

PROCESS CONTROL PROGRAM AS AN ELEMENT OF DISTRIBUTED CONTROL SYSTEM

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Abstract. Monitoring and control of technological processes in many production units demands transfer of information and interaction with the process from remote distances. For this purpose, the process control systems have been designed and developed. In the first project phase, the separate production lines were covered by independent control systems. In the second phase, the individual control systems were interconnected in a large heterogeneous industrial network, forming the distributed control system (DCS). This paper presents results of development of specific hardware and software solutions for monitoring of technological processes, with special regards to communication systems structure.

Keywords: process control, distributed control system, industrial network, measuring, software solutions.

1. Introduction

The plant process control systems are based on dedicated industrial computers able to get the information of process parameters and execute actions in order to keep or change relevant process conditions. Microprocessor measuring station (MMS) fully designed and developed at the Department of Industrial Informatics of the Institute of Mining and Metallurgy [4] is used as a programmable logic controller (PLC). The master PC is added as an interactive workstation, forming an entity which is a core of complex distributed control and monitoring system (see Figure 1).

MMS was designed with suitable performances for monitoring and control of relatively slow technological processes. It is based on MC68HC11 microcontroller and 8-bit architecture. The main module, one board computer (OBC), contains residential executive system [5, 8] in EPROM and adequate RAM configuration. The input/output logic is designed to support 64 independent analog input channels and 2×64

digital inputs and outputs. The 8-bit A/D converter is integrated in microcontroller itself. The serial communications are performed using specially designed logic, connecting MMS to standard serial input/output PC port. The executive code of self-test programs, operational and communication program modules are contained in EPROM [6]. Although microprocessor measuring station can be an autonomous system unit, it is more frequently used as a node in a very simple network (entity), which contains MMS and PC workstation, Figure 1. The complex communication subsystem on both sides was developed for efficient entity functioning.

In hardware point of view, MMS contains the serial communication interface logic (SCI) with several options [3]. The direct back-to-back connection to standard PC RS232 serial port is in use. In order to support the data transfer in both directions appropriate communication protocol named Asynchronous Serial Protocol (ASP) is developed [7]. The connection between PC and MMS is permanent. The two-node

network runs according to master-slave principles. The PC as a master node is starting the session, maintaining the data transfer and regular end of session. The MMS has to respond to every PC demand.

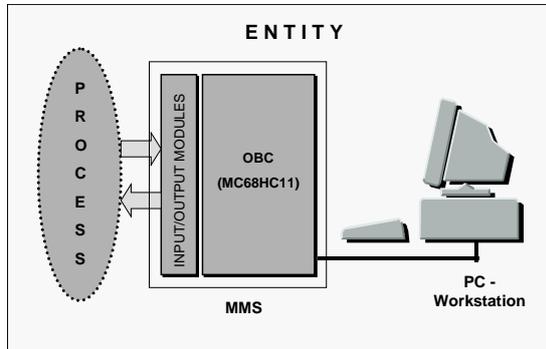


Figure 1. Simplified block diagram of a plant control system

2. Process control program – an application for real time monitoring and control

The special SCADA (Supervising Control and Data Acquisition) real-time application, working in Windows environment, is developed in order to support MMS functions and to perform data transfer, analyses and real-time interpretation of results. It is based on client/server architecture running on both master and remote stations, enabling integration in a complex distributed control and monitoring system. Let us call this program in further text Process Control Program (PCP). PCP is developed using Microsoft Visual C++ development kit [12]. Microsoft Foundation Class (MFC) library was used as a framework for manipulation with windows, menus and dialogs. Single Document Interface (SDI) with Document/View architecture was used. The principle is that all the variables are declared in Document class, while visual representation of data is performed in View

class. PCP has a complex structure and consists of several modules. Main program modules are designed for:

- communication with MMS,
- data acquisition, real-time data processing and results presentation,
- interaction with technological process according to appropriate algorithm and values of monitored parameters,
- creation of reports, data archiving, off-line data processing, database management.

