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Measuring systems based on Modbus protocol within plant Ethernet network

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Abstract

Measurement systems are important tools for the maintenance group. Due to the modularity of automation equipment, diversity of sensors and measuring devices, such systems can be individually adapted. The article presents two measurement systems, implemented in the car plant for two press lines. The article contents is focused on configuration of Modbus communication between PLCs of two different suppliers and measuring devices. As a final result, the part of SCADA visualization was presented. The benefits of having this type of system and possibility of its development are substantial from the perspective of diagnostics as well as purely economic reasons.

Keywords: Modbus protocol, SCADA, PLC, Ethernet.

Systemy pomiarowe oparte na protokole Modbus w sieci Ethernet zakładu produkcyjnego

Streszczenie

Systemy pomiarowe są istotnym usprawnieniem prac służb utrzymania ruchu, szczególnie w przypadku produkcji wielkoseryjnej. Eliminują konieczność ręcznych pomiarów i umożliwiają wykrycie prawdopodobieństwa awarii na podstawie analizy trendów. Ze względu na modułowość urządzeń automatyki, mnogość rozwiązań czujników i urządzeń pomiarowych, system tego typu może być indywidualnie dostosowany do potrzeb zakładu [1]. W artykule zostały przedstawione dwa systemy pomiarowe, zaimplementowane w fabryce samochodów osobowych na wydziale tłoczni dla dwóch linii pras, monitorujące wartości parametrów sprężonego powietrza oraz drgań elementów mechanicznych napędu pras. Zaprezentowano schematy systemu (rys. 1) w świetle zakładowej sieci Ethernet. Wskazano użyte w systemach elementy, w szczególności moduły komunikacyjne sterowników PLC. W sposób szczególny opisano sposób konfiguracji komunikacji protokołem Modbus [3, 6] pomiędzy sterownikiem PLC oraz urządzeniami pomiarowymi dla dwóch typów sterowników [2, 4, 5]. Przedstawiono różnice w procesie konfiguracji obu sterowników i ich modułów (rys. 2, 3, 4). Zarysowano również sposób przetwarzania pozyskanych danych. Jako efekt końcowy w artykule zamieszczono fragment wizualizacji SCADA (rys. 5) z *Systemu Kontroli i Monitorowania Procesu Produkcyjnego* fabryki. Podsumowując proces realizacji założeń projektu, wskazano możliwości rozwoju systemów tego typu. Opisano, w jaki sposób można wykorzystać pozyskane dane, jakie korzyści niesie ze sobą posiadanie w zakładzie tego typu systemu, zarówno z perspektywy diagnostyki i eksploatacji maszyn, jak i powodów czysto ekonomicznych.

Słowa kluczowe: protokół Modbus, SCADA, PLC, Ethernet.

1. Introduction

Progress in the field of industrial automation during recent decades has enabled the possibility of diagnostics development in the direction of complex measurement systems. Their main aim is to monitor condition of machine with the use of technical diagnostics methods. In this case disassembly is not required.

If objects and devices in a manufacturing plant are arranged in considerable distances from each other, it is necessary to install Distributed Control System (DCS) [1]. Standard network communication of industrial control system is used in order to build this type of network structures [2].

This paper presents two examples of measurement systems which were implemented in the passenger car plant at the press department for two press lines: the transfer one and the tandem one. Their task is to monitor parameters of compressed air and vibrations of mechanical parts of presses.

This project was developed on the base of Modbus protocol - one of the industrial networks, classified as local network, which has the ability to connect to other elements of main network in a plant [3]. Nowadays, it is a standard for information exchange between automation devices and control and measuring instruments. Modbus bus topology is as follows: slave nodes (e.g. a hub of signals) are controlled with master nodes (e.g. PLC). The names "client-server" or "master-slave" are commonly used for this type of communication [3].

2. Description of measuring systems

The described systems (Fig. 1) differ in the method of Modbus implementation (PLCs from different suppliers, OPC server intermediation in data transmission or its absence), as well as in types and numbers of sensors.

