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AUTOMATION INTEGRATED USING PROFIBUS AND SUPERVISORY SYSTEM

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Abstract. *This paper presents a solution for implementing an automation integrated control system, through interconnecting network equipment. It aims to introduce the basic equipment, the network configuration, the development of a supervisory control system, and the necessary requirements to establish information exchange among systems with different languages. The OPC and PROFIBUS protocols standardize the equipment languages, enabling the communication and integration of those in a process. The objective is to achieve overall control of an industrial process through a single point, in order to provide better physical arrangement of equipment, field equipment diagnosis and parameterization, integration of equipment from different manufacturers, and reduced wiring costs as well as installation projects.*

Keywords: Industrial automation, Industrial protocol, Supervisory system

1. **Introduction.** The automation involves the implementation of systems interconnected and assisted by communication networks, comprising supervisory systems and man-machine interfaces in order to assist operators in monitoring and analyzing problems that may occur [1].

In a control and automation system, there are different technologies and equipment. There is not a single manufacturer of those, but many manufacturers who have expertise in specific technological sectors. Thus, to develop an automation system, the customer often becomes dependent on the use of equipment from the same manufacturer [2].

For this reason, industrial networks are increasingly standing out because, through standardized protocols, equipment from different suppliers can interact, making the automation process flexible and easy, as well as reducing the cost if compared to centralized systems [2].

The work proposed by Galloway and Hancke [3] presents a theoretical foundation on industrial networks and its main applications. Already in the works presented in [4-7] the concept of supervision of automation systems using OPC protocol is presented; however, the authors did not explore the practical use and limitations of communication protocols used in the industrial environment to control and supervision.

In this context, this work aims to develop a solution for implementing an automation integrated control system. The control and monitoring of the process, which is represented by frequency inverters connected via bus network, will be accomplished through a supervisory system.

The development was divided into two parts: the first is the establishment of communication between the machine that holds the supervisory system and a PLC (Programmable Logic Controller). This communication is possible due to the use of the OPC protocol "Object Linking Embedding – OLE" for Process Control, ensuring that the communication language of both is converted into a unique language of mutual understanding. The second part is the development of control logic and connection of the inverters through a PROFIBUS bus network, allowing communication between PLC and inverters in a standardized language.

This article is organized as follows. Section 2 presents in detail the equipment and technologies used at work. In Section 3, the development of practical implementation and the results are presented. Finally, Section 4 presents the conclusions.

2. General Concepts.

This manuscript shows a supervisory system integrated with an industrial network, PROFIBUS DP. The basic concept is to use a supervisory system to monitor the parameters and diagnoses from motors, using the industrial network. The great contribution from this manuscript is in the communication of the supervisory system, using the OPC protocol, with an industrial network (PROFIBUS DP) to control the motors. The motors are controlled by frequency inverters.

2.1. PLC.

The programmable logic controller is a device designed for the industrial environment, being a highly versatile in the programming mode. It uses a programmable memory where it stores the instructions and specific functions such as logical relations, mathematics, integers and binary numbers, floating point (real), trigonometric and arithmetic operations, transportation, data storage, comparison, timing, counting, and sequencing [1,8].

PLCs are characterized by their robustness suitable for industrial environments, programming via personal computers, friendly languages for the automation designer of discrete events. It allows both logic and the dynamic controls (P + I + D) and includes models able to connect with large data networks [1].

Its basic architecture consists of power supply, central processing unit, memories of fixed and volatile types, input and output devices, and programming terminal [1].

Figure 1 shows an illustration of PLC.

Figure 1. Illustrative picture of PLC [9]

To implement the industrial application described in this work, we used one commercial PLC with the following characteristics: Processor: Intel Celeron 266 comp.; Main Memory: 32MB SDRAM; Program memory: 1MB SRAM; PROFIBUS DP Master Interface; Input and Output modules; model manufactured X20CP3484 by B & R Automation.

2.2. **Frequency inverter.** The frequency inverter is one of the main devices of industrial automation, and its evolution has greatly helped to optimize manufacturing processes. Its function is to control the speed and torque of an AC motor, according to an electronic command. It is widely used in various areas such as elevators, pumps and mechanical traction [8].

A basic circuit of the inverter is formed by a rectifier unit, a capacitor bank, and filtering circuit formed by a converter block IGBT transistor (Insulated Gate Bipolar Transistor).

Figure 2 illustrates the internal blocks of the frequency inverter and Figure 3 shows a picture of a commercial frequency inverter.

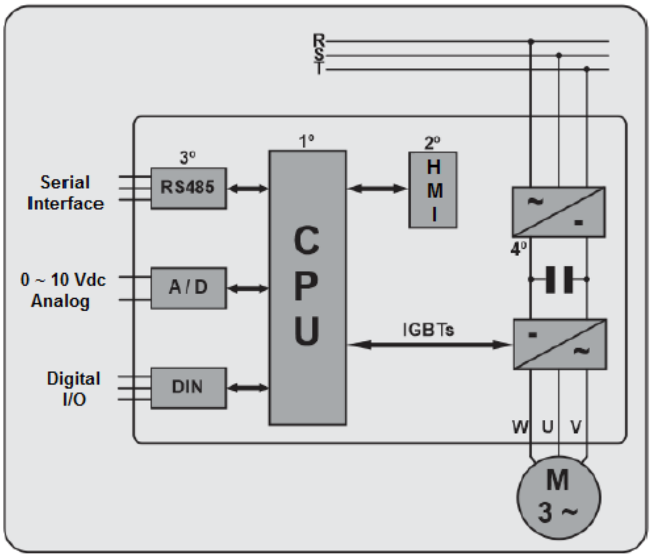


FIGURE 2. Illustrative picture of PLC [10]

FIGURE 3. Illustrative picture of frequency inverter [10]

Due to its characteristics and various applications, it is necessary to adopt the operation to achieve the desired performance through its parameterization. In general, its parameters are reading or writing values, by which the user can perform reading or values programming to display, tune, or adjust the behavior of the inverter and the motor in its implementation [8].

