCALE.EU_100 PV_SCALE.EU_0 PV_SCALE.UNITS_INDEX OUT_SCALE.EU_0 OUT_SCALE.UNITS_INDEX GAIN	Value           Auto           417.7           0           L/min           100           %           0.5	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow. Range of the Output Variable (OV) (0 to 100%). In the present case, the OVsets the valve opening. Proportional gain (Kp) of the PID controller.
FCV2_RB (Resource Block) FCV2_TB1 (Transducer Block)	Process Process Scaling	Parameter         MODE_BLK.TARGET         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.EU_100         OUT_SCALE.EU_00         OUT_SCALE.EU_0         OUT_SCALE.UNITS_INDEX         GAIN         RESET	Value           Auto           Auto           47.7           0           L/min           100           0           %           0.5           5 Sec	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow. Range of the Output Variable (OV) (0 to 100%). In the present case, the OVsets the valve opening. Proportional gain (Kp) of the PID controller. Reset time (Ti) of the PID controller.
FCV2_RB (Resource Block) FCV2_TB1 (Transducer Block)	Process Process Scaling Tuning Options	Parameter MODE_BLK.TARGET MODE_BLK.TARGET PV_SCALE.EU_100 PV_SCALE.EU_0 PV_SCALE.UNITS_INDEX OUT_SCALE.EU_100 OUT_SCALE.EU_0 OUT_SCALE.UNITS_INDEX GAIN RESET RATE	Value           Auto           Auto           47.7           0           L/min           100           0           %           0.5           5 Sec           1 Sec	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow. Range of the Output Variable (OV) (0 to 100%). In the present case, the OVsets the valve opening. Proportional gain (Kp) of the PID controller. Reset time (Ti) of the PID controller. Derivative time (Td) of the PID controller. If the block input goes bad (due to a communications failure,
FCV2_RB (Resource Block) FCV2_TB1 (Transducer Block)	Process Process Scaling Tuning	Parameter MODE_BLK.TARGET MODE_BLK.TARGET PV_SCALE.EU_100 PV_SCALE.EU_0 PV_SCALE.UNITS_INDEX OUT_SCALE.EU_100 OUT_SCALE.EU_0 OUT_SCALE.EU_0 OUT_SCALE.UNITS_INDEX GAIN RESET RATE STATUS_OPTS	Value           Auto           Auto           47.7           0           L/min           100           0           %           0.5           5 Sec           1 Sec           IFS if bad IN	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow. Range of the Output Variable (OV) (0 to 100%). In the present case, the OVsets the valve opening. Proportional gain (Kp) of the PID controller. Reset time (Ti) of the PID controller. Derivative time (Td) of the PID controller. If the block input goes bad (due to a communications failure, for example), initiate fault state in the cascaded block.
FCV2_RB (Resource Block) FCV2_TB1 (Transducer Block)	Process Process Scaling Tuning Options	Parameter         MODE_BLK.TARGET         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.UNITS_INDEX         OUT_SCALE.EU_100         OUT_SCALE.EU_00         OUT_SCALE.EU_00         OUT_SCALE.EU_100         OUT_SCALE.EU_00         OUT_SCALE.EU         PV_SCALE.UNITS_INDEX         GAIN         RESET         RATE         STATUS_OPTS         SP.VALUE         MODE_BLK.TARGET	Value           Auto           Auto           47.7           0           L/min           100           0           %           0.5           5 Sec           1 Sec           IFS if bad IN           xxx	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow. Range of the Output Variable (OV) (0 to 100%). In the present case, the OVsets the valve opening. Proportional gain (Kp) of the PID controller. Reset time (Ti) of the PID controller. Derivative time (Td) of the PID controller. If the block input goes bad (due to a communications failure, for example), initiate fault state in the cascaded block. Flow set-point.
FCV2_RB (Resource Block) FCV2_TB1 (Transducer Block)	Process Process Scaling Tuning Options	Parameter         MODE_BLK.TARGET         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.UNITS_INDEX         OUT_SCALE.EU_100         OUT_SCALE.EU_00         OUT_SCALE.EU_00         OUT_SCALE.EU_100         OUT_SCALE.EU_100         OUT_SCALE.EU         PV_SCALE.UNITS_INDEX         GAIN         RESET         RATE         STATUS_OPTS         SP.VALUE         MODE_BLK.TARGET         PV_SCALE.EU_100	Value           Auto           Auto           47.7           0           L/min           100           0           %           0.5           5 Sec           1 Sec           IFS if bad IN           xxx           Auto           100	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow. Range of the Output Variable (OV) (0 to 100%). In the present case, the OVsets the valve opening. Proportional gain (Kp) of the PID controller. Reset time (Ti) of the PID controller. Derivative time (Td) of the PID controller. If the block input goes bad (due to a communications failure, for example), initiate fault state in the cascaded block. Flow set-point. Activates the block.