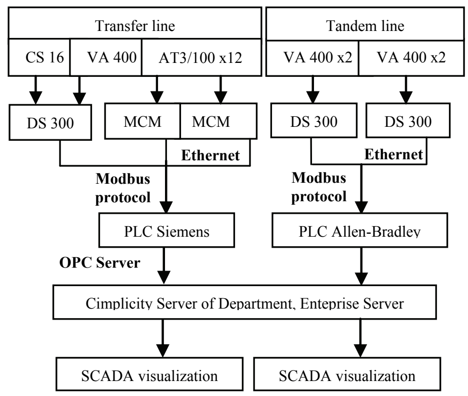

Fig. 1. Diagram of systems: CS 16 – Air pressure sensor (CS Instruments), VA 400 – Air flow sensor (CS Instruments), AT3/100 – Piezoelectric industrial accelerometer (Technicad), DS 300 - Multifunctional measuring device (CS Instruments), MCM - 8-channel monitor of vibration (Technicad)

Rys. 1. Schemat systemów: CS 16 - Czujnik ciśnienia powietrza (CS Instruments), VA 400 - Czujnik przepływu powietrza (CS Instruments), AT3/100 – Piezoelektryczny akcelerometr przemysłowy (Technicad), DS 300 - wielofunkcyjne urządzenie pomiarowe (CS Instruments), MCM - 8-kanałowe monitory drgań (Technicad)

These differences are dependent on the drive solution of line (a common shaft for presses within the transfer line is the reason for vibration measurements; the tandem line, which use robots to transfer parts between stations, has individual drive for each press) and controllers already used at shop.

Compressed air, which parameters are measured in the system, is used to equilibrate weight of the press slider.

The nominal pressure of the compressed air for the transfer line is 1,5 MPa (it is distributed to whole machine), while in the case of the tandem line each press has its own air system and required air pressure is 0,6 MPa.

The project of the systems proceeded analogously for both press lines. After installation of measuring devices, communication within Ethernet network via Modbus protocol was established. Protocol Function 3 (Read Holding Registers) was used to read 16-bit binary numbers. (There was no need to give real Modbus address of register e.g. 40001, the function counts registers from 0 – it "knows" which part of memory should be search.) Then, PLC programs for data processing and data transmission were prepared. The read values are now used in SCADA visualizations. The visualizations' screens provide monitoring archive.

3. System for the transfer line (Siemens PLC)

First system uses controller S7-317 PN–DP. In order to establish TCP/IP communication via Modbus protocol dedicated communication processor CP 343-1 was also used. According to the scheme (Fig. 1), Ethernet interface of controller was used for communication with servers for SCADA visualization.

Apart from standard hardware configuration, special library "MODBUS_TCP_CP" from materials included in module was added to the project in STEP7 software in order to access special Function Block for performing Modbus communication [4].

3.1. Network Configuration (NetPro)

Settings related to CP 343-1 were changed within the window *Object Properties* (IP address, subnet mask, selection of network). PLC (or actually CP module) is a client and two measuring devices are servers. Two network connections of type "TCP connection" were configured. Parameters ID and LADDR from the window *Properties – TCP connection* are significant when it comes to Modbus function parameterization (par. 3.3.). IP settings of devices and connection ports (Modbus - port 502) are also important part of configuration.

3.2. Required functions

The following elements were added to the project:

- block FB100 from Modbus library; this function [4]:
  - initiates execution of communication functions,
  - generates data frame of protocol, verifies it and generates error messages,
  - verifies specified memory areas, sends/downloads data
  - monitors time-out.
- communication blocks: FC5 (AG SEND) and FC6 (AG RECV) from library "SIMATIC_NET_CP".

3.3. Program in STL language

The most important element of the program was Modbus function parameterization - repeated many times in the program for each hub (in various configurations - for the call and for obtaining data). Communication was initiated and all of its startup parameters were assigned in OB100 block (executed during startup).

