Using Moeller PLC in automation of an artesian fountains

C Barz¹, T Latinovic², S Deaconu³, D Preradović⁴, P P Pop⁵ and A Pop-Vadean⁵

¹Technical University of Cluj-Napoca, North University Centre of Baia Mare, Victor Babes str., no. 62A, 430083 Baia Mare, Romania.
²University of Banja Luka, Faculty of Mechanical Engineering, 73 Vojvode Stepe Stepanovića Blvd., 78000 Banja Luka, Bosnia and Herzegovina.
³Politehnica University of Timișoara, Faculty of Engineering of Hunedoara, Department of Electrical Engineering and Industrial Informatics, 5 Revolution Street, 331128 Hunedoara, Romania.
⁴University of Banja Luka, Faculty of Economics, 4 Majke Jugovića Street, 78000 Banja Luka, Bosnia and Herzegovina.
⁵Technical University of Cluj-Napoca, Department of Mechatronics and Machine Dynamics, Blvd. Muncii, no. 103-105, 400641 Cluj-Napoca, Romania.

E-mail: crbarz@yahoo.com

Abstract. The paper presents the use of a Moeller PLC in the automation of an artesian fountains from Baia Mare. The application is developed in Ladder Diagram and contains two modes of operation. The first mode is the Automatic Mode in which are defined certain operating times of the artesian fountains pumps. These set times make recurrence of the operation. The second mode is the Manual Mode in which each pump is operated independently. Manual mode is only active for service personal, according to the user accounts and authorization rights of its. All orders are made with a touch screen Weintek in menus that are created for application. Using the Service Menu can visualize defects occurred during the regime of operation, which is recorded.

1. Introduction

The PLC is a specialized industrial computer for real-time applications. The PLCs appeared in the late 60s and are integrated systems that usually contain a processor, a power supply, input modules, output modules and special modules dedicated (Figure 1).

Last standard (IEC 61131-3) attempted to combine the programming languages of PLCs in an international standard. As a result of these efforts, today we have PLCs which can be programmed through diagrams with block functions, instructions lists, the C language and structured text, all at once [1].

IEC 61131-3 is the third part (of 8) of the open international standard IEC 61131 for programmable logic controllers, and was first published in December 1993 by the IEC. The current (third) edition was published in February 2013.

Part 3 of IEC 61131 deals with programming languages and defines two graphical and two textual PLC programming language standards:
- Ladder diagram (LD), graphical
- Function block diagram (FBD), graphical
- Structured text (ST), textual
- Instruction list (IL), textual
- Sequential function chart (SFC), has elements to organize programs for sequential and parallel control processing.
- Continuous Function Chart (CFC). This language is an extension to the IEC 61131-3 standard, which gives free positioning of graphic elements.

The PLCs are some devices designed to replace the sequential relay circuits which are used to control various machines. They are used for the operation of machine tools, machinery, installations, etc. to perform certain tasks, and for start and stop them, however they are achieved through the program memorized by PLC. The PLC operates by inspecting its inputs and, depending on their condition and the program designed for automation, switching the outputs on or off.

![Figure 1. The Moeller PLCs](image)

By using the PLCs, the execution times of products and services and the work performed by personnel can be reduced, improving the efficiency of industrial production.

On the PLCs market are many brands of appliances (Siemens, Moeller, Omron, Mitsubishi Electric, Schneider, Telemecanique, Omron, General Electric), every brand trying to attract with certain special specifications, but also with facile software interfaces in their programming.

2. The Moeller PLC

2.1. Moeller history

In 1899 Franz Klöckner founds a switchgear production company in Cologne, Germany and Hein Moeller joins the firm in 1911.

In 1940 Moeller starts to deliver switchgear to electrical wholesalers and undergoes a change in name to Klöckner-Moeller. Felten & Guilleaume Carlswerk is founded in Kleedorf, Lower Austria.

In 1980s, the companies that make up the Moeller Group are united into Moeller Holding GmbH & Co. KG, achieved with the help of 7,000 employees in 75 countries. Moeller becomes one of the first suppliers of compact programmable logic controllers (PLCs), with the PS3 PLC being launched on the market to great success.

In the years 2000-2003, the economic downturn all over the world and growing competition on global markets starts to impede the company's development, which is further hampered by the owner's efforts – lasting almost two years – to sell it. Despite these difficulties, Moeller continues to invest in forward-looking production technology and the development of new product series like:

- RMQ-Titan command and signaling devices
- Easy 600/800 Control relays
- NZM 1–4/I2M circuit-breakers
- Rapid Link decentralized motor control system
2.2. The PLC design XC-CPU100

The XC-CPU100 controllers have been designed for application in machinery and plant control systems having a compact design.

These controllers are fitted with interfaces for connecting to a programming device (RS232) and for linking to decentralized CANopen expansion units, so they can form the core of a comprehensive automation system [3].

The basic unit consists of:
- Rack,
- A CPU for control or visualization, with integral power supply unit (PSU) and local inputs/outputs,
- XIOC signal modules.