Almost all inverters available on the market have similar variables and programmable parameters. They typically split into reading variables (to preview several programmed values), regulation variables (to adjust the inverter functions values), and configuration variables (to define the motor start characteristics) [8].

2.3. **OPC protocol.** The OPC protocol was developed in 1995 by a group of companies that had the goal of creating a data access pattern based on OLE and DCOM (Distributed Component Object Model) technologies inside the Windows system. The OPC establishes rules to develop systems for communication standard interfaces of field devices such as PLCs, and sensors with monitoring systems such as SCADA (Supervisory Control and Data Acquisition), MES (Manufacturing Execution Systems), and ERP (Enterprise Resource Planning) [11].

As the OPC is an open standard, it helps systems to solve communication difficulties, creating a single patterned layer, allowing easy integration among different systems. Its operation is based on the standard client-server architecture, as shown in Figure 4 [12].

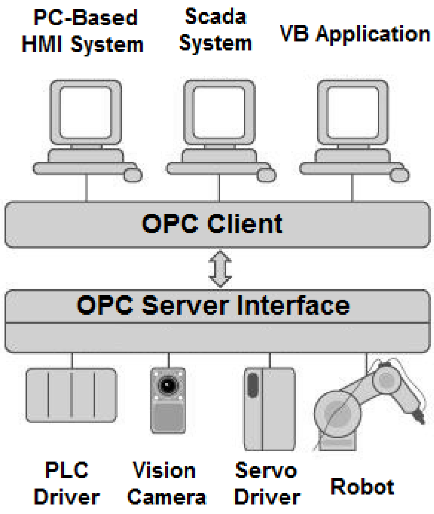


Figure 4. Architecture of client-server OPC [13]

It is interesting to use the OPC due to the possibility of an application, which acts as a client, requesting data to one or more OPC servers, and the opposite is also possible. Therefore, it is evident that the OPC enables a wide variety of communications, and it only requires applications to be compatible with the OPC protocol. Importantly, the OPC server does not eliminate the proprietary protocol of the PLC or field equipment, but converts the proprietary protocol into the OPC standard. Therefore, it is necessary to develop an OPC server specific to each of the different existing communication protocols [12].

The OPC architecture contains two types of interfaces: OPC custom and OPC automation. OPC custom interfaces are designed to be used with programming languages that use pointers, such as C/C++, while for simpler languages such as Visual Basic, Delphi and VBA (Visual Basic for Applications), OPC automation interfaces must be used. In the latter, there is one more component in OPC server, called the automation wrapper, which encapsulates and manages calls among languages without pointers and OPC custom interface [12].

2.4. **Profibus.** PROFIBUS (PROcess FIeldBUS) is a standardized and open system protocol for communication equipment in industrial network. With it, devices from different manufacturers can communicate without the necessity of adapting in the interface. The PROFIBUS specifies the technical and functional characteristics of an industrial communication system [14].

The industrial communication breakthrough in automation technology showed tremendous potential in the process systems optimization and has made an important contribution towards the improvement in the use of resources. Basically, PROFIBUS is used as a central link in the information flow in automation [15].

The process information transmission is performed cyclically, while alarms, parameters, and diagnostics are transmitted, in an acyclic manner, only when needed [15].

The PROFIBUS DP (Decentralized Peripherals) is the most commonly used profile and offers a solution for high speed and low cost in PROFIBUS. Its development was optimized especially for communications between automation systems and decentralized equipment, aimed at control systems, in which the access to I/O distributed devices stands out. It can be used to replace centralized systems with PLCs in manufacturing automation, as well as for transmission of signals from 4 to 20 mA for analogical automation process. However, there are some limitations on configurations and parameterizations and they are served only in the PA version. The PROFIBUS DP uses RS-485 as a physical layer, or optical fiber, in environments with susceptibility to noise or needing to cover large distances. It requires less than 2 ms for transmitting 1 Kbyte input and output and is widely used in critical time controls [14,16].

The PROFIBUS DP network allows the connection of up to 32 devices per segment, and up to four segments interconnected through repeaters. The maximum number of DP stations is 122, and the maximum length is 1.2 km using RS-485 interface. It can be extended with repeaters up to 15 km with optical fiber. An active terminator should be added at the beginning and end of each segment and both terminators must be fed [14,17].

Currently, the maximum speed PROFIBUS DP network is 12 Mbps, and the standard speed is 1.5 Mbps. The network speed is unique, being determined by the slowest slave and also by the length of the cable segment, as shown in Table 1 [14,17].