FCV2_RB (Resource Block) FCV2_TB1 (Transducer Block)	Process Process Scaling Tuning Options	Parameter         MODE_BLK.TARGET         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.EU_100         OUT_SCALE.EU_100         OUT_SCALE.EU_100         OUT_SCALE.EU_0         OUT_SCALE.EU_100         OUT_SCALE.EU_100         OUT_SCALE.EU         PV_SCALE.UNITS_INDEX         GAIN         RESET         RATE         STATUS_OPTS         SP.VALUE         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0	Value           Auto           Auto           47.7           0           L/min           100           0           %           0.5           5 Sec           1 Sec           IFS if bad IN           xxx           Auto           100           0	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow. Range of the Output Variable (OV) (0 to 100%). In the present case, the OVsets the valve opening. Proportional gain (Kp) of the PID controller. Reset time (Ti) of the PID controller. Derivative time (Td) of the PID controller. If the block input goes bad (due to a communications failure, for example), initiate fault state in the cascaded block. Flow set-point.
FCV2_RB (Resource Block) FCV2_TB1 (Transducer Block)	Process Process Scaling Tuning Options	Parameter         MODE_BLK.TARGET         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.UNITS_INDEX         OUT_SCALE.EU_100         OUT_SCALE.EU_100         OUT_SCALE.EU_0         OUT_SCALE.EU_0         OUT_SCALE.EU_0         OUT_SCALE.UNITS_INDEX         GAIN         RESET         RATE         STATUS_OPTS         SP.VALUE         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.UNITS_INDEX	Value           Auto           Auto           47.7           0           L/min           100           0           %           0.5           5 Sec           1 Sec           IFS if bad IN           xxx           Auto           100           0	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow. Range of the Output Variable (OV) (0 to 100%). In the present case, the OVsets the valve opening. Proportional gain (Kp) of the PID controller. Reset time (Ti) of the PID controller. Derivative time (Td) of the PID controller. If the block input goes bad (due to a communications failure, for example), initiate fault state in the cascaded block. Flow set-point. Activates the block.
FCV2_RB (Resource Block) FCV2_TB1 (Transducer Block)	Process Process Scaling Tuning Options Process	Parameter         MODE_BLK.TARGET         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.EU_100         OUT_SCALE.EU_100         OUT_SCALE.EU_100         OUT_SCALE.EU_0         OUT_SCALE.EU_100         OUT_SCALE.EU_0         OUT_SCALE.EU         PV_SCALE.UNITS_INDEX         GAIN         RESET         RATE         STATUS_OPTS         SP.VALUE         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.UNITS_INDEX         XD_SCALE.EU_100	Value           Auto           Auto           47.7           0           L/min           100           0           %           0.5           5 Sec           1 Sec           IFS if bad IN           xxx           Auto           100           %           100	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow. Range of the Output Variable (OV) (0 to 100%). In the present case, the OVsets the valve opening. Proportional gain (Kp) of the PID controller. Reset time (Ti) of the PID controller. Derivative time (Td) of the PID controller. If the block input goes bad (due to a communications failure, for example), initiate fault state in the cascaded block. Flow set-point. Activates the block. Input range (0 to 100%).
