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CASE STUDY OF A PROFIBUS NETWORK

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Abstract: Industrial communication plays a major role in both automation types of industrial process decentralized and in distributed ones. An industrial process is equipped with devices from different manufacturers that must exchange information. This paper presents a PROFIBUS network achieved with three Variable Frequency Drives (VFD) from different manufacturers (Siemens, Sew and Lenze) that are controlled with PLC (S7 1516F-3PN/DP, Siemens), a Pushbutton Panel PP17 (Siemens) and a TP700 Comfort HMI (Siemens).
Keywords: PROFIBUS-DP; industrial communication; variable frequency driver; HMI

1. INTRODUCTION

Automation of industrial processes is used in order to eliminate or reduce manual labor in a manufacturing process [1]. For this, the industry usually is automated, in decentralized or distributed structures, with equipment developed by different manufacturers. So, all equipment is connected in one or several industrial networks and must share data in order to meet the specifications of the process [1] – [4]. To give students a closer experience of real-world applications, the paper presents a workable solution: a PROFIBUS network where three Variable Frequency Drives (VFD) from different manufacturers (Siemens, Sew and Lenze), a programmable logic controlled – PLC (S7 1516F-3PN/DP, Siemens), a Pushbutton Panel PP17 (Siemens) and a human machine interface - HMI model TP700 Comfort (Siemens) are connected. Thus a small part of an industrial process is simulated. Hence, students can learn the necessary steps to be taken to control various VFDs models with PLC. The first step is to establish communication within the whole equipment. To this end, they have to study the manual for each VFD and set the necessary parameters to configure it in order to be controlled via communication by PLC. The next step is to create the software application for PLC and HMI.

The PROFIBUS (the acronym for PROcess FIeld BUS) is an international open source and vendor-independent communication protocol used for process automation [1]. PROFIBUS was developed by BMBF (German Department of Education and Research) in 1989 in collaboration with several automation manufacturers. Today two variants of PROFIBUS are used:

— PROFIBUS-DP (Decentralized Peripherals), developed on RS485 physical layer is used to operate sensors and actuators via a centralized controller in industrial applications. This is the most frequently used type of PROFIBUS communication.

— PROFIBUS-PA (Process Automation), was developed as an evolution of HART (an acronym for Highway Addressable Remote Transducer) communication and used to monitor measuring equipment via a process control system in process automation [5], [6].

2. MICROMASTER 440 set up to be controlled via PROFIBUS-DP

VFDs are widely used in industry due to their ability to control induction motor speed. Most often for the automation of an industrial process are used devices from different manufacturers that need to exchange data in the same industrial network. Each device that supports PROFIBUS communication has different performance characteristics, such as a number of I/O signals or diagnostic messages. All information about these communication parameters is written in the datasheet manual for each VFD. Therefore, before developing the PLC automation software application, the engineer must study the manuals of all devices connected in the industrial network in order to make their configuration. After this, it is necessary to configure these devices in the PLC software application. To make easier the device configuration in PLC programming software, the producer offers an electronic device datasheet, called GDS (General Station Description), for each device that can be controlled via PROFIBUS. The paper presents an
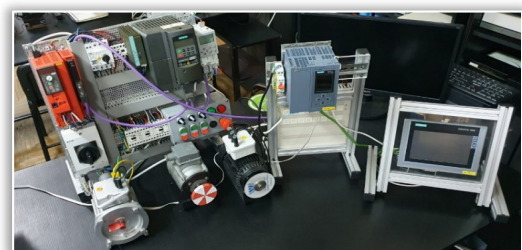
a)
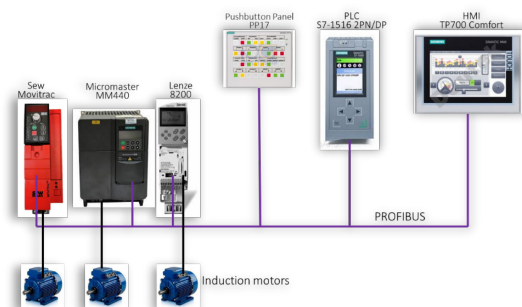
b)

Figure 1. Experimental arrangement with PROFIBUS network

example of a PROFIBUS DP network where are connected three VFDs from different manufacturers (Sew, Siemens and Lenze) that are controlled by the same PLC through two human machine interfaces variants (Pushbutton panel – PP17 and touchscreen HMI TP700). The experimental stand, shown in Figure 1.a, is used at Stefan cel Mare University of Suceava laboratory to offer students an experience closer to real-world applications. The schematic block diagram of the experimental stand is described in Figure 1.b.