Table 1. PROFIBUS transmission rate [17]

Baud rate (kbits/s)	9.6	19.2	93.75	187.5	500	1500	12000
Segment length (m)	1200	1200	1200	1000	400	200	100

However, PROFIBUS PA (Process Automation) is a PROFIBUS solution that meets the requirements of process automation, which has the connection process with field equipment, such as pressure transmitters, temperature, converters, and others. It was designed to transmit signals from 4 to 20 mA or HART (Highway Addressable Remote Transducer) [14,17].

Its main advantage over the SD version is that it has the possibility of communication and parameterization integrated in the field instrument; it also has advanced standards supervision of the market, such as failure analysis technologies, advanced diagnostics and parameters of a field network to analogical instruments [14].

It uses Manchester protocol as environment access layer and allows the measurement and control by a simple two-wire line. It also supplies energy to field equipment in intrinsically safe areas, i.e., areas where equipment may not be able to release electrical or thermal energy, either under normal conditions or under fault conditions [17].

It is possible to perform maintenance and connection/disconnection of equipment even with the network in operation without interfering with other stations in classified areas (potentially explosive) [14,15].

Figure 5 illustrates the PROFIBUS architecture in the field level and its applications.

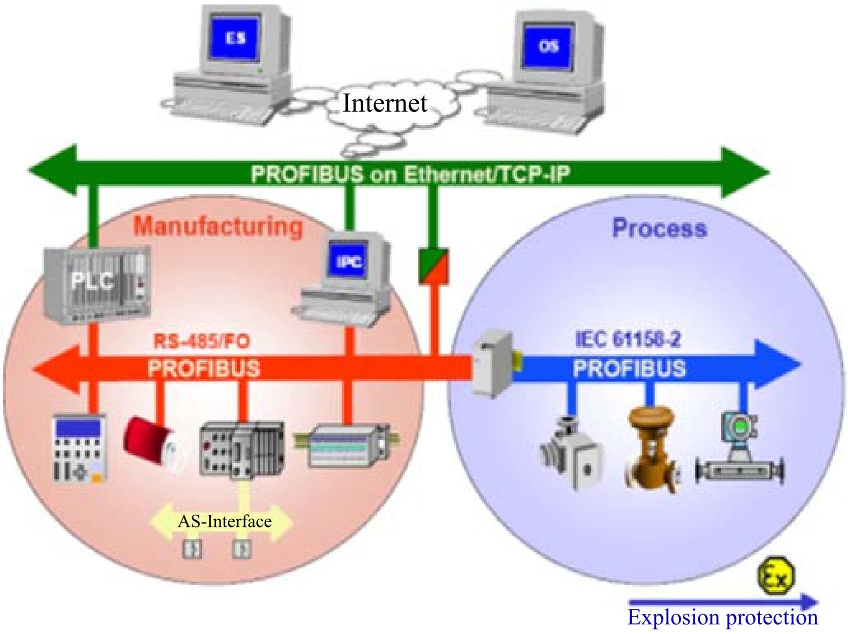


FIGURE 5. Architecture PROFIBUS [18]

Each existing PROFIBUS device has different characteristics and ways of communication parameterization, and then, it is necessary to use technical manuals to access all information about them. The GSD (General Specification Default) manufacturers provide files and offer the option to integrate a piece of equipment in a PROFIBUS system, being divided into general specifications, master, and slave specifications. Each type of equipment has its GSD file, which is a text file with details on hardware and software revisions and information on the cyclic data exchange, characterizing the PROFIBUS communication [14].

Information, such as lists parameters and available modules description, is in the GSD files. If the GSD file is not installed correctly, the communication via the PROFIBUS network will not be possible [14].

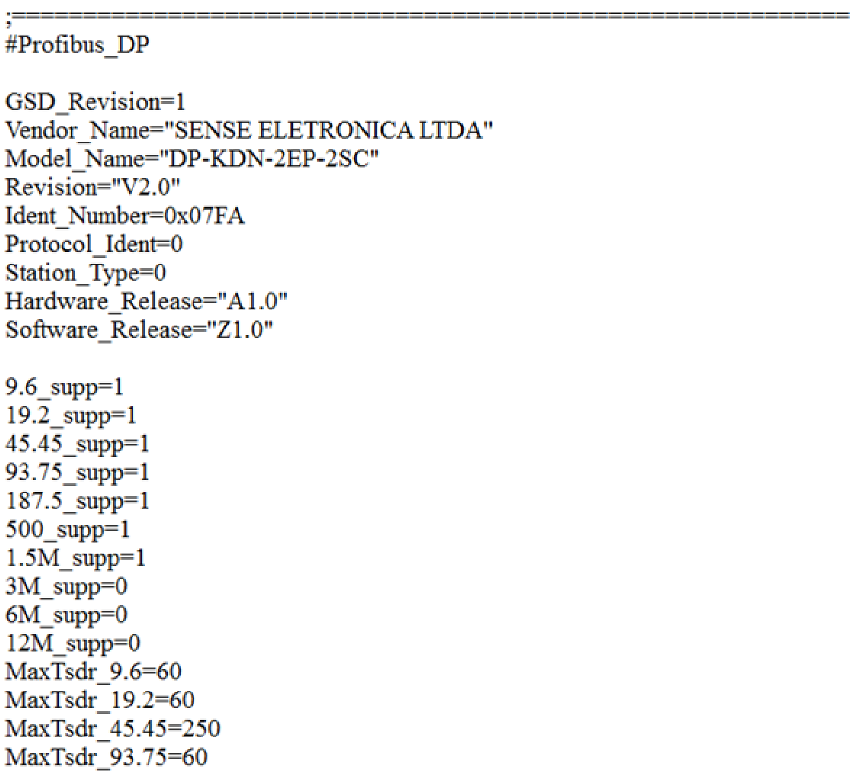
Figure 6 shows a GSD example.