FCV2_RB (Resource Block) FCV2_TB1 (Transducer Block)	Process Process Scaling Tuning Options Process	Parameter         MODE_BLK.TARGET         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.EU_0         OUT_SCALE.EU_100         OUT_SCALE.EU_100         OUT_SCALE.EU_0         OUT_SCALE.EU_0         OUT_SCALE.EU_0         OUT_SCALE.EU_0         OUT_SCALE.UNITS_INDEX         GAIN         RESET         RATE         STATUS_OPTS         SP.VALUE         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.EU_0         PV_SCALE.EU_100         XD_SCALE.EU_0         XD_SCALE.EU_0	Value           Auto           Auto           47.7           0           L/min           100           0           %           0.5           5 Sec           1 Sec           IFS if bad IN           xxx           Auto           100           0           %           100           0           %           100           0           %           100           0           0           0	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow. Range of the Output Variable (OV) (0 to 100%). In the present case, the OVsets the valve opening. Proportional gain (Kp) of the PID controller. Reset time (Ti) of the PID controller. Derivative time (Td) of the PID controller. If the block input goes bad (due to a communications failure, for example), initiate fault state in the cascaded block. Flow set-point. Activates the block. Input range (0 to 100%).
FCV2_RB (Resource Block) FCV2_TB1 (Transducer Block) FCV2_PID1 (PID FB)	Process Process Scaling Tuning Options Process	Parameter         MODE_BLK.TARGET         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.UNITS_INDEX         OUT_SCALE.EU_100         OUT_SCALE.EU_100         OUT_SCALE.EU_0         OUT_SCALE.EU_100         OUT_SCALE.EU_100         OUT_SCALE.EU_0         OUT_SCALE.UNITS_INDEX         GAIN         RESET         RATE         STATUS_OPTS         SP.VALUE         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.EU_100         XD_SCALE.EU_100         XD_SCALE.EU_0         XD_SCALE.EU_0         XD_SCALE.EU_0         XD_SCALE.EU_0         XD_SCALE.EU_0	Value           Auto           Auto           47.7           0           L/min           100           0           %           0.5           5 Sec           1 Sec           IFS if bad IN           xxx           Auto           100           0           %           100           0           %           100           0           %           100           0           %	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow. Range of the Output Variable (OV) (0 to 100%). In the present case, the OVsets the valve opening. Proportional gain (Kp) of the PID controller. Reset time (Ti) of the PID controller. Derivative time (Td) of the PID controller. If the block input goes bad (due to a communications failure, for example), initiate fault state in the cascaded block. Flow set-point. Activates the block. Input range (0 to 100%).
FCV2_RB (Resource Block) FCV2_TB1 (Transducer Block) FCV2_PID1 (PID FB)	Process Process Scaling Tuning Options Process Scaling	Parameter         MODE_BLK.TARGET         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.EU_100         OUT_SCALE.EU_100         OUT_SCALE.EU_100         OUT_SCALE.EU_0         OUT_SCALE.EU_100         OUT_SCALE.EU_0         OUT_SCALE.EU         GAIN         RESET         RATE         STATUS_OPTS         SP.VALUE         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.EU_0         PV_SCALE.EU_100         XD_SCALE.EU_0	Value           Auto           Auto           47.7           0           L/min           100           0           %           0.5           5 Sec           1 Sec           IFS if bad IN           xxx           Auto           100           0           %           100           0           %           100           %           100           %           Fault state to value	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow. Range of the Output Variable (OV) (0 to 100%). In the present case, the OVsets the valve opening. Proportional gain (Kp) of the PID controller. Reset time (Ti) of the PID controller. Derivative time (Td) of the PID controller. If the block input goes bad (due to a communications failure, for example), initiate fault state in the cascaded block. Flow set-point. Activates the block. Input range (0 to 100%). Actuator's output range (0 to 100%). The input range is linearly converted to the output range.