The MICROMASTER drive can be controlled via PROFIBUS DP if a dedicated communication board is attached to the drive. The MICROMASTER drive can be used as PROFIBUS slave and be controlled by PLC if the following steps are followed:

— change the value of P0003 to 3 in order to access the expert configuration mode where all the VFD parameters can be accessed. In default setting the parameters that can be accessed are sufficient only for the simplest applications.

— define PROFIBUS address (except the following values: 0, 126 and 127 which are not allowed), that can be achieved in two ways:
  ✓ via a user-entered value set in P0918, on condition that all DIP switches = 0:
  ✓ via DIP switches on the PROFIBUS CB (communication board). In this case the address can be calculated as is exemplified in Figure 2 [8].

$$Adresa = 1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 0 \cdot 2^3 + 0 \cdot 2^4 + 0 \cdot 2^5 + 0 \cdot 2^6 = 5$$

$$Adresa = 1 \cdot 2^0 + 0 \cdot 2^1 + 1 \cdot 2^2 + 1 \cdot 2^3 + 1 \cdot 2^4 + 0 \cdot 2^5 + 0 \cdot 2^6 = 29$$
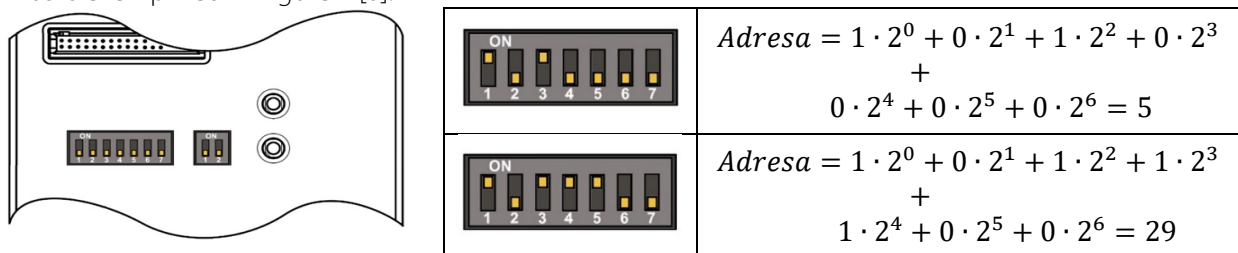
Figure 2. DIP switches on the MICROMASTER PROFIBUS communication board

— Set P0700 = 6, for selection of the digital command source from PLC through PROFIBUS using communication board (CB);
— Set P0700 = 6, for selection of the frequency set-point source from PLC through PROFIBUS using communication board (CB);

3. SOFTWARE APPLICATION

Two channels (cyclic and acyclic) are used for communication with VFDs via PROFIBUS DP. The cyclical channel is used both to control the VFD and to exchange parameters. The user data structure with which a master can access the drive slaves using the cyclical data communication method is defined in PROFIdrive profile, version 2.0 and designed as the Parameter Process data Object (PPO) [8], [10]. The PPO is divided into two areas:

— *Process data area (PZD)*, used by the PLC to control the drive (i.e. control word and speed setpoint) and for drive monitoring (i.e. status word and actual speed).
— *Parameter area (PKW)*, which usually is processed less rapidly than PZD area, is used for reading / writing parameter values.

Depending on the model of MICOMASTER 4 used in application (420 or 440), there are different telegrams for communication via PROFIBUS DP. The model of MICROMASTER used in this application is

Figure 3. The PROFIBUS network in TIA Portal

440 and the Telegram chosen is PPO1, as is presented in Figure 4. The PLC address automatically allocated in TIA Portal for Control Word, Target Speed, Status Word and Actual Speed are %QW22, %QW24, %IW18 and %IW20 respectively.