Fragment of cyclically repeated during whole PLC operation OB1 block is presented below (initialization parameters that can be changed only during initiation of Modbus function during restart are bold). It was written on the basis of Siemens manual [4].

```
NETWORK 1: START – DS300
A M 0.3
=DB223.DBX 38.5       //Data Block with initialization parameters
NETWORK 2: MODBUS FUNCTION FOR DS300 - VIBRATIONS
CALL FB100, DB101
IN0 :=2               //Server ID from Siemens NetPro Configuration
IN1 :=W#16#100        //Address of CP module from HW Configuration
IN2 :=T1              //Timer number
IN3 :=10              //10*100 ms = 1 s (communication time-out)
IN4 :=W#16#B          //Data block number (mapping registers)
IN5 :=W#16#0          //First register address
IN6 :=W#16#7C         //Last register address
IN7 :=
//....parameters with no value (used for larger amount of data)...
IN23 :=                       //Write Protection (only in server mode)
IN24 :=DB223.DBX38.5          //Initialization (1)
IN25 :=FALSE                  //CP module is client when (0)
OUT26 :=DB223.DBX40.0         //Communication with no disturbances (1)
OUT27 :=DB223.DBX40.1         //Error when (1)
OUT28 :=DB223.DBW42           //Error number
IO29 :=DB223.DBW44            //Address of the first register to read e.g. 0
IO30 :=DB223.DBB46            //Number of registers to read e.g. 50
IO31 :=DB223.DBX47.0          //Read mode when (1)
IO32 :=DB223.DBW48            //Transaction identifier
IO33 :=DB223.DBB50            //Slave ID e.g. 192
A DB223.DBX40.0               //If no error,
JC M002                       //conditional jump to increment TI.
A DB223.DBX40.1               //If error,
BEU                           //end of block.
NETWORK 3: INCREMENTATION OF TI
M002:     L DB223.DBW 48
          L 1
          +I
          T DB223.DBW 48
```

The part of the program presented above leads to mapping of values read from the device registers to the specified block of data for further processing and transmission.

Technical documentation of the measuring devices describes in which way understand obtained data and how to read particular indexes (e.g. values from DS300 are divided into two words in hexadecimal code; they are proper 32-bit floating point number after combining them into one double word).

In this case, values were acquired from registers and then processed into a form which is understandable by the OPC server (existing servers' configuration of the plant was not changed).

4. System for the tandem line (Allen-Bradley PLC)

This time, MVI56E-MNET communication module from ProSoft Technology (dedicated to Allen-Bradley controllers) was used to obtain Modbus communication.

4.1. Required elements of the project

For a project in RSLogix 5000 environment, Modbus *Add-On functions* had to be added. They were attached to the module. These functions are sets of instructions and their procedures in this case are not editable. Along with the instructions, new variables called *Controller Tags* (environment nomenclature) were also initialized within the project.

4.2. Module configuration

MNET communication module configuration is independent of the PLC program. All the necessary parameters are defined within dedicated program - ProSoft Configuration Builder (Fig. 2) [5]. They are analogous to those presented during describing the configuration of the Siemens controller, as they result directly from the protocol data frame.

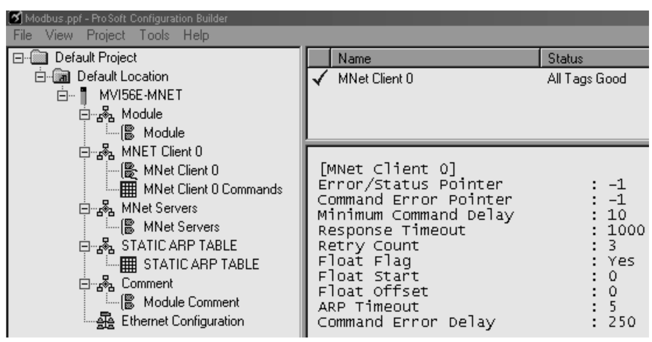

Fig. 2. MVI56E-MNET module configuration (ProSoft Configuration Builder)
Rys. 2. Konfiguracja modułu MVI56E-MNET (ProSoft Configuration Builder)

Apart from configuration of Ethernet connection (IP), each option of module (including: module registers which stored downloaded data, size of reserved memory) and parameters of a client (the module) had to be defined. They are common for all communication processes (for all servers).

Commands (Fig. 3) directed individually to the measuring devices were added to the list of module commands in PSCB (in the case of Siemens controller, each device has its own part of Modbus function within OB1 and OB100 blocks). Parameters of commands are the same as previously.

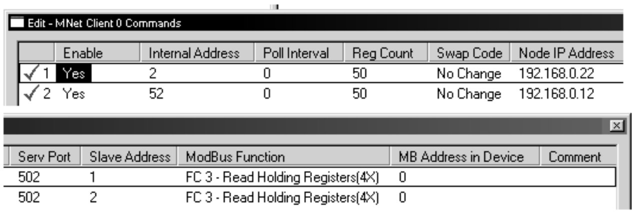

Fig. 3. Commands for communication with servers (ProSoft Configuration Builder)
Rys. 3. Polecenia komunikacji z serwerami (ProSoft Configuration Builder)

PSCB Software allows to upload prepared settings directly to the module and it provides the user with diagnosis and direct view of data downloaded from servers and stored in its memory (Fig. 4). This feature considerably facilitates the setup process.