FCV2_RB (Resource Block) FCV2_TB1 (Transducer Block) FCV2_PID1 (PID FB)	Process Process Scaling Tuning Options Process	Parameter         MODE_BLK.TARGET         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.UNITS_INDEX         OUT_SCALE.EU_100         OUT_SCALE.EU_100         OUT_SCALE.EU_0         OUT_SCALE.EU_100         OUT_SCALE.EU_100         OUT_SCALE.EU_0         OUT_SCALE.UNITS_INDEX         GAIN         RESET         RATE         STATUS_OPTS         SP.VALUE         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.EU_100         XD_SCALE.EU_100         XD_SCALE.EU_0         XD_SCALE.EU_0         XD_SCALE.EU_0         XD_SCALE.EU_0         XD_SCALE.EU_0	Value           Auto           Auto           47.7           0           L/min           100           0           %           0.5           5 Sec           1 Sec           IFS if bad IN           xxx           Auto           100           0           %           100           0           %           100           0           %           100           0           %	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow. Range of the Output Variable (OV) (0 to 100%). In the present case, the OVsets the valve opening. Proportional gain (Kp) of the PID controller. Reset time (Ti) of the PID controller. Derivative time (Td) of the PID controller. If the block input goes bad (due to a communications failure, for example), initiate fault state in the cascaded block. Flow set-point. Activates the block. Input range (0 to 100%).
FCV2_RB (Resource Block) FCV2_TB1 (Transducer Block) FCV2_PID1 (PID FB) FCV2_A01	Process Process Scaling Tuning Options Process Scaling	Parameter         MODE_BLK.TARGET         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.EU_100         OUT_SCALE.EU_100         OUT_SCALE.EU_100         OUT_SCALE.EU_0         OUT_SCALE.EU_100         OUT_SCALE.EU_0         OUT_SCALE.EU         GAIN         RESET         RATE         STATUS_OPTS         SP.VALUE         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.EU_0         PV_SCALE.EU_100         XD_SCALE.EU_0	Value           Auto           Auto           47.7           0           L/min           100           0           %           0.5           5 Sec           1 Sec           IFS if bad IN           xxx           Auto           100           0           %           100           0           %           100           %           100           %           Fault state to value	Activates the block. Activates the block. Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow. Range of the Output Variable (OV) (0 to 100%). In the present case, the OVsets the valve opening. Proportional gain (Kp) of the PID controller. Reset time (Ti) of the PID controller. Derivative time (Td) of the PID controller. If the block input goes bad (due to a communications failure, for example), initiate fault state in the cascaded block. Flow set-point. Activates the block. Input range (0 to 100%). Actuator's output range (0 to 100%). The input range is linearly converted to the output range. If the fault state persists for more than two seconds, close the
FCV2_RB (Resource Block) FCV2_TB1 (Transducer Block) FCV2_PID1 (PID FB) FCV2_A01	Process Process Scaling Tuning Options Process Scaling	Parameter         MODE_BLK.TARGET         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.EU_0         OUT_SCALE.EU_100         OUT_SCALE.EU_100         OUT_SCALE.EU_0         OUT_SCALE.EU_100         OUT_SCALE.EU_0         OUT_SCALE.UNITS_INDEX         GAIN         RESET         RATE         STATUS_OPTS         SP.VALUE         MODE_BLK.TARGET         PV_SCALE.EU_100         PV_SCALE.EU_0         PV_SCALE.EU_0         XD_SCALE.EU_100         XD_SCALE.EU_0         XD_SCALE.EU_0	Value           Auto           Auto           47.7           0           L/min           100           0           %           0.5           5 Sec           1 Sec           IFS if bad IN           xxx           Auto           100           0           %           100           0           %           100           %           Fault state to value           2 Sec	Activates the block.         Activates the block.         Range of the Process Variable (PV) (0 to 47.7 l/min). In the present case, the PV is the outgoing water flow.         Range of the Output Variable (OV) (0 to 100%). In the present case, the OVsets the valve opening.         Proportional gain (Kp) of the PID controller.         Reset time (Ti) of the PID controller.         Derivative time (Td) of the PID controller.         If the block input goes bad (due to a communications failure, for example), initiate fault state in the cascaded block.         Flow set-point.         Activates the block.         Input range (0 to 100%).         Actuator's output range (0 to 100%). The input range is linearly converted to the output range.         If the fault state persists for more than two seconds, close the