All of the PCP functions, except the first one, are time irrelevant, and the response time for them is not critical [11]. But, the communication is timely critical. ASP requires an uninterrupted session controlled by PC. That is the reason why some PC resources (serial communication port, for example) must be controlled by PCP during the complete data transfer in both directions. The MMS responds with a portion of measured data, or as an acknowledgment to a command sent from PC within the same communication session. In other case, the message transfer is considered unsuccessful and the data are lost.

The collected data are stored in database, in uncompressed or compressed form. File management class including functions for data archiving is responsible for this task. Further processing consists of number of actions:

- data processing for graphical display (dynamic screens, time trends, tabular form) (see Figure 2),
- data processing for alarm system,
- data processing for distribution over LAN,
- forming of daily and monthly archives.

Interactions with technological process are performed according to an algorithm for remote control, considering the actual values of measured parameters. The appropriate commands are generated and sent to MMS, which are executed via actuators.



Figure 2. Dynamic process control screen

In order to display data in the user demanded way, independent of channel's order in a communication message, Channel Switch class has been created. An appropriate dialog box is generated in order to enable user friendly interface for manipulation with input signals to PCP, independent of their physical connections to MMS (Figure 3).

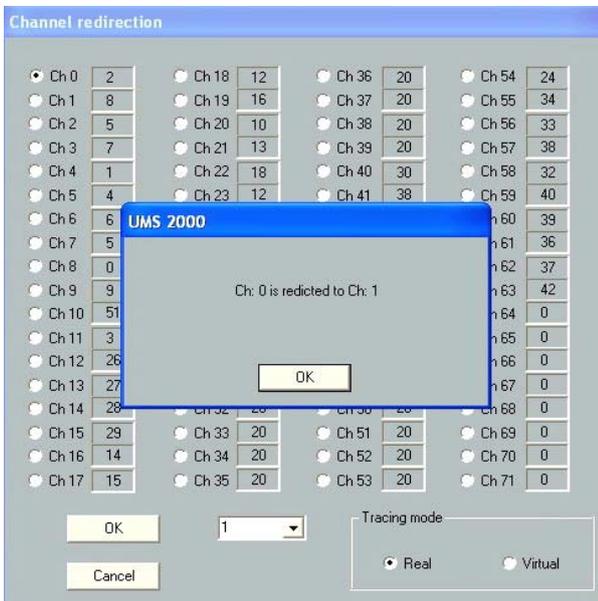


Figure 3. Channel redirection

Other classes are responsible for configuration of different parameters of PCP and MMS, such as sampling rate, communication frequency, type of measuring, number of analogue and digital channels, time synchronization etc.

3. The PCP and MMS communication software modules

The PCP communications program module contains driver for communications with MMS. Communication protocol is ASP (Asynchronous Serial Protocol) [4]. Communication class is the most important class of PCP, with the following main objectives:

- request for communications,
- connection establishment,
- data transfer,
- control of transfer quality,
- state indication of network nodes.

Functions of the Communication class are responsible for configuration of the serial PC port by setting its parameters to appropriate values. It is performed every time the session starts executing the following program sequence¹ [2, 9]:

```
mov dx,02FBh
(Line Control Register – LCR)
```

```
mov al, 83h
(83h = No parity, 8-bit character, 1 stop bit :
N81)
out dx,al
mov dx,02F8h
mov al,06h
(06h = 19200 bps)
out dx,al
mov dx,02F9h
(Interrupt enable register)
mov al,00h
(00h = disable interrupt)
out dx,al
mov dx,02FBh
(LCR)
mov al,03h
(polling)
out dx,al
```

It is important that the port configuration has to stay unchanged until the end of the session. On the other hand, other active applications running at the same time can reconfigure the port during the session. PCP has to prevent that. In order to satisfy this request, the priority of the PCP has to be increased. Namely, Windows operating system allows concurrent executions of multiple tasks (processes) allowing each task to have limited time slices on the CPU. To keep the system balanced, threads are given priorities so that more critical threads are scheduled more frequently or given longer time slices. User applications are usually given *normal priority*. It means that custom applications run using the computer resources with equal rules. If there is a need, it is possible to increase the process priority level. There are six priority levels corresponding to numerical values expressed by numbers from -15 to 15, listed below:

REAL TIME_PRIORITY_CLASS	15
HIGH_PRIORITY_CLASS	2
ABOVE_NORMAL_PRIORITY_CLASS	1
NORMAL_PRIORITY_CLASS	0
BELOW_NORMAL_PRIORITY_CLASS	-1
IDLE_PRIORITY_CLASS	-15

The priority class of the target process can be changed using a function *SetPriorityClass* [10]. The following program sequence chooses the priority of the PCP:

```
HANDLE hProcess=GetCurrentProcess();
if (prioritet == "Realtime")
SetPriorityClass(hProcess,
REALTIME_PRIORITY_CLASS);
else if (prioritet == "High")
SetPriorityClass(hProcess,
HIGH_PRIORITY_CLASS);
else if (prioritet == "Normal")
```

¹ Intel chip assembler language

```
SetPriorityClass(hProcess,
    NORMAL_PRIORITY_CLASS);
else if (prioritet == "Low")
SetPriorityClass(hProcess,
    IDLE_PRIORITY_CLASS);
```

```
else SetPriorityClass(hProcess,
    HIGH_PRIORITY_CLASS);
```

Practical realization of process priority level ordering is performed by simple choosing of a priority in a menu in the dialog box given in Figure 4.

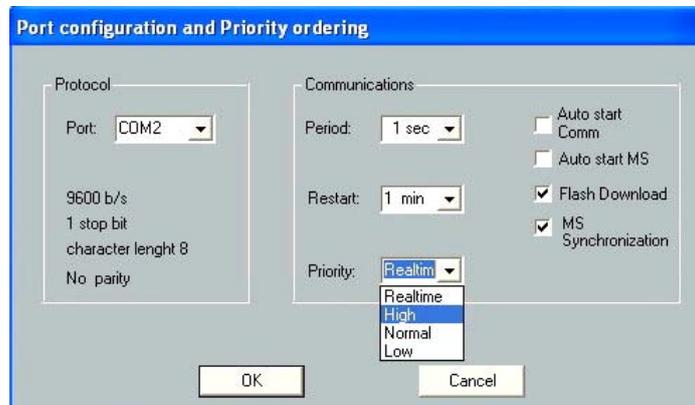


Figure 4. PCP dialog box for Serial I/O port configuration and priority ordering

Table 1. Experimental results

Number of comm. sessions	Priority level	Running programs	Message lost	[%]
259200	"Realtime"	PCP only	0	0
259200	"High"	PCP only	88	0.03395
259200	"Normal"	PCP only	176	0.06791
259200	"Low"	PCP only	195	0.07523
259200	"Realtime"	PCP + 3	1	0.00038
259200	"High"	PCP + 3	324	0.12500
259200	"Normal"	PCP + 3	2181	0.84104
259200	"Low"	PCP + 3	5468	2.10956

PCP running in the "Realtime" or "High" priority level guarantees efficient communications with MMS. In order to check the efficiency of communications, the following experiment was performed: system was tested for the period of three days, having 259200 communication sessions (every second). Ten tests were performed (three days each) and average results were summarized in Table 1. Two program environments were chosen:

- PCP is the only running process (excluding the system processes),
- PCP is running concurrently with three other user processes.

The results are summarized in Table 1. It is obvious that the best effects are obtained with "Realtime" priority level, but considering the usual requests, the "High" priority is acceptable as well. The number of lost messages in upper half of the table could be explained as an influence of execution of Windows OS routines dealing with communication port. The results shown in lower half of the table are

the consequence of interactions with other user processes.

The communications on MMS side are handled by its operational program, which is a kind of real-time executive system. It has a modular structure, designed for measuring, data processing and process control. One of the most important modules of real-time executive system is communication module, responsible for information transfer between MMS and PC workstation. The MMS is a slave node in entity network and the communication session starts as a quite stochastic event. That is the reason why the data transmission has to have the highest priority level compared to other MMS functions. It is provided by priority ordering mechanism [10].