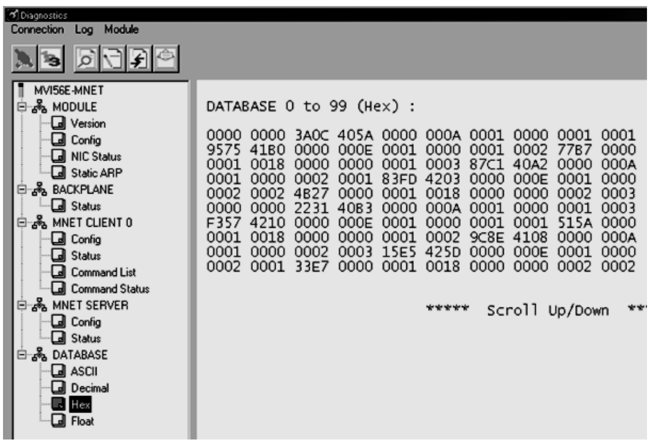

Fig. 4. Direct access to module's registers (ProSoft Configuration Builder)
Rys. 4. Bezpośredni dostęp do rejestrów modułu (ProSoft Configuration Builder)

4.3. Program

Because of facilitated module configuration, further process of controller programming consisted only of acquired data processing and providing the servers with them according to the diagram (Fig. 1). This time there was no intermediary in the form of OPC server.

5. Exemplary SCADA visualization

After implementing Modbus communication between measuring devices and PLC, next step was mapping of the data and processing them from two 16-bit words to double variable. Then, obtained value were multiplied by coefficients to allow transmission of integer value or, as in the case of continuously increasing consumption, reduction of the value so that it won't go out of scope in a long period of time. Data prepared in presented way were sent to appropriate places in the controller's memory.

According to the presented scheme of the systems (Fig. 1.), visualization screen was prepared in Cimplicity environment within CimEdit program. In addition to screen's visual side, display of actual readings and access to the archives of measurements were provided. In *Process and Measurement Control System* of the plant standardized objects and visualization screens' templates (with proper menu, header and footer) are obligatory.

Obtaining proper values for visualization was possible thanks to the list which assigns memory space in controller (double word in the specified data block in the case of Siemens PLC and respective variable defined in the project of the main AB controller) to the particular values and which is defined in Cimplicity server. In the project of visualisation screens, particular values were identified via so-called PointIDs which carry above information (that means also reference to the trend of variable defined in Cimplicity server). What's important, standard objects used for the screen contain Monitoring Archive functionality. Because of plant network settings, the displayed values should be multiplied by some factors in order to obtain values of parameters in the units used by the hub. This additional information was provided within the visualization screen (Fig. 5.).

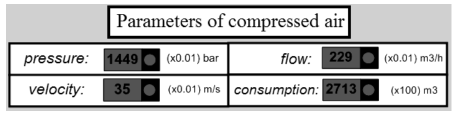

Fig. 5. Part of SCADA visualization for the transfer line
Rys. 5. Fragment wizualizacji SCADA dla linii transferowej

6. Conclusions

Open Modbus TCP/IP, which was used in the project, combines many advantages: it is relatively simple protocol, which is available in many solutions on the market. What's more, it requires minimum amount of equipment to operate and its development cost is low [6].

The article demonstrates that solutions from manufacturers of measuring devices and communication modules for drivers (dedicated function blocks, specialized software) and existing global plant standards of data transmission streamlined the process of setting up systems. Shown method of the master-slave communication configuration is universal and can be used also for other measurement systems.

Possible benefits from implementation of such systems include lack of need to carry out periodic measurements using handheld devices or less planned and unplanned downtimes.

The next step of systems' development should be careful analysis of the collected data, which could lead to systems with automatic line diagnostics. The line would be emergency stopped and its controller would generate an alarm message, if indicators exceeded acceptable level, set on the base of some standards, experiences and observations. What's important, on the basis of implemented monitoring archive it is already possible to optimize presses' operating parameters. However, in the case of vibration measurements, it is advisable to extend the system to enable filtering of acquired signals with specialized software (such task is currently in progress).

Production facilities are profit-oriented, so avoiding or quick detection of failures, which are waste in many ways, and optimal configuration of machines parameters are more and more often taken into account as a tool for improving financial condition of the company.

7. References

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