#### Table 2 (continued) Configuration of FF instruments.

Notes: a) For sake of simplicity the configuration of the display transducer block was omitted.

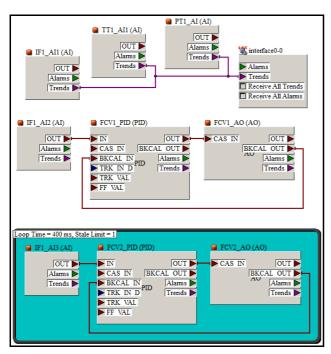


Fig. 5 – Control application

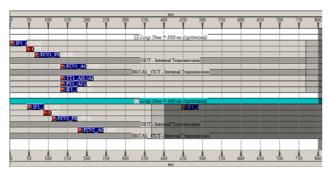


Fig. 6 – Schedule of the control application

# 4. SUPERVISION SOFTWARE

The supervision software allows the pilot plant to be operated by people that are not experts on the FF technology. It hides low level configuration details and exposes system variables as numeric quantities.

The supervision software was developed in LabVIEW using the facilities provided by the DSCmodule [14]. The communication with FF infrastructure was done using the OPC-DA(Open Process Control Data Access) server [15-16] that comes with the NI-FBUS Configurator. The development went through the following stages:

- 1. An OPC client was created and connected to the OPC-DA server. The server exposes data items representing the parameters of all online functional blocks.
- 2. The data items of interest (those related with IN,OUT,SP, tuning and state parameters) were bound to shared variables created expressly for that purpose.
- 3. Each shared variable was configured in terms of

data type, access type (read only or read/write), alarming (HiHi, Hi, Lo and LoLo alarms), update dead band, alarm and data logging, and security (remote access permissions).

4. A virtual instrument was built to provide a rich graphical interface for the operator (see figure 7). The controls and indicators were bound to the shared variables to make the front panel synchronized with the system. The operator can read process variables, adjust set-points and tune controllers. No alarm support was implemented (that was left to future work).

It should be noted that stages 1, 2 and 3 were done following the procedures described in [17].

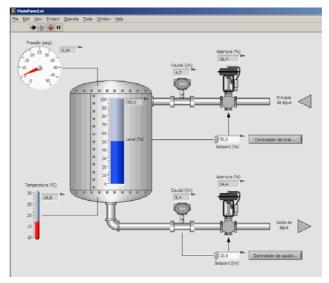


Fig. 7 – Supervision program

# **5. EXPERIMENTAL RESULTS**

Both control loops were tested over their dynamic ranges. For each controller, the set-point, process and output variables were remotely monitored and recorded. The experiments were carried out according the following methodology:

- 1. The PID controllers were tuned in advance using the trial and error method. The level controller was configured with proportional gain Kp = 6, reset time Ti = 4 s and derivative time Td = 4 s. The flow controller was configured with Kp = 0.5, Ti = 5 s and Td = 1 s.
- 2. The system was started with level and flow setpoints of 50% and 10 l/min, respectively. Time was given for all variables to stabilize.
- 3. Data recording was started at t = 0 min.
- 4. At t = 1 min the level set-point was changed to 80%.
- 5. At t = 5 min the levelset-point was changed to 20%.
- 6. At t=14 min the levelset-point returned to 50%.
- 7. At t=18 min the flow set-point was changed to

15 l/min.

- 8. At t=21 min the flowset-point was changed to 5 l/min.
- 9. At t=24 min the flow set-point returned to 10 l/min.
- 10.Data recording was stopped at t = 28 min.

Regarding the level control loop (see figure 8), the collected data can be analyzed as follows:

- At t = 1 min and t = 14 min the controller opens valve FCV1 to increase the level. The process response has a small overshoot and stabilizes after 1 min (approximately).
- At t = 5 min the controller closes valve FCV1 to decrease the level. The process response has negligible overshoot and stabilizes almost immediately.
- The level controller is insensitive to flow variations due to the large capacity of the tank.
- The level controller is characterized by good tracking capability, small overshoot, short settling time, and good immunity to external disturbances (in particular those related with flow variations). Nevertheless, the oscillations observed in the output variable suggest that the controller should be less "nervous" by reducing the gain or increasing the reset time. The derivative time could also be increased to add more capacity

of anticipation.

With respect to the flow control loop (see figure 9), the comments are similar:

- At t = 1 min and t = 14 min the flow has a slight increase (caused by the increment of the level) that is quickly canceled by the controller.
- From t = 5 min to t = 11 min the controller struggles to compensate the loss of flow caused by the continuous decline of the level.
- At t = 18 min and t = 24 the controller opens valve FCV2 to increase the flow. The process response has no overshoot and stabilizes after 1 min (approximately).
- At t = 21 min the controller closes valve FCV2 to decrease the flow. The process response has no overshoot and stabilizes after 1 min (approximately).
- The flow controller is characterized by good tracking capability, no overshoot, short settling time and good immunity to external disturbances (in particular those related with level variations).

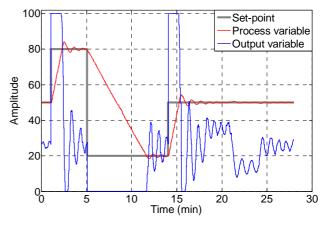
The system was also tested in terms of safety by shutting down the LAS during a limited amount of time. With the system working normally, the interface board was disconnected from the bus and then reconnected one minute later. The response of the system was as follows:

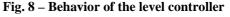
• At the beginning the system seemed "frozen"

with all variables retaining their value.