To highlight how different are the VFDs that can be used in the same industrial network, the MOVITRAC drive from SEW is chosen by the authors for proposed application [11]. In this case to control via PROFIBUS MOVITRAC drive a communication interface module FSC11B and a PROFIBUS interface type DFP21B installed in gateway housing are used [12], [13]. Two interfaces communication CAN and RS-485 are presented in FSC11B module. Using CAN bus a maximum of 64 participants can be addressed using the system bus (SBus) and using RS-485 communication the maximum number of participants is 32. In addition, a service interface is installed only for
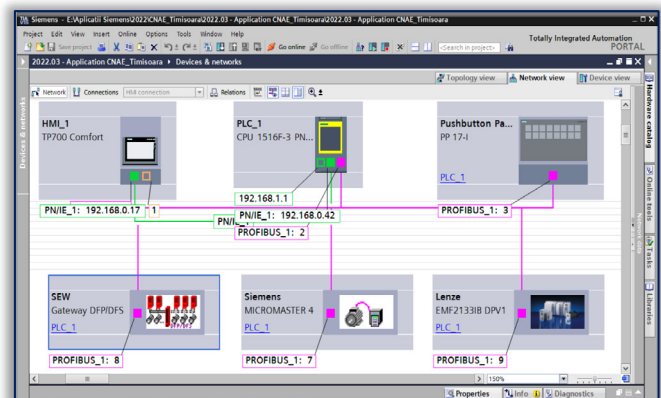
service purposes. To use this model of drive in a PROFIBUS network, one possible solution is to use an UOH11B gateway housing where a PROFIBUS interface card DFP21B is installed. At one UOH11B gateway housing up to 8 VFDs can be connected. Each drive connected at PROFIBUS card must have different SBus addresses that can be set at P813. The addresses are assigned. It is recommended to begin with address 1 in ascending order, based on the arrangement of drivers in the control cabinet. The process image on the fieldbus side is expanded by three words for each detected drive. The PROFIBUS address for interface card can be chosen using DIP switch in a similar mode with MICROMASTER PROFIBUS card.

The 8200-vector model, from Lenze is the third VFD used in the proposed application. A function module E82ZAFPC010 inserted at Lenze 8200 vector drive is necessary for PROFIBUS communication. The PROFIBUS node address can be selected via code C1509 [14], [15]. For all converters connected in PROFIBUS network it is necessary to study the manuals in order to be parameterized to accept the control and the setpoint via fieldbus, as is presented in detail for MICROMASTER drive.

Figure 4. Select in TIA Portal the telegram for communication via PROFIBUS for MICROMASTER drive
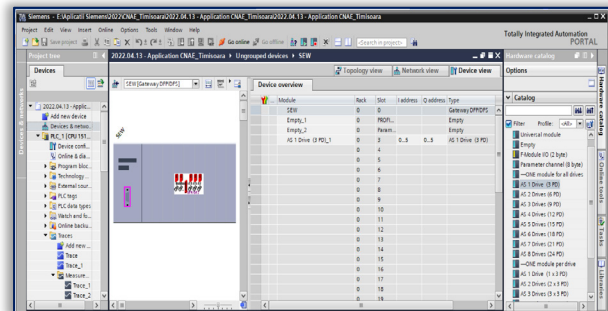
Figure 5. Select in TIA Portal the telegram for communication via PROFIBUS for MOVITRAC drive

To interface the application proposed with the operator a TP700 Comfort HMI (Siemens) is used. Different screens are achieved to control and monitor each VFD used. In Figure 6 two screens (for MICROMASTER drive and Lenze drive) are presented. In each screen the operator can observe different drive parameters (Actual speed, the value of the Status Word bits) and can control the drive (START/STOP, the reversing of rotation direction, the Target Speed adjustment, acknowledge fault).
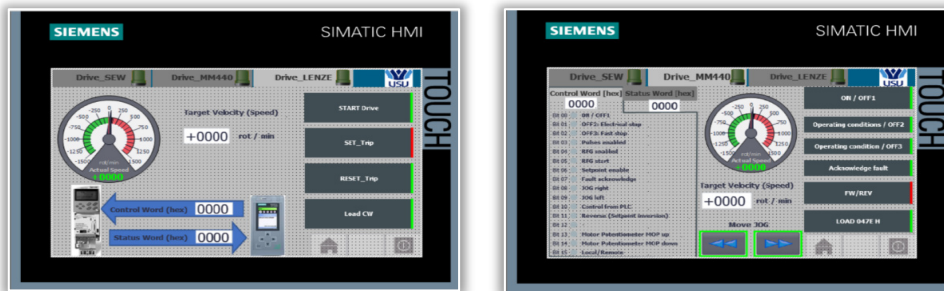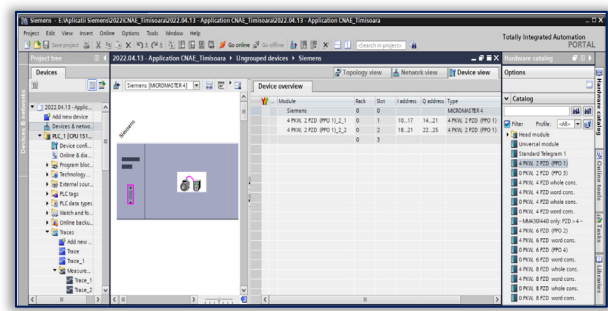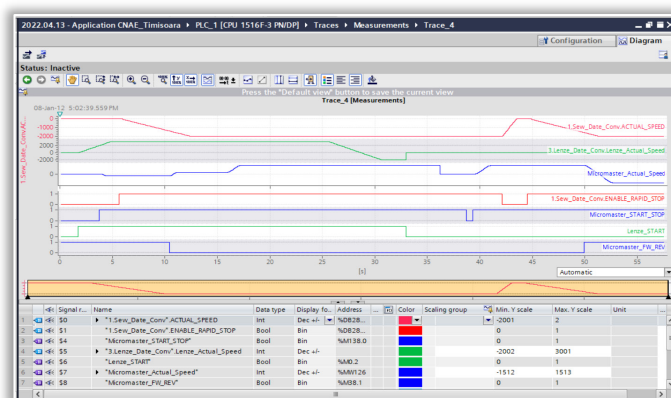