The main step in communications initialization is programming of serial I/O for desired operational regime. It is performed by execution of the following program sequence²:

```
{Receiver Sleep! - Option}
```

² Motorola assembler language

```

Procedure Sleep;
begin
pshx;
psha;
ldx INDEX;
ldaa $20;    {set DWOM-bit to SPCR}
staa x[SPCR];
ldaa $30;    {19200 bps to BAUD reg.}
staa x[BAUD];
ldaa $08;    {set WAKE-bit to SCCR1}
staa x[SCCR1];
ldaa $2E;    {set RIE, TE, RE, RWU to SCCR2}
staa x[SCCR2];
clr [SemRcv];

```

```

cli;
pula;
pulx;
rts;
end;

```

This procedure prepares MMS to detect communications interrupt request. The current process stops and the communication service routine takes place. Actual command from PC workstation can now be received, and appropriate response sent back. The response can be either MMS status, remote command execution status, measured data, or all of them. The general message format (according to ASP protocol) contains all of these fields, a shown in Figure 5.



Figure 5. General MMS message format

During the data transfer (in both directions) MMS operational program is busy and cannot perform usual tasks such as measuring or process control. In some cases, data transfer can take more then 50 ms per session. To increase the measuring and control efficiency, the communication message can be shortened. If the sampling frequency is critical, header, date and time fields can be omitted.

For special applications with small number of process parameters, the data field contains just the ordinal number and input channel values. The real time is

reconstructed on PC using starting time, sampling rate and received ordinal number. The measuring performance of MMS becomes more efficient and response time improved in this way. Results empirically achieved in practice show possibility of performing data transfer in less then 5 ms (Figure 6), allowing MMS response time of 10 ms.

The MMS working regime, the communications mode and frequency (polling rate) may be chosen from PCP menu, Figure 2 (“Options”), or locally on measuring station.

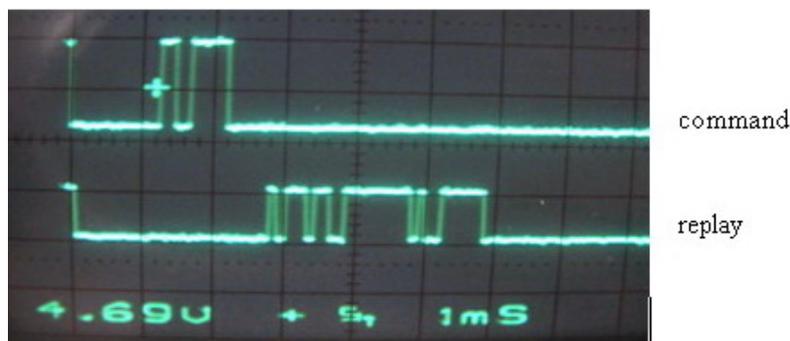


Figure 6. Time diagram of shortened communication session

4. Integration of mms and PCP in distributed control system

Realized Monitoring Measuring Station and Process Control Program are applied mainly in metallurgy industry. Production plants are often dislocated in a several kilometers wide area. To cover the main process parameters and monitor them in a real-time, it is necessary to realize a distributed control system (DCS). The complex decentralized industrial network is built for this purpose [1]. The basic network nodes are entities consisted of MMS and PC workstation (server in network configuration), running appropriate PCP. The remaining network nodes (clients in network

configuration) are PC’s running a passive version of PCP called Remote Control Program (RCP). RCP is used for distant monitoring only, without having the possibility of sending commands to server (or MMS). It can only access databases stored on the server side and read the data. Data analysis, processing and presentation are performed locally, on client PCs. Client PC is able to run as many RCPs as needed at the same time (accessing different servers). In practice, realized network consists of 8 servers and over 20 clients. Every plant is covered by server entity consisting of MMS and PC, building some kind of clusters, and interconnected with a number of clients for distant monitoring (see Figure 7).

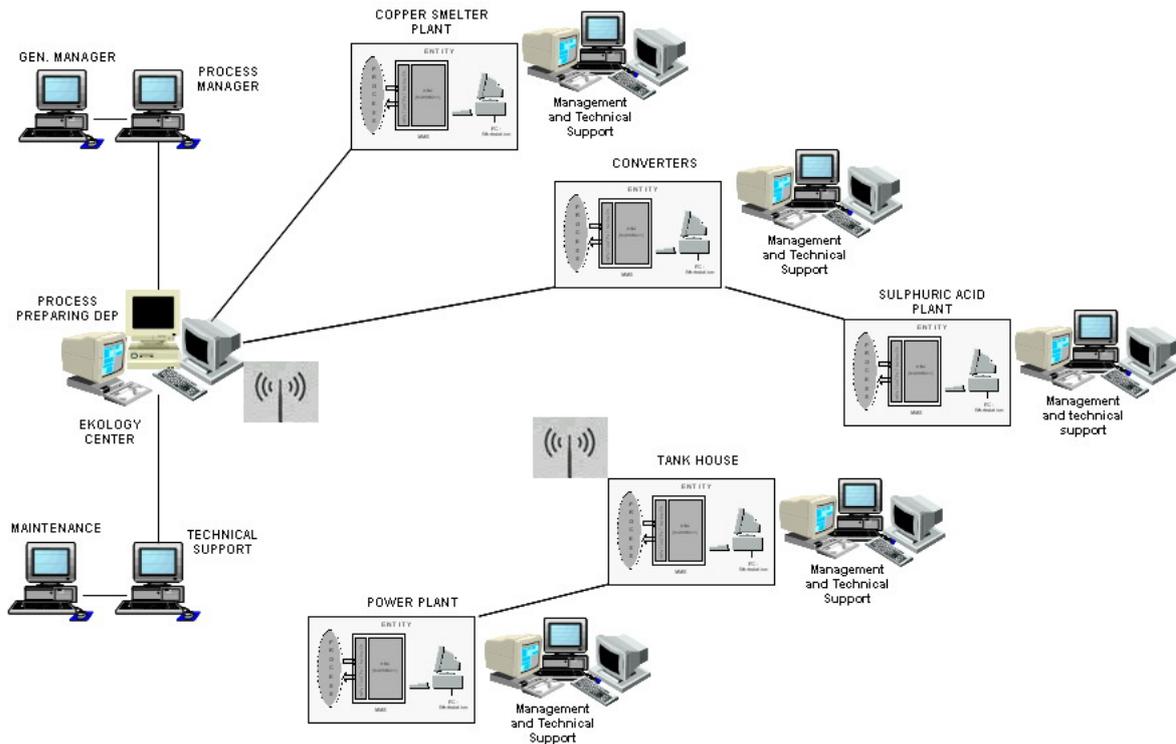


Figure 7. The overall block schema of realized industrial network structure

5. Conclusion

The realized distributed control system is an example of practical solution for complex industrial network built of heterogeneous nodes. Communication between MMS and PC workstation is realized using the specially designed protocol (Asynchronous Serial Protocol) with defined priority levels, which guaranties efficient and reliable data transfer. The main advantage of ASP is minimal length of header and control characters compared to the amount of useful data to be transferred.

Another significant characteristic of the realized distributed control system is the possibility of multiplying source databases at secondary network nodes (clients in realized industrial network), enabling multiple backup in real-time.

The system showed good stability and resistance to external influences. The system response time varies from plant to plant, depending on actual process demands. The possibility of distant monitoring is very important for making different business and production strategy decisions on time. In that way, management at different levels is able to monitor and follow the relevant process parameters in real time. Appropriate data analyses and creation of reports can be also performed on client side at any time. It can be horizontally upgraded by adding the new client PCs.

In a near future vertical network expansion is planned, by integration with two other information systems. Namely, in order to control high level of air pollution, which is a direct consequence of controlled technological process, a global network air quality

monitoring system independent of our DCS is in use. Having the picture of technological process and ecological parameters at the same time will be very important for making real time analyses and decisions in order to reduce the environment pollution with optimal process production.

Integration with the existing information system for electrical power supply optimization and costs reduction is the other important step in overall increase of efficiency. This information system covers two transformer stations and all power consumers at different production plants. Simultaneous monitoring of technological process parameters and electrical power consumption is necessary to make the technological processes more efficient and decrease electrical energy costs.

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