- Two seconds after (the value of parameter  $FSTATE_TIME$ ) the control valves got into the fault state and closed their opening ( $FSTATE_VAL = 0$ ). The tank was isolated from the exterior and the level and pressure on its interior were kept constant. Thus, thanks to the fault state mechanism implemented by AO function blocks, the system became safe.
- Two seconds after the reconnection (the value of parameter *FSTATE\_TIME*) the control valves got out of the fault state and the system resumed its normal operation. This demonstrates that the H1 bus has self-recovery capability.

During all experimental tests the supervision software worked as expected demonstrating good robustness, performance and ergonomics.





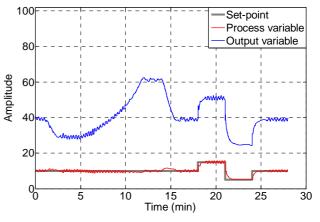


Fig. 9 - Behavior of the flow controller

#### 6. CONCLUSION

The main topics of the FF technology were presented and a real application was implemented on a pilot plant. Two different control loops, involving level and flow, were tested to validate the safety mechanisms and the real-time capabilities of the FF system. The dynamic behavior of each control loop and the mutual effects caused by set-point changes were investigated. Everything worked as expected, with the system showing good performance even when large changes in set-points occurred.

### 7. REFERENCES

- [1] *Foundation Technical Specifications*, Fieldbus Foundation, 1994-1998.
- [2] David A. Glanzer, Foundation Fieldbus Technical Overview, Fieldbus Foundation, 2003.
- [3] Ian Verhappen, Augusto Pereira, *Foundation Fieldbus, 4<sup>th</sup> Edition,* ISA – The International Society of Automation, 2012.
- [4] Kim R. Fowler, *Electronic Instrument Design: Architecture for the Life Cycle*, Oxford University Press, 1996.
- [5] [Online] www.fieldbus.org
- [6] Jonas Berge, Fieldbuses for Process Control: Engineering, Operation and Maintenance, ISA

   The International Society of Automation, 2004.
- [7] [Online] http://sine.ni.com/nips/cds/view/p/lang/ en/nid/207760
- [8] [Online] www.natinst.com/fieldbus
- [9] Function Blocks Instruction Manual, Smar, 2007.
- [10] TT302 Fieldbus Temperature Transmitter Operation and Maintenance Instructions Manual, Smar, 2011.
- [11] LD302 Fieldbus Pressure Transmitter Operation and Maintenance Instructions Manual, Smar, 2012.
- [12] IF302 Triple Channel Current to Fieldbus Converter – Operation and Maintenance Instructions Manual, Smar, 2011.
- [13] FY302 Fieldbus Valve Positioner Operation and Maintenance Instructions Manual, Smar, 2012.
- [14] [Online] www.ni.com/labview/labviewdsc
- [15] Jurgen Lange, Frank Iwanitz, Thomas J. Burke, OPC – From Data Access to Unified Architec-

ture, 4<sup>th</sup> Edition, Verlag GmbH, 2010.

- [16] OPC Data Access Specification version 3.00, OPC Foundation, 2003.
- [17] LabVIEW Datalogging and Supervisory Control Module Developer's Manual, National Instruments, 2000.



*Vítor Viegas*was born in Portugal in 1976. He received his degree in Electrical Engineering and Computer Science from the Instituto Superior Técnico (IST) of the Universidade Técnica de Lisboa (UTL) in 1999. After pursuing

studies, he received the MSc and PhD degrees from the same school in 2003 and 2012, respectively. He works as Assistant Professor at the InstitutoPolitécnico de Setúbal (IPS). His main research activities concern smart transducers, fieldbus/distributed control systems, and industrial informatics.



J. M. Dias Pereira (M'00 – SM'04) was born in Portugal in 1959. He received his degree in Electrical Engineering from the Instituto Superior Técnico (IST) of the Universidade Técnica de Lisboa (UTL) in 1982. During almost eight years he worked for Portugal Telecom in digital switching and trans-

mission systems. In 1992, he returned to teaching as Assistant Professor at the Instituto Politécnico de Setúbal (IPS), where he is, at present, as Coordinator Professor. In 1995 he received the MSc degree and in 1999 the PhD degree in Electrical Engineering and Computer Science from IST. His main research interests are included in the Instrumentation and Measurement areas.