3. Application and Results.

The application was developed in an automation and control lab. Figure 7 shows the assembly on the desks with their respective inverters connected to the PROFIBUS bus next to the PLC, and connected to the supervisory system. The objective is to integrate the elements of the PROFIBUS network via OPC protocol monitored by the supervisory system.

3.1. The supervisory system development.

The first stage of the application was the supervisory system development, which represents the overall system and the interface of each individual inverter as shown in Figure 8 and Figure 9. In each interface, the



```
;==================================================================
#Profibus_DP

GSD_Revision=1
Vendor_Name="SENSE ELETRONICA LTDA"
Model_Name="DP-KDN-2EP-2SC"
Revision="V2.0"
Ident_Number=0x07FA
Protocol_Ident=0
Station_Type=0
Hardware_Release="A1.0"
Software_Release="Z1.0"

9.6_supp=1
19.2_supp=1
45.45_supp=1
93.75_supp=1
187.5_supp=1
500_supp=1
1.5M_supp=1
3M_supp=0
6M_supp=0
12M_supp=0
MaxTsdr_9.6=60
MaxTsdr_19.2=60
MaxTsdr_45.45=250
MaxTsdr_93.75=60
```

Figure 6. GSD file [19]

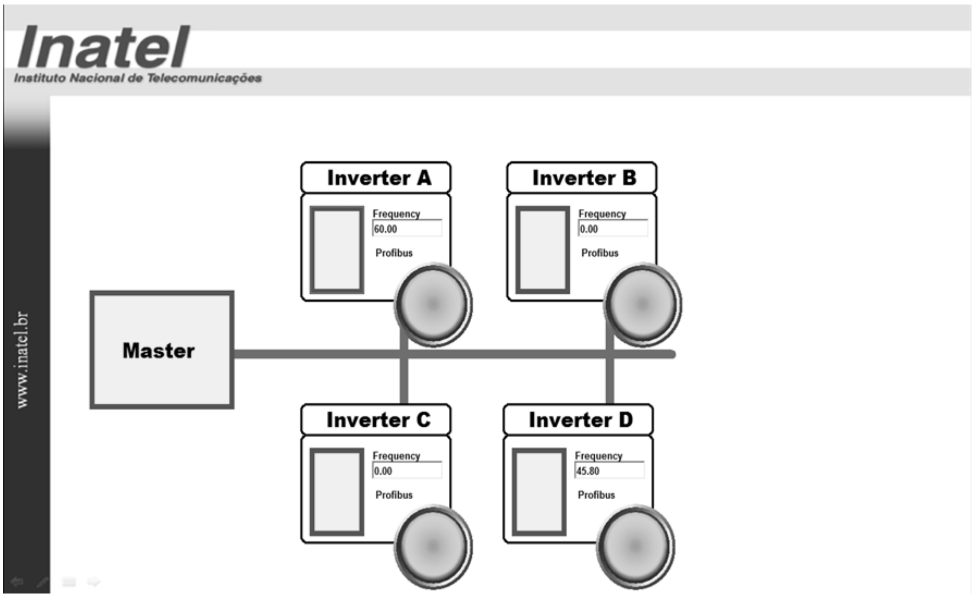
Figure 7. Supervisory with PLC and inverters interconnected

developers entered the elements needed for the control, such as buttons, text fields, and indicative lighting, which should be associated to the corresponding variables of the PLC program.

3.2. Logic development in the PLC.

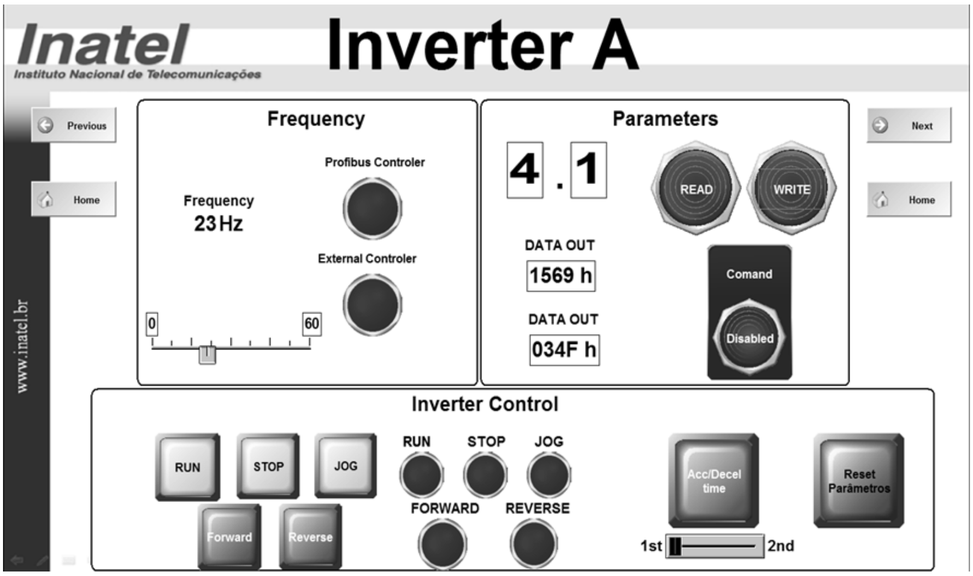
The variables used by the supervisory system originating from the inverters must be set in the PLC development program. The logic to control the inverters, as well as those required to operate the inverter functions was developed with the PLC programming tool using structured text language.