Figure 6. HMI screens design example

4. EXPERIMENTAL RESULTS

To record the PLC inputs/outputs the TIA Portal trace function is used. The signals recorded can be used for analyzing the functionality of the process. Figure 7 illustrates the Actual Speeds and Start/Stop bits for all three VFDs recorded in different work regimes.

Figure 8 presents in detail different work regimes for MICROMASTER drive controlled through the bits from Control Word (CW) via PROFIBUS communication. The drive is started when the PLC sends CW = 047E followed by 047F (the rising edge at the LSB of the CW) as is shown in Figure 8 at $t1$ [8]. Three different variants of STOP for the drive are obtained by the falling edge of the bits 0, 1 and 2 of CW, as follow:

Figure 7. The Actual Speeds and Start/Stop bits for all three VFDs

—— at falling edge of the Bit 0 (OFF1) the drive stops with deceleration along ramp-function generator (RFG) and the pulse is disabled when *f* < *fmin*, as is illustrated in Figure 8 at *t2*.

—— at falling edge of the Bit 1 (OFF2) the drive Coast to Stop. In this case the drive instantaneously inhibits the pulses and the motor will stop by itself on its own inertia, as is presented in Figure 8 at *t3*.

—— at falling edge of the Bit 2 (OFF3) the drive will stop in time set in P1135, differentiated by ramp-down time for OFF1, as can be seen in Figure 8 at *t4*.
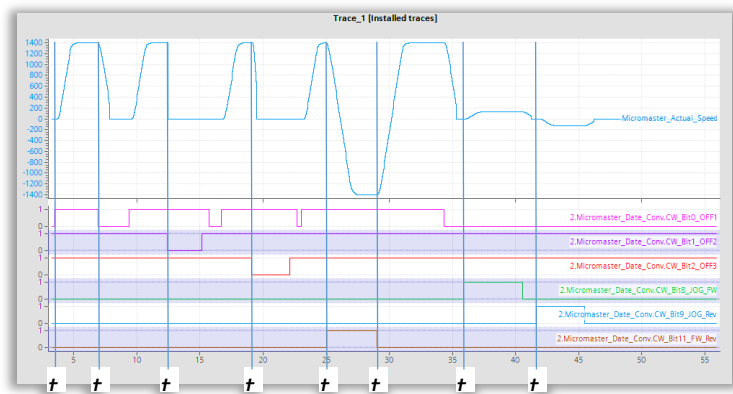

Figure 8. MICROMASTER drive controlled via PROFIBUS communication

Generally, OFF3 is defined for emergency stop if a fault appears to prevent high damage.

The reverse rotation command can be made by Bit 11 of CW, as is illustrated at time *t5* and *t6* in Figure 8. To move the motor with JOG speed in clockwise direction we activate Bit 8 of CW (Figure 8 at *t7*) and in counterclockwise direction we activate Bit 9 of CW (Figure 8 at *t8*).

5. CONLUSIONS

In this paper, a case study of PROFIBUS network is presented. The PROFIBUS network is achieved with three VFDs from different manufactures (Sew, Siemens, Lenze), S7-1516F PLC (Siemens), PP17 Pushbutton Panel (Siemens) and TP700 Comfort HMI (Siemens). The purpose of this article is to highlight the amount of work required to reach the hardware and the software of this application. Thus, in order to accept control via PROFIBUS, these converters must each be properly configured. This can be done only if the manuals of these converters have been thoroughly studied. Once the configuration of the PROFIBUS network is finalized, we can move on to the next step: achieving the application software. The engineers and students can be trained using an application similar to the solution presented in this paper because it offers a closer experience of real-world applications.

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