DESIGN AND CONSTRUCTION OF A REMOTE MEASUREMENT AND CONTROL FACILITY FOR A WATER SUPPLY PROJECT

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ABSTRACT: In the present paper we describe a method for the design and construction of a remote measurement and control point usable in a water supply project. The structure of the project is designed in such a way as to allow incorporation into a larger SCADA-type project. The proposed solution is a generic one that can be realized with the help of a small PLC and a GSM communication equipment or radio modem. The work includes both the electrical design of the assembly as well as the software configuration used together with the structure of the PLC program.

KEY WORDS: PLC, design, monitoring, SCADA, automation system.

1. INTRODUCTORY NOTIONS

SCADA-type systems are made up of two distinct components, a hardware component necessary to achieve connectivity between the monitored equipment and the monitoring center and a software component that includes the settings of the equipment used, the automation and control programs implemented in the monitored equipment as well as the necessary software for storage and remote control contained in the dispatch part of the project [1,2].
To be able to acquire and control remote equipment, distributed technological processes use dedicated communication equipment of the RTU type that integrates the equipment necessary to communicate with the SCADA center and one or more secondary communication paths with the role of controlling and acquiring data from local equipment monitored and controlled remotely via RTU as seen in Figure 1.
Depending on the complexity and importance of the monitored process, two distinct command structures can be created [1,2]. In cases where the amount of information exchanged with the control center is small, integrated RTU type equipment is used that has a compact structure and integrates a small number of digital and analog inputs and outputs.
If the technical solution is more complex, or it is necessary to achieve local control over the process, then the hardware structure requires the use of a PLC, an HMI and a standard

communication equipment for the interface with the SCADA center [2,3].
Using a PLC imposes configuring and writing a program code capable of acquiring and storing data as well as scaling them so that they can be viewed in an accessible form on the display of a local HMI [3-5].
In order to be able to control the process remotely, and also locally, it is necessary to implement more complex control methods. The aim is to be able to follow the changes made in both control regimes and also to follow regime synchronization with the SCADA application [5,6].
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Is difficult to make a clear distinction between a modern RTU and a PLC due to the fact that recent RTU equipment is more complex and gradually takes over the functions of a PLC.
A comparison between a PLC and an RTU can be made in terms of configuration and programming. A PLC is a more complex equipment programmed using dedicated languages like Leader, Instruction List or Function Block. Thus, it requires solid programming knowledge, in order to be able to configure the communication ports and the necessary control logic [5-13].

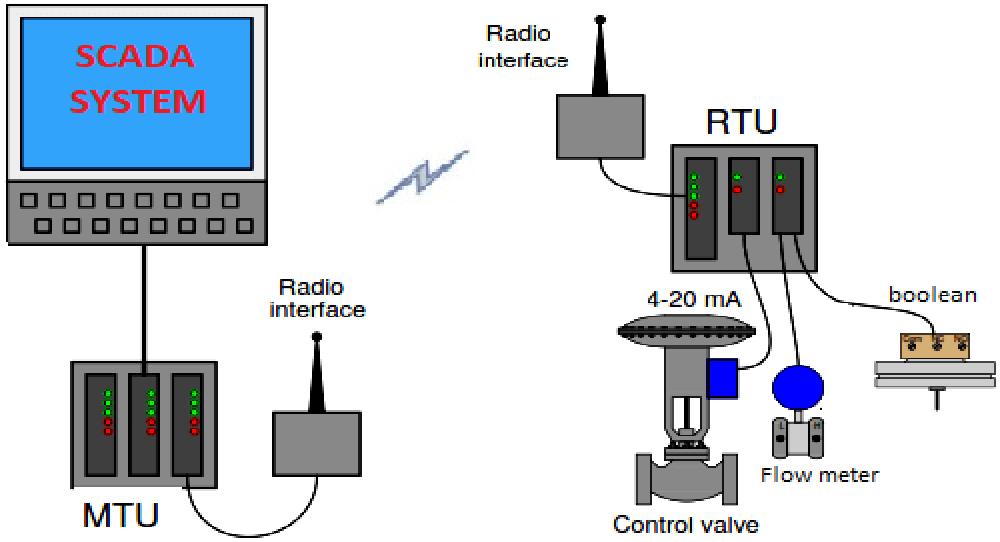

Figure 1. The operating principle of an RTU connected to a SCADA system

The RTU terminals, on the other hand, are configured with the help of simplified graphic interfaces, through dedicated software or through an integrated web interface provided by the configured equipment.
Due to the simplicity of interface for configuring RTU terminals, they are preferred in places where only the interfacing between remote technological processes is carried out or where only the data acquisition is carried out by the means of a GSM-type communication of equipment located in isolated places [8,9,10].
The structure that contains a PLC and a standard communication equipment shows greater flexibility in choosing the communication protocols compared to an RTU based structure. At the same time, it offers greater flexibility for the technological process, due to the control logic implemented in the same PLC. Thus, the PLC fulfills both roles, that of command – control, and that of the communication node with the dispatcher application [10].

2.COMMUNICATION PROTOCOLS

In order to achieve communication between the various equipment within a larger technical project, one must use standardized communication protocols. The physical medium used can be a two-wire serial transmission cable, a four-wire serial transmission cable or an ethernet cable.
The choice of the communication protocol is dictated, on one hand, by the existing drivers of SCADA environment and by the protocols supported by the equipment (RTU or PLC)

and on the other hand by the environment used for data transmission between the two equipment [6-15].

The existence of a small amount of data that constantly exchanges between the dispatcher and the RTU allows the use of GSM communication and the use of less optimized communication protocols, such as Modbus TCP, where the amount of transmitted data is quite large due to the way this protocol works.

Modbus-type protocols have a cyclic operation in which the desired values are queried directly without taking into account whether they have changed or not in the time interval that has elapsed since the last query made by the driver [16].

The communication protocols Modbus RTU and Modbus ASCII, introduced by the Schneider company in 1979 for their series of PLCs, and the advanced version Modbus TCP have become a standard in industrial communication due to their simplicity and versatility. These have been implemented in all industrial equipment as a universal connection compatible with other older generations or with equipment from other manufacturers [17,18].

More advanced protocols, such as DNP3 or IEC 62351-5, allow generating events for changes in monitored values, and even the priority transmission of various event classes, based on occurrence of events, depending on classification and implementation. So, it is possible to choose the immediate transmission of certain alarms or critical values and the transmission of less significant values at certain intervals [16-20].

The DNP3 protocol allows the application of a timestamp for each value transmitted so that the lack of information in the SCADA graphs due to the lack of communication can be combated for time intervals from a few minutes to a few hours, depending on the amount of information stored and transmitted. When communication is restored, these values are passed to the dispatcher and existing gaps are automatically filled by the DNP3 driver [19-23].

The biggest disadvantage of using the DNP3 protocol is that it is not included for free in SCADA packages and imposes additional licensing costs. Field equipment, such as PLCs and RTUs, has not implemented this protocol except for more expensive equipment because this protocol requires a consistent communication buffer and a processor capable of processing and storing this data in real time [12-23].

After establishing what hardware structure and what sensors we will use in the desired application, the amount of information required for effective control and monitoring of the process, depending on the speed of its development over time, is determined. If the process is slow or the amount of data acquired is small, then we can resort to less efficient communication protocols such as cyclical ones, otherwise we will have to create a catalog of events and measured values to transmit to the dispatcher to implement more efficient protocols, such as DNP3 or similar [19-21].

3. AUTOMATION DESIGN FOR A REAL CASE

The design theme is to make an automation electrical panel for a remote control and monitoring project i nan isolated place.

The purpose of this automation panel is to monitor the measurable parameters of the drinking water and to allow the regulation of the outlet pressure by means of an electrically controlled valve, and to allow the integration of this project into a SCADA type application with the help of universal communication protocols such as Modbus TCP.

The monitored water parameters will be the pressure, the instantaneous flow, the amount of residual chlorine and the totalized daily flow.

In addition to these parameters, the application will have to monitor the electrical parameters of the supply voltage, the flood sensor and the burglary signals from the sensors in the premises.

The application will have to be able to function independently, even in the absence of communication.

The main electrical panel fixed above the ground will be designed in the immediate vicinity of the electricity supply block from the public network and will supply 24V DC to all measurement, control and remote transmission equipment and for the automation panel.

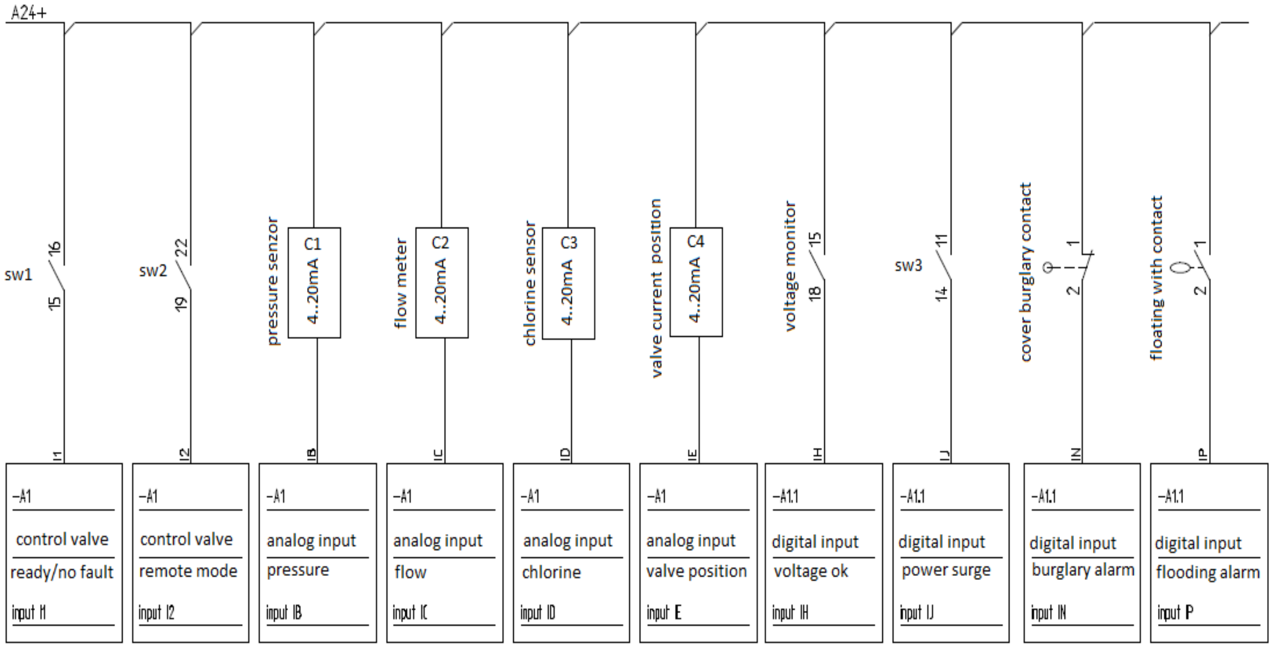

Figure 2. The electrical diagram for connecting the signals to the PLC

Figure 2 shows the simplified electrical connection diagram of the PLC, and the type of data acquired from the sensors and relays for monitoring the equipment within the project.

Because of the isolation of the measuring room, it is necessary to monitor remotely other parameters that are directly related to the operational safety of the respective automation. Therefore, we have taken into account the monitoring of the network parameters by means of a dedicated measuring relay, whose contract signaling is received in the PLC. This relay monitors the presence of all phases, the minimum and maximum values and the correct phase sequence. This last requirement is dictated by the fact that the valve has a three-phase drive motor and its two-phase operation leads to rapid damage to it.

To increase safety in operation, we have monitored the protection circuit breakers of the regulation valve motors and the contacts on the surge arrester, all these digital signals are received in the PLC, reversed if necessary and then transmitted together with burglar alarms or chamber flood signal.

For a better immunity to atmospheric discharges, we chose the option of powering the automation through a step-down transformer directly between 2 phases, where it is known that the influence of atmospheric discharges is greatly reduced, thus ensuring increased safety in case of direct or indirect contact with the mains phase, which is thus isolated from ground.

All monitoring contacts are powered directly from the 24V DC source via a circuit breaker so as not to completely block communication and the PLC in the event of grounding the voltage outside the panel. The lack of 24V DC voltage or its intentional disconnection triggers the burglar alarm.

The power source is connected to an external battery that allows a control voltage reserve and in the event of a mains voltage failure, a reserve sufficient for 24 hours of remote parameter monitoring.

For more efficient management of addresses and limited memory within PLCs, their addresses are assigned names created by the programmer, similar to variable programming in PC programs. Also, digital and analog inputs and outputs can have distinct names for easier design and debugging of PLC programs.

The main addresses in the PLC memory, together with their names and the data they store are briefly presented in Table 1

Table 1. Inputs and outputs used in the project

PLC memory address	PLC assigned tag	Type and value
%MD24	FLOW_INDEX	Double Word
%MD26	OLD_FLOW_INDEX	Double Word
%MW1	T_ALARM	WORD
%MW2	T_CHLORINE	WORD
%MW3	T_SETPOINT	WORD
%MW4	T_PRESSURE	WORD
%MW5	T_FLOW	WORD
%MW6	T_FLOW_DAY	WORD
%MW101	ALARAM_SCADA	WORD
%MF102	CHLORINE_SCADA	FLOAT
%MF104	SETPOINT_SCADA	FLOAT
%MF106	PRESSURE_SCADA	FLOAT
%MF108	FLOW_SCADA	FLOAT
%MW110	FLOW_INDEX_SCADA	WORD
%MF194	CUR_VALVE_POS	FLOAT

The automation panel receives the information from the electromagnetic flowmeter in the form of a unified current and converts the read value to the actual value by scaling the value in the minimum-maximum range of the flowmeter and transmits this value to the dispatcher through communication. The value of pressure and residual chlorine are taken from the sensors in the form of a unified current that is applied to the analog input module of the PLC. The output signal generated by the PLC for the output pressure control is also a unified current that is applied directly to the regulating valve controller that follows the compliance of the imposed pressure in a closed loop.

```
9 - Copy data for SCADA
Master Task
Rung0
0000 LD     1
0001 [ %MW101 := %MW1 ]                      Copy ditial alarms to SCADA register
Rung1
0000 LD     %I0.4                            test key postion for on
0001 [ %MW1 := %MW1 OR 1024 ]                set bit 10
Rung2
0000 LDN    %I0.4                            test key position for off
0001 [ %MW1 := %MW1 AND 16#FBFF ]            reset bit 10
Rung3
0000 LD     1
0001 [ %MF102 := %MF66 / 4096.0 ]            Copy chlorine to SCADA
0002 [ %MF150 := INT_TO_REAL ( %MW3 ) ]
0003 [ %MF104 := %MF150 / 100.0 ]            Copy setpoint to SCADA
0004 [ %MF106 := %MF46 / 4096.0 ]            Copy Pressure to SCADA
0005 [ %MF108 := %MF56 / 4096.0 ]            Copy Flow to SCADA
0006 [ %MW110 := %MW6 ]                      Copy daily counter to SCADDA
0007 [ %MF194 := %MF76 / 4096.0 ]            Copy current vale position to SCADA
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Master Task
> 1 - Init
> 2 - Reference point
> 3 - Conversion
> 4 - Adjusment mechanism fault
> 5 - Analog alarms
> 6 - Digital alarms
> 7 - Flow metering
> 8 - Booster pump
> 9 - Copy data for SCADA
Free POUs
> S_Digital Alarms generate (SR12)
> S_Flow counter (SR13)
> S_Reference setup (SR11)
> S_Generate alarms for analog values (SR14)
> S_Adjustment mechanism fault (SR15)
> S_Conversions (SR10)
```

a) PLC program listing for copying data to SCADA b) The structure of the PLC program

Figure 3. Listings from the PLC program implemented in IL

4. THE PLC PROGRAM

Figure 3 shows the structure of the completed program. It includes in the initial cycle only lines that call on the routines presented as Free POU. In this way, the application is made modular, each subroutine realized has a well-defined purpose and testing or excluding one or the other of them is just a matter of commenting a single line that ensures the invocation of the respective subroutine.

PLC programming languages do not automatically perform conversions on the type of data used, therefore during the program we have to repeatedly convert the necessary values to be able to repeat the desired arithmetic operations or the comparisons necessary to establish various limits or alarms.

The programming language used is IL (Instruction List) due to the fact that it is much more compact and easier to use for larger applications. This language has similarities with the assembly language on the PC due to the use of assignment registers, the way of performing arithmetic operations, the comparison using flags but especially due to the use of jump tags to implement the desired command logic.

The IL language is more convenient to use if many conversion and assignment functions are used on passed values due to its clear and concise syntax. For the LD format, even the most basic assignment or comparison operations require a fairly large construction of assignment blocks, a fact that considerably complicates the tracking of the completed program.

The conversion from the IL language to LD (Ladder logic) can be done for most programs written in IL directly from the application menu for each individual line or for all displayed functions.

3. CONCLUSION

The application is put into practice, the hardware and software structure allow expansions and big changes to the final solution of the project.

This project can be seen as an example to take into account due to the relatively low implementation costs and the universality of the solution achieved thanks to the communication protocols used.

The existence of a PLC implies the possibility of adapting other communication equipment or other types of sensors that were not taken into account in the initial phase.

The analog acquisition modules also allow the acquisition of voltages in the 0-10V range produced by other types of equipment with standardized analog outputs or temperature-voltage converters for other types of sensors.

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