Figure 10 shows part of the control program of the inverters.



Inverter A — Frequency: 60.00
Inverter B — Frequency: 0.00
Inverter C — Frequency: 0.00
Inverter D — Frequency: 45.80

FIGURE 8. Overall system interface



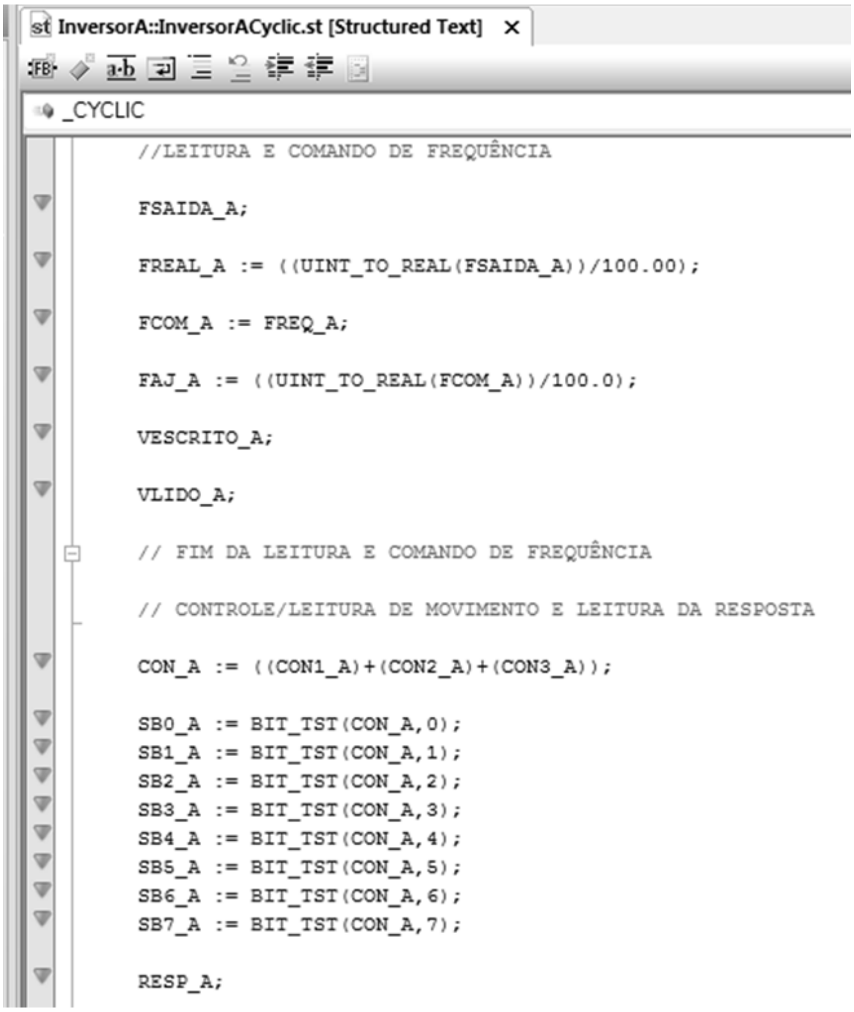
Frequency 23 Hz
4 . 1
DATA OUT 1569 h
DATA OUT 034F h

FIGURE 9. Inverter interface

3.3. **PROFIBUS network implementation.** After the development of the logic control, it is necessary to set the slave type that was used. The PROFIBUS module of the equipment used must be added through its GSD file and all the parameters must be associated with their respective fields. The profile used for the developed application was PROFIBUS DP.

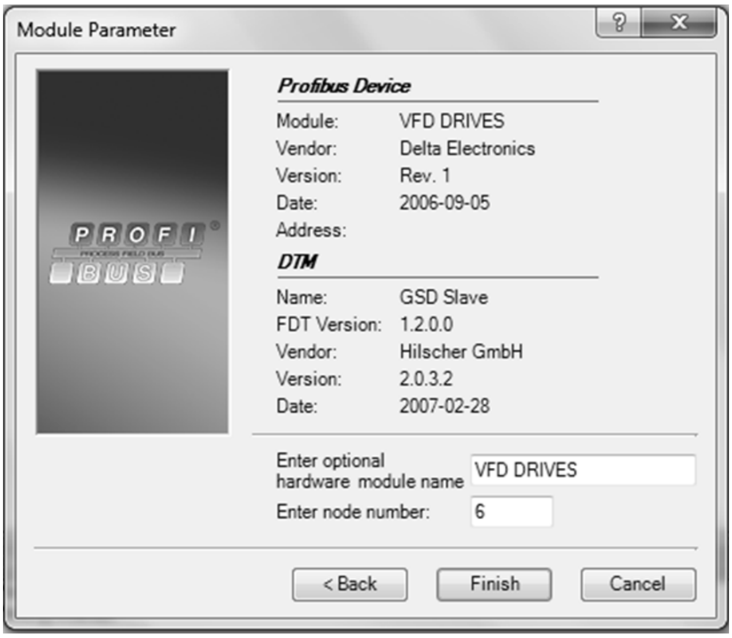
The necessary configurations such as data transmission rate, inverters addressing, PROFIBUS module type and PROFIBUS profile, as well as the assembly and inverters connection and PLC on PROFIBUS bus were made according to the requirements outlined in Section 2, Subsection 2.4, using RS-485 as the physical environment.

Figure 11, Figure 12, Figure 13 and Figure 14 illustrate the addressing of a new network inverter, the configuration of the transmission rate, the choice of the inverter module and the connection of the inverter with PROFIBUS cable.



```
//LEITURA E COMANDO DE FREQUÊNCIA

FSAIDA_A;

FREAL_A := ((UINT_TO_REAL(FSAIDA_A))/100.00);

FCOM_A := FREQ_A;

FAJ_A := ((UINT_TO_REAL(FCOM_A))/100.0);

VESCRITO_A;

VLIDO_A;

// FIM DA LEITURA E COMANDO DE FREQUÊNCIA

// CONTROLE/LEITURA DE MOVIMENTO E LEITURA DA RESPOSTA

CON_A := ((CON1_A)+(CON2_A)+(CON3_A));

SB0_A := BIT_TST(CON_A,0);
SB1_A := BIT_TST(CON_A,1);
SB2_A := BIT_TST(CON_A,2);
SB3_A := BIT_TST(CON_A,3);
SB4_A := BIT_TST(CON_A,4);
SB5_A := BIT_TST(CON_A,5);
SB6_A := BIT_TST(CON_A,6);
SB7_A := BIT_TST(CON_A,7);

RESP_A;
```

Figure 10. Control inverters logic



Profibus Device

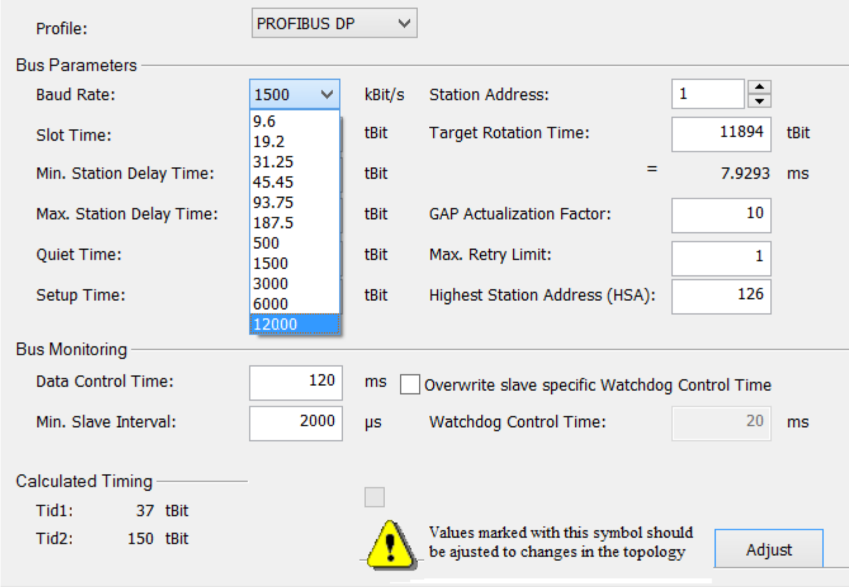
Module: VFD DRIVES
Vendor: Delta Electronics
Version: Rev. 1
Date: 2006-09-05
Address:

DTM

Name: GSD Slave
FDT Version: 1.2.0.0
Vendor: Hilscher GmbH
Version: 2.0.3.2
Date: 2007-02-28

Enter optional hardware module name: VFD DRIVES
Enter node number: 6

Figure 11. Inserting and addressing a new inverter



Profile: PROFIBUS DP

Bus Parameters

Baud Rate: 1500 kBit/s

Station Address: 1

Slot Time: tBit

Target Rotation Time: 11894 tBit

= 7.9293 ms

Min. Station Delay Time: tBit

Max. Station Delay Time: tBit

GAP Actualization Factor: 10

Quiet Time: tBit

Max. Retry Limit: 1

Setup Time: tBit

Highest Station Address (HSA): 126

Bus Monitoring

Data Control Time: 120 ms

☐ Overwrite slave specific Watchdog Control Time

Min. Slave Interval: 2000 μs

Watchdog Control Time: 20 ms

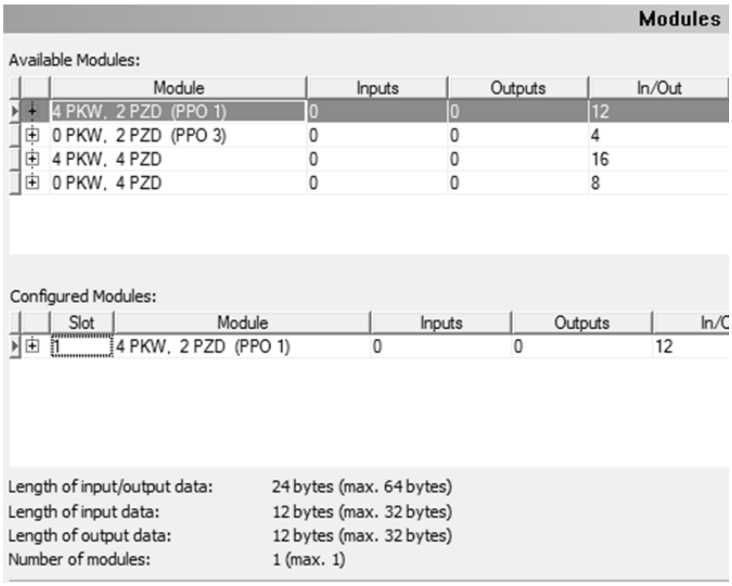
Calculated Timing

Tid1: 37 tBit

Tid2: 150 tBit

Values marked with this symbol should be ajusted to changes in the topology

FIGURE 12. Configuration of the transmission rate



Modules

Available Modules:

Module	Inputs	Outputs	In/Out
4 PKW, 2 PZD (PPO 1)	0	0	12
0 PKW, 2 PZD (PPO 3)	0	0	4
4 PKW, 4 PZD	0	0	16
0 PKW, 4 PZD	0	0	8

Configured Modules:

Slot	Module	Inputs	Outputs	In/C
1	4 PKW, 2 PZD (PPO 1)	0	0	12

Length of input/output data: 24 bytes (max. 64 bytes)

Length of input data: 12 bytes (max. 32 bytes)

Length of output data: 12 bytes (max. 32 bytes)

Number of modules: 1 (max. 1)

FIGURE 13. Inverter module choice

3.4. **OPC network implementation.** After the establishment of PROFIBUS communication and logic control, it is necessary to associate the process variables to the supervisory system. Because the CLP language is different from the language used by the supervisory system, it is necessary to perform the conversion of variables via a standardized protocol to enable the association. The OPC protocol is used for this application.

The first step is the creation of the OPC tags for each variable of the development program, aiming to set the characteristics of the variable to its general use. After this, you must set the OPC server, assigning the IP address (Internet Protocol), Ethernet communication, and association of the tags map. Figure 14 illustrates the frequency inverter used in project and its connections. Figure 15 illustrates the creation of tags to the OPC server.

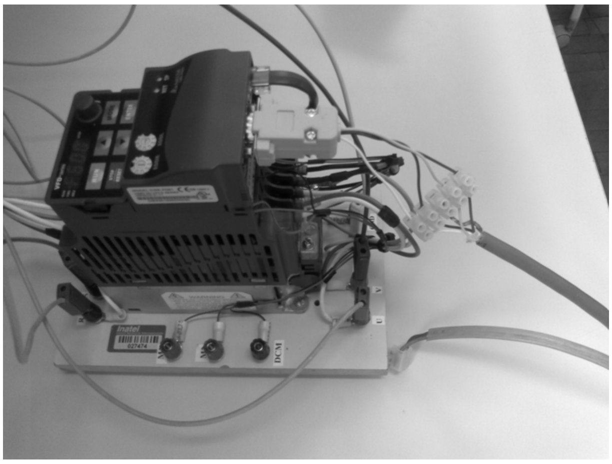
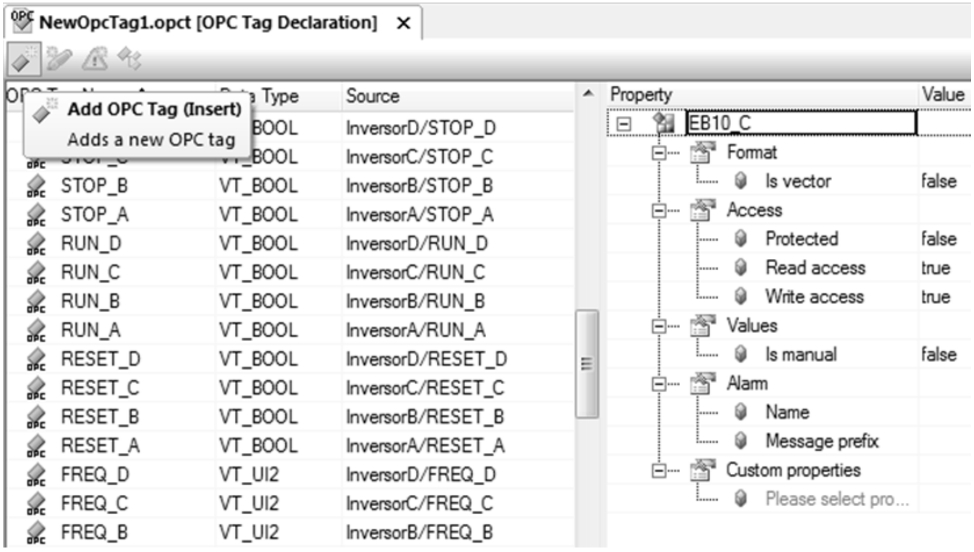


FIGURE 14. Connecting the inverter to PROFIBUS bus



	Type	Source
	BOOL	InversorD/STOP_D
	BOOL	InversorC/STOP_C
STOP_B	VT_BOOL	InversorB/STOP_B
STOP_A	VT_BOOL	InversorA/STOP_A
RUN_D	VT_BOOL	InversorD/RUN_D
RUN_C	VT_BOOL	InversorC/RUN_C
RUN_B	VT_BOOL	InversorB/RUN_B
RUN_A	VT_BOOL	InversorA/RUN_A
RESET_D	VT_BOOL	InversorD/RESET_D
RESET_C	VT_BOOL	InversorC/RESET_C
RESET_B	VT_BOOL	InversorB/RESET_B
RESET_A	VT_BOOL	InversorA/RESET_A
FREQ_D	VT_UI2	InversorD/FREQ_D
FREQ_C	VT_UI2	InversorC/FREQ_C
FREQ_B	VT_UI2	InversorB/FREQ_B

Property	Value
EB10_C	
Format	
Is vector	false
Access	
Protected	false
Read access	true
Write access	true
Values	
Is manual	false
Alarm	
Name	
Message prefix	
Custom properties	
Please select pro...	

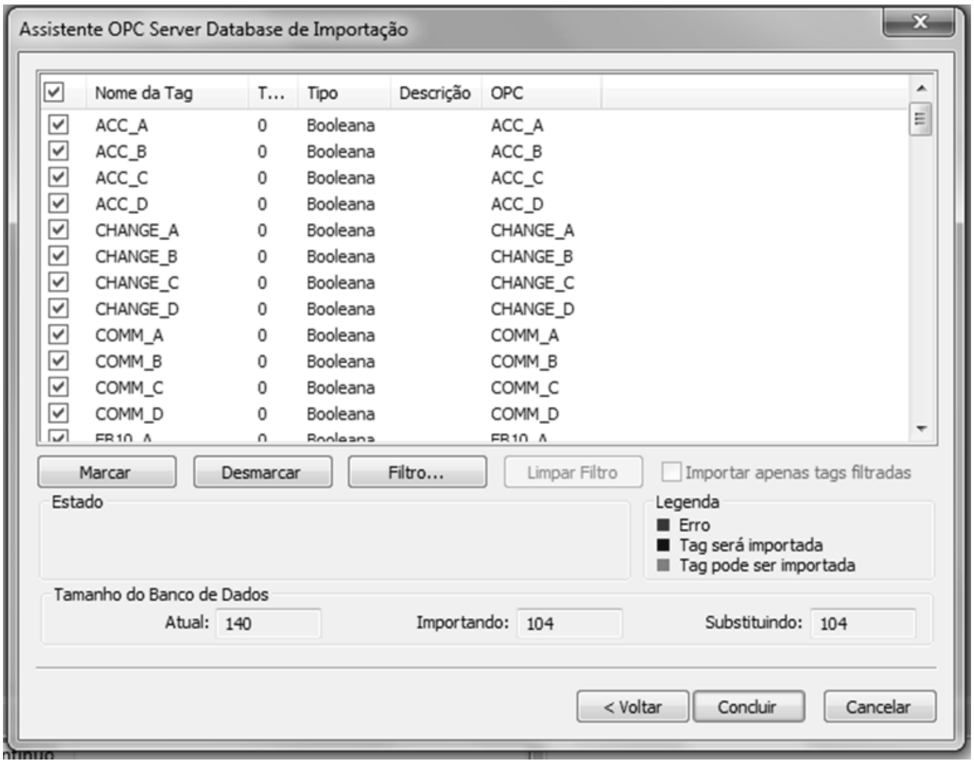
FIGURE 15. OPC tag configuration

Next, one must import the OPC tags to the supervisory system and associate them with their respective objects on the screen. First, it is necessary to set the IP address, so that the location of the OPC server is possible, and after that, set the access permissions to data, enabling the information exchange.

Figure 16 illustrates the import of OPC tags to the supervisory system.

4. **Conclusions.** Systems integration through industrial networks provides great benefits, increasing its use in industries. The solution presented in this paper provides a possibility to implementation using frequency inverters as slaves of the PROFIBUS network, where control is performed through a single supervisory system.

The use of standardized communication protocols such as OPC and PROFIBUS enables new possibilities to control a process. The ability to add different field devices, which were unable to exchange information among them, is one of the benefits of using the PROFIBUS protocol. With the OPC protocol, in addition to performing all the control from one single point, it is possible to distribute it in different locations because of protocol characteristics that allow data access to multiple servers and clients, simultaneously.



☑	Nome da Tag	T...	Tipo	Descrição	OPC
☑	ACC_A	0	Booleana		ACC_A
☑	ACC_B	0	Booleana		ACC_B
☑	ACC_C	0	Booleana		ACC_C
☑	ACC_D	0	Booleana		ACC_D
☑	CHANGE_A	0	Booleana		CHANGE_A
☑	CHANGE_B	0	Booleana		CHANGE_B
☑	CHANGE_C	0	Booleana		CHANGE_C
☑	CHANGE_D	0	Booleana		CHANGE_D
☑	COMM_A	0	Booleana		COMM_A
☑	COMM_B	0	Booleana		COMM_B
☑	COMM_C	0	Booleana		COMM_C
☑	COMM_D	0	Booleana		COMM_D
☑	FB10_A	0	Booleana		FB10_A

☐ Importar apenas tags filtradas

■ Erro
■ Tag será importada
■ Tag pode ser importada

Tamanho do Banco de Dados
Atual: 140
Importando: 104
Substituindo: 104

Figure 16. OPC tags import

Therefore, with the OPC protocol it is possible to create the control via the supervisory system in several distinct points of the application, making the control decentralized and distributed in regard to the user operation in the industrial plant. In addition, due to the use of the OPC, it makes the project as a whole, independent of proprietary solutions.

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