![Image of PLC XC-CPU101](image-url)

**Figure 2.** The PLC XC-CPU101

The CPU module of the XC100 (Figure 2) is divided into two functional units:
1. Processor unit with interfaces
2. 24 V PSU with integral digital inputs (8) and digital outputs (6).

The XC-CPU101...(-XV) types of CPU are based on a processor with an integrated CAN interface, and include battery-buffered flash and SRAM memories.

The monitoring of the system voltage ensures that the data-saving routine will be initiated if the voltage goes below a fixed preselected level. The internal real-time clock facilitates time and date dependent control functions.

The available operating and interface control devices are:
- LED display for RUN/Stop and general error
- Operating-mode selector switch RUN/Stop
- RS232 interface, e.g. for programming device interfacing
- CAN open interface as a fieldbus interface
- Interface for a multimedia memory card (MMC).

The multimedia card is used as an optional backup medium for the (boot) project and to save recipe data.

2.3. Local digital inputs/outputs
The 18-pole terminal block which has the power supply to the CPU (Figure 3), the local I/Os and the physical connection to the local inputs/outputs is located on the right half of the CPU. The 8 digital inputs (I0.0 - I0.7) and 6 semiconductor outputs (Q0.0 - Q0.5) are designed for 24 V signals and have a common 0VQ/24VQ power supply which is potentially isolated right up to the bus.

![Figure 3. Connections for PSU and local I/O](image)

2.4. The XSoft program
XSoft is a program which gives the PLC programmer an easier access to the powerful IEC language. XSoft provides us with a variety of important functions to debug, test and put quickly and efficiently our control application into operation [4], [5].

Using the editors and running functions is based on the many programs developed and demonstrated from the advanced programming languages (like Visual C ++).

XSoft contains all the programming languages for IEC 61131-3:2013. This suite consists of textual languages, Instruction List (IL) and Structured Text (ST), and graphical languages, Ladder Diagram (LD) and Function Block Diagram (FBD), Sequential Function Chart (SFC), Continuous Function Chart (CFC). The main extensions are new data types and conversion functions, references, name spaces and the object-oriented features of classes and function blocks [1].

XSoft is a system based on CoDeSys programming for industrial automation, conducted in accordance with the international standard. Developed technical features, easy operation and the widespread use of this software in the automation components used by different manufacturers guarantee the success.
It can be tested your application program without being connected to the PLC. XSoft present for
this one integrated online simulator. Do not need to get out of current interface and does not change
the operation mode against the online command connected.

Into a program are included the following items: POU (Program Organization Unit), characteristics
information, views, resources and libraries.

All editors of POU programs contain a declaration and a body part, the Ladder Diagram editor is a
graphical editor and the most important commands are found in the content menu (Figure 4).

Each network in the Ladder Diagram contains the left side of the network of contacts (contacts are
represented by two parallel lines | |) showing the condition "On" or "Off" from left to right. These
conditions correspond to the boolean values TRUE and FALSE.

In the right side of the Ladder Diagram network can be multiple coils represented by
parentheses ( ), but they may be connected only in parallel. A coil transmits the value of connections
from left to right and copying them into a nearest boolean variable [6], [7].

3. The frequency inverter

The frequency inverters used in application are the types DF51-340-3K0 and DF51-340-4K0, from
Moeller.

The DF51 frequency inverters (Figure 5) are electrical apparatus for controlling variable speed
drives with three-phase motors. They are designed for installation in machines or for use in
combination with other components within a machine or system.

The DF51 frequency inverters convert the voltage and frequency of an existing three-phase supply
to a DC voltage and use this voltage to generate a three-phase supply with adjustable voltage and
frequency. This variable three-phase supply allows stepless variability of three-phase asynchronous
motors [8].

The DF51 frequency inverters are not domestic appliances. They are designed for industrial use as
system components and presents different functions for control the frequency inverters.
4. The artesian fountain application

4.1. The principle of fountain automation
The artesian fountain (Figure 6) is made with 8 circularly disposed jets, fueled into 2 groups of 4 jets, each group is powered by a 3 and 4 kW pump, controlled by two frequency inverters.

The inverter is used to drive the pumps for the fountain jets variation of the intensity, jets intensity being controlled by the Moeller PLC through its analog outputs and by inverters analog inputs.

The artesian fountain also presents an optic fiber lighting system for jets which function only during the evenings. The Fountain is designed for automatic mode based on a time switch and it is set to function between 07:00-23:00 daily.

The fountain has an auxiliary building such as a small waterfall which is controlled by the same automation. This consists in 3 waterfall pumps which are simultaneously operated because of the high water flow rate that need to be used for this to function. These pumps are dependent also on the level sensors which indicate presence of water in the tank.
There were established certain conditions for the operation of the fountain, which are given by the existence of recirculation water corresponding to the pumps tank. There are sensors in order to know if the minimum or maximum level of water in the tank has been reached and to signal possible alarms (lack of water, etc.).

Also, in case of unsuitable weather conditions (powerful wind, storm, ...) the fountain will be stopped. Another condition is that the fountain cannot operate during the winter when there is frost risk. For the winter period the pipes and the water pumps will be emptied.

All these commands and parameters settings of the fountain are performed in a manual operation mode only for the service personnel.

4.2. The phases of operation
In the normal regime of the fountain operation, jets are operated in 3 phases, these having various values for the intensity of jets but also different function times.

In the first part of the automation ladder diagram was defined the daily operation period of the fountain, by reading the internal clock of the PLC (using the function rtc1.CDT) and comparing it with the hours’ interval 07:00 to 23:00. The comparison values operate on an internal marker MX3.1 which allows or doesn’t allow the jets to function (Figure 7).

![Figure 7. Defined the daily operation period of the fountain](image)

In the first phase are initialized the analog inputs values of the frequency inverters to a value of 34 Hz (corresponding to a value of 1400). If it drops below this frequency threshold for pump operation, the pumps will enter into the blank area where the pumps do not succeed to realize the pressure for jets.

Initialization at the value 1400 of the analog outputs is made on the outputs by data words type QW2 and QW4 of the PLC (Figure 8). The outputs QW2 and QW4 accept the maximum value of 2080, which corresponds to the voltage value of 10V on the analog outputs of the PLC. The voltage value is transferred to the inverter which makes the engine pump to function at 50 Hz, being the maximum operating frequency of the pump.

![Figure 8. Initializing the analog outputs](image)
In the first phase both pumps are turned on, their jets will ascend step by step at the same time to the maximum value established at 2080 (corresponding to 10V at the analog output), the value of a step is 30 which increments the initial values 1400 of QW2 and QW4 through the ADD block. The moment of maximum value (2080) is given by the comparison GE block which activates the internal marker MX0.7 to stop the analog outputs incrementation. From that moment begins the decrementation of analog output values with the SUB block, all with the same values of 30, like as the incrementing (Figure 9).

![Figure 9. Increment and decrement of the analog outputs QW2 and QW4](image)

The second phase of operation (Figure 10) begins when the jets level reach the minimum set (1400), then only the first pump starts and goes up to the maximum, activated by the analog output QW2. After reaching the maximum level (2080), the amount of analog output QW2 decreases to initial values in steps of 10secs, given by relay timer t3. From that moment the same procedure begins for pump 2.

![Figure 10. The incrementation of analog outputs QW2 for the second phase](image)

In the third phase of operation the artesian fountains repeat the second phase of operation but with a higher incremented step (50), to make the jets faster.

This also applies to the decrease slope of analog outputs QW2 and QW4, after achieving the initial value for QW4 the internal marker MX2.4 (Figure 11) it’s enabled to reboot the operation parameters and to restart the cycle from the beginning.
Decrement the analog outputs QW4 for resetting

The reset of the fountain operating parameters (Figure 12) is performed when the jets working cycle is resumed through MX2.4 marker, also after stopping one of the pumps through outputs QX0.0 and QX0.1 or through emergency command QX0.5 coming from the fountains sensors. Resetting brings the involved markers values to 0 and it also initializes the analog outputs QW2 and QW4 values to 1400 (Figure 8).

In Figure 13 is presented the stop command of the fountain given by the low water sensor IX0.3 when tanks are not filled to full capacity, in a time of 30 minutes (timer t5). This condition is necessary so that we can control the water losses which could occur during time or the lack of water supply to the fountain.
5. Graphic interface for WEINTEK panel

To view directly the program behavior in the PLC XC-CPU101, it has been used a HMI touchscreen from Weintek series.

The application made for the WEINTEK panel (Figure 14) presents the pumps operating state, the status of the PLC inputs and outputs and it can also read and modify the values by the analog outputs of the PLC XC-CPU101. The graphics application for WEINTEK panel was made using EasyBuilder8000 [9], [10].

The main menu of the panel presents the principal information for any user (Figure 14), having also the additional menus (screens) for manual mode service and for real time behavior of the pumps operation where, from the history menu, you can see what had happened a certain time ago (Figure 15).

The P1 LED indicates the first pumps status in the automatic mode, this is turned on or off depending on the pumps switch key position. LEDs are functional only when the switches key is in automate position and the pumps are controlled by PLC XC-CPU101 and frequency inverters DF5-350-3K0 and DF5-350-4K0.

The fault LED indicates the occurrence of faults from the fountains, waterfalls, filters or frequency inverters.
The numeric indicator *Val freq P1* displays the operating frequency of the pump 1 which is contained between 0 – 50 Hz, and this value is provided by frequency inverter. Similarly, in case of the pump P2.

Service button connects the main menu and the service menu, as well as *Grafice* button link the menu graphics.

![Graph menu](image)

**Figure 15.** The Graph menu

The menu Graph gives the values plot of the frequency inverter output, to be able to follow how the program works in real time and if there is any anomaly in operation, they can be rectified.

6. Conclusions

Using the program designed in XSoft it can be built complex operation steps of the fountain jets, another main element in the automation being frequency inverters using.

By controlling them through analog inputs, it can easily juggle the motors speeds in the frequency range 0 - 50 Hz, in order to obