SCADA System for a Central Heating and Power Plant

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Abstract—Modern process control systems are used in industrial automations for flexibility, modularity and reliability, employing state of the art technology based on three concepts: Distributed Control System (DCS), Programmable Logic Controller (PLC) and most importantly Supervisory Control and Data Acquisition (SCADA). This paper deals with design and implementation of a SCADA system for a central heating and power plant, which is planned to supervise and control field distributed electric devices using Siemens equipment and software “Process Control System 7” (PCS7). The system also allows web-based applications via OPC and web server by using the existing communication infrastructure. Redundancy is present at the server levels. The system is currently in use at COLTERM Central Heating and Power Plant South (CET South) of Timisoara.

I. INTRODUCTION

Continuous innovation guarantees sustained market success for machines and plants. The innovation steps become easier if one can exploit previous investments for machine generations. In today automation world, the requirements are high and complex. Each new system has to be better, more reliable, more flexible and more user-friendly than the ones before it.

New software technologies have also emerged due to machine integration requirements, control and monitoring equipments in easy-to-use web-based applications, e.g. platforms: PCS7 – Siemens, CX-Supervisor – Omron, Genesis 32 – ICONIX. All these merged concepts and modules can have as result a successful, reliable and fully functional SCADA, DCS or PLC systems.

SCADA has been around as long as there have been control systems. The first SCADA systems utilized data acquisition by means of meter panels, lights and strip chart recorders; the operators manually operate various control knobs exercising supervisory control [1], [2]. Process automation makes use not only of SCADA concept but also of DCS and PLC.

The advantages of process control systems using SCADA, DCS and PLC, all together are:

- Many types of data can be collected from PLCs;
- Data can be viewed from anywhere, not just on site;
- Existing plant infrastructure can be used;
- Redundancy can be applied at the required levels;
- Distributed profiles DCS with hot swapping (if needed) can be used for unreachable locations (by wire);
- Open systems in comparison to traditional static ones;
- Communications and telemetry are improved.

The standardized concepts make the project foundation developed to improve monitoring, energy and material saving, to assure a superior scalability and remote command execution.

This paper presents the design and implementation of a SCADA system for a central heating and power plant, meant to supervise and control field distributed electric devices using Siemens software and equipment. The old equipments are replaced by using PLCs, servers, modern approaches regarding network equipments and topologies and flexible monitoring stations. Remote actions and uninterrupted monitoring are possible due to redundant servers and web-based applications via OPC server and web server.

II. PROBLEM DEFINITION

Every existing plant, no matter the case, needs monitoring and control systems, either by means of old hardwired relays, either by modern electronic components capable of replacing older systems. This is also the case at Central Heating and Power Plant South of Timisoara. Historically, the old plant informatics system was engineered in 1990 by ISPE Bucharest. The equipments delivered at that time were put out of production many years ago. The old process control system was started in function in 1993, a software upgrade being developed in 2002.

The desire for a new SCADA system has emerged from the following drawbacks:

- Poor reliability and maintenance;
- Process computers DAS 900 (Data Acquisition System) can no longer be maintained in function due to lack of spare parts and obsolete ARCNET network technology;
- SICONIX pseudo-SCADA software engineered by ISPE Bucharest is a closed system, making impossible the integration and communication with new SCADA system in the plant;
Inability of interfacing and transmitting parameters to the energetic group installed in the SICONIX monitoring system;

Need of releasing/removing the cable routes with a standard industrial field data bus;

Long acquisition times and lack of protection circuits against electromagnetic disturbances;

Not able to execute commands on field elements and does not have web-based capability;

No redundancy at any level.

Regarding these limitations, few problems are taken into account as specific requirements for the new design:

Power supplies feeding sensors must have separate connectivity of the protection earth and null wires in order to attenuate electromagnetic disturbances;

Keep a close evidence of events and actions;

Have a well defined set of rules based on a selection key (manual/remote concept), not allow two operators to command the same equipment at the same time;

Real-time capability with upon-change display regarding I/O;

Design the web-based system in such a way that the monitoring and command tasks are distributed according to the needs of each operator.

The solution for the new SCADA system of CET Sud Timisoara (Fig. 1) is a web-based process control and monitoring application that uses the following devices:

A PLC with I/O modules as master station, with a central rack and 3 expansion racks, capable of collecting and processing data from 3 plant boilers and heating station (Fig. 2). Another function is to execute command algorithms for pumps and valves. This is a centralized station.

Two distributed slaves acquire heating data from long distant sensors and control execution elements, where direct cable connection with the centralized PLC is not possible. Data are acquired via Profibus Distributed Periphery (DP).

Two OS servers working in redundant regime for data transport and synoptic implementation of the heating plant areas. The servers also record data, show evolution graphics for one week, display alarms and events. All these data are available for clients via OS web-server.

SCADA system with an OS web-server capable to publish reports, synoptic images, dynamics, process values and commands to clients.

Eight Human Machine Interface (HMIs) clients for centralized process control and plant monitoring. Maintenance is also possible here by displaying the servers and PLC status.
An engineering system (ES) used for programming, downloading the server configurations and PLC programs. Furthermore, diagnostics, I/O checkout and simulation are executed on the ES.

Four switches used for two communication busses: plant bus (PB) and terminal bus (TB) to design two Industrial Ethernet redundant rings (Fig. 3) [3].

Several 4-20 mA to 4-20 mA converters for signal filtering and disturbance attenuations.

III. APPLICATION ARCHITECTURE

All web-based applications are centered on the N-Tier architecture that is a client-server architecture combined with layer architecture [4]. The architecture for our application has field components (PLCs, sensors), two OS application servers with databases, an engineering system (ES), a web-server and 8 clients.

According to this structure, the clients correspond to the Presentation Tier helping to translate the information from EBCDlc and ASCII into audio, video and images.

The Application Tier is associated with the web-server, which deals with the client requests and acts as an intermediate between the OS servers and clients.

The Database Tier contains the database management system that manages all persistent data. The OS server and the OS redundant server work for this tier.

The Field Tier deals with the distributed modules, PLC and sensors and has the task of acquiring and processing data [5].

Data from heating hot plant boilers are acquired by distributed modules. Data from heating plant boilers and plant boilers are acquired by the main cabinet, which contains the CPU and expansion racks. The processor with 3 Profibus interfaces contains on his racks modules for the acquisition of binary and analog inputs like distributed modules. The difference is that the distributed stations only take data without processing it, but the Automation System (AS) does. The communication is made via SIMATIC Profibus DP, which is a field bus with baud rate up to 12 Mbit/s based on the RS-485 standard with 1 km maximum length.

The two electric ring networks (Fig. 3) allow the Servers and the Engineering System (ES) to exchange data with each other and with the AS. The flexibility of these networks is obviously, when the engineers run diagnostics, execute signal test or download. The PB uses SIMATIC Industrial Ethernet, ISO protocol (MAC Based) and the TB uses TCP/IP. The networks employ X414-3E and X208 switches that exchange data at 1000 Mbit/s.

How it’s made: The first step is to design the system architecture and to establish the hardware emplacement. The second step is to choose the appropriate modules for processing and acquiring data. The system monitors 737 binary inputs, commands 10 binary outputs (4 valves and 2 pumps) and acquires 324 analog inputs. Also, a reserve module of 20% resources is taken into account.

IV. PLANT BUS LEVEL

A. Hardware Configurations

At the Plant Bus level (PB), the automation system contains a central controller (CC) placed in the universal rack UR1, and another 3 expansion units (EU) placed in the expansion racks (ER1), which communicates via send/receive interface modules IM460-0 and IM461-0 always used together (Fig. 2). The send modules (send IMs) are inserted in the CC, while the corresponding receive modules (receive IMs) are plugged into the series-connected EU [6]. Due to the lack of voltage transfer between the IMs, each EU needs separate power supply. The hardware rack specifications are:

• Rack 0 contains Power Supply (PS) 24Vdc/20A, CPU (3 Profibus and 2 Industrial Ethernet interfaces), communication processor for Industrial Ethernet CP, 3 Digital Input modules 32xDI of 24Vdc, 8 Analog Input modules 8xAI with 13Bit resolution and the send/receive module.
• Rack 1 contains one PS 24Vdc/10A, 6 modules 32xDI of 24Vdc, 6 modules 16xAI of 16Bit resolution, 2 modules 8xAI of 13Bit resolution and a receive module.
• Rack 2 contains PS 24Vdc/10A, 5 modules 32xDI of 24Vdc, 10 modules 8xAI of 13Bit resolution and a receive module.
• Rack 3 contains PS 24Vdc/10A, 5 modules 32xDI of 24Vdc, 10 modules 8xAI of 13Bit resolution and a receive module.

The distributed stations communicate with the AS via 1.5Mb/s Profibus with a distributed profile. The first station contains 3 modules 32xDI of 24Vdc and 4 modules 8xAI of 13Bit resolution. The second station contains 1 module 32xDI of 24Vdc and 1 Digital Output module 32xDO of 24Vdc/0.5A.

The 8xAI module has the measuring type of 4-20mA / 2 wire; the 16xAI module has 4 wire on 4-20mA. Analog modules also have wire-break signaling capability; a “configuration in run” (CIR) is also possible (if needed). CIR supports hot swapping by adding/removing new slaves and modules and making new parameter settings for inserted modules [7].

Using EU is a cost effective solution in comparison with distributed profiles (DCS). On the other hand, if the signals pass long distances in the plant, the slave solution used with the CIR capability is the best one.

The tool used to define the connections, communications and configurations on all levels is “HWConfig” (Fig. 4) from the PCS7 software by Siemens.
B. Software Using Process Control System 7 - PCS7

The PLC programming is made with PCS7 software package, which has the following main tools: Continuous Function Chart (CFC) and Sequential Function Chart (SFC). In PCS7, these high-level languages have replaced the classic ladder diagram (LAD), S7Graph, function-block diagram (FBD) and so on, that were used to build process control applications. The overall plant process is described by continuous sequences. For this purpose CFC charts are used in the CFC Editor of PCS7 [8]. CFC uses predefined blocks that are stored in Master Data Library to use them for signaling, scaling process values and build control algorithms for pumps and valves. In CFC, before working with signals, we must pass them through channel drivers.

The logic for Signaling procedure, e.g., the produced heating energy (Fig. 5) is the following:

1. Identify the signal address from the AI module.
2. Pass the values to virtual channels by connecting their address to the “value” signal. The channels are called “CH_AI” and are standard CFC blocks. Scale the values by giving them upper and lower limits through the “VHRANGE” and “VLRANGE” parameters. Hysteresis can also be applied on the “CH_AI” block.
3. Get the values from the output of the CH_AI block, put them in a comparator “CMP_R”. If the value goes into overflow then substitute the value with “0” by connecting the output of “CMP_R” to the “SUBS_ON” signal. By activating this signal, the output of the “CH_AI” block will get the value from the “SUBS_V” parameter. Underflow situations are eliminated in the same manner.
4. Add the values and place them to a measure and monitoring “MEAS_MON” block. Define on this block, the alarm and warning limits for the scaled value. When executing the “Create/Update block icon” function, an interface for the operator is created on the associated process picture.

The “Val_Mot” block is a dedicated CFC for controlling motor driven valves. The valve command algorithm is implemented following the functions:

- There is a time control mechanism for the valve opening/closing. If the time passes then the valve disables itself. The block can be used again only if the error is acknowledged. A stop in an intermediate position is also possible: not (RB) & not (LB) & not (SK).

If SK is activated then the valve blocks itself. Linking the input signal SK at “Link_Man” and “Liop_Sel” valve signals, we switch and activate from operator control to interconnected inputs. By this fact, the possibility of simultaneous commands from the clients and from the buttons in the command rooms is eliminated. The valves controlled are IV3, T24, UA1 and UA2.

The “MOTOR” is a CFC block, which starts/stops the pumps. It is used to control motors by means of a control signal ON/OFF. The motor speed feedback-signal (on/off) can be monitored optionally by means of a contactor relay.

Various inputs are available for controlling the motor. They are implemented in a concrete hierarchical relationship to each other and to the motor states. In particular, the locking, the feedback monitoring and the motor circuit breaker influence the control signal “QSTART”. A SK is also implemented on the block.

In order to test the blocks to work properly, they are downloaded in PLC under simulation mode. By activating “Test Mode on/off” function, we can execute tests and diagnostics directly on PLC. The channel drivers (analog or binary) have a “SIM_ON” signal, which activates the “SIM_V” parameter, so that the driver outputs its value. All the programming, testing and diagnostics are done on the ES.

V. TERMINAL BUS LEVEL - SERVERS

At the Terminal Bus level, there are the redundant OS servers and the web servers. The OS servers are the main components of the SCADA system. Each server or station, with an OS indicative, is configured with a WinCC Application. WinCC is the integrated software in PCS7 that permits SCADA operations.

A. Terminal Bus-Database Tier-OS Redundant Servers

They hold 34 synoptic main images, which are arranged in a hierarchical mode depending on the area they belong to.

Secondary images, which are not associated with the plant areas, hold and display evolution charts of the process values for one week. Other secondary pictures
have the functions of showing synthesized tables with all the process values on the associated areas.

Evolution charts are created in “Tag Logging” editor in the server WinCC application, which archives the process values to be able to display their history. The archiving system processes runtime tags stored in the runtime database and after, writes them in the archiving database. Archived values can be exported in Excel.

The following sequences are executed (Fig. 6):

- Automation System (AS) saves the process values, which are sent to the WinCC application through communication drivers;
- Data manager (DM) processes the values and returns them to the archiving system through process tags;
- Archive system processes the acquired values (depends on the archive configuration);
- Runtime database (DB) saves the process values, which are going to be archived.

The synoptic images are created with the “Graphics Designer” tool. Here, the user interface with the process is created. Different C scripts are created for signaling the functioning state of equipments in the field, e.g., coal and gas burners. Some signaling modes have 3 states and some have 2 states.

Reference of the C functions:
GetTagBit(bit_name) reads bit and returns a boolean value;
SetTagBit(bit_name) sets a bit and returns a boolean value.

The interface of CFC blocks for command and monitoring are placed on the associated area images by activating the “Create Update block/icon” function. The alarms are automatically generated by the “MEAS_MON” CFC block, in association with the limits defined on it. The operator interface for “MEAS_MON” provides: value visualization, alarm redefinition and acknowledgement, dynamic scaling and 5 minutes evolution charts.

The OS Servers run in redundant regime. They are configured with the “Redundancy” editor from WinCC. The main server and the redundant server (stdby) have WinCC applications. The servers exchange data through COM1 RX-232 interface.

The servers monitor each other in runtime to allow preventive acknowledge of partner failure. This fact assures the clients of uninterrupted control. During fault, the active server will continue archiving all messages and process data for the WinCC project. After the failed server comes back on-line, the contents of messages and user archives will automatically be copied to the warm returned server. This operation fills the data gaps of the server.

This action is called “Synchronization after server comes back on-line”. This type of redundancy is called “Hot standby system” because the spare system is operated in synchronization with the active system. The structure can be considered as a parallel redundancy. The process reliability for such structures can be determined using the following equations [9]:

\[
Rp = 1 - QA \cdot QB
\]
\[
Rp = RA + RB - RA \cdot RB
\]

where Qi is the system unreliability: Qi = P(Xi) is the probability of unit failure; RA and RB are the reliabilities of the two servers; Rp is the overall process reliability.

The process pictures are published to the OS Web Server from the OS Server and further to the clients. There will be two publications, one on the OS Server and other on the OS Web-Server. “Web navigator” is the WinCC tool used for this action.

B. Terminal Bus and Local Network – Application and Presentation Tier – OS Web Server and Clients

Within a PCS7 OS multiple station system, the PCS7 OS Web server is an OS client with PCS7 OS Web server functionality. An OS client, which is configured as a PCS7 OS Web server, can no longer be used as an operating station (OS client) within the PCS7 system.

A PCS7 OS Web client accesses the project data provided on the PCS7 OS Web server via Intranet or Internet using Internet Explorer [10], so the process can be operated and monitored. The setup of Web Clients can be done by accessing the Web Server by remote operations. It is important to review the number of licenses. In our current system, 9 clients can simultaneously access the Web Server.

User monitoring and command rights are configured via “User administrator” tool on the Web Server. All servers run on Windows 2003 Server operating system.

C. PCS7 Programming Software Architecture

The main concepts of industrial automation PLC, DCS and SCADA are implemented here through Siemens PCS7, composed of two main tools WinCC and Step7. PCS7 comes with new development tools and facilities:

- 2 new editors CFC and SFC with libraries;
- different views:
  - Plant View - for configuring the plant hierarchy and associating programming blocks with plant areas;
  - Process Object view shows details for the individual object;
  - Component View shows the physical location where the objects are (e.g. CFC, process picture).

The system is created on a multi-project architecture. There are two main projects, one for the AS and one for the OSs in order to allow distributed engineering.
VI. CONCLUSION

This paper presents the design and implementation of a SCADA system for a central heating and power plant (CET) South Timisoara, meant to supervise and control field distributed electric devices using Siemens software and equipment. Remote actions and uninterrupted monitoring are possible due to redundant servers and web-based applications via OPC server and web server.

The new system has replaced the old existing SCADA system, it is currently in use and fully functional.

The system has the following advantages that allow: remote and safe operation and monitoring from anywhere in the world, suggestive synoptic images (Fig. 7), evolution charts for one week, archives, easy to interpret alarm system, but the main features are flexibility, scalability and powerful modular structure.

REFERENCES


Figure 7. Functional SCADA system Air – Gas circuit for heating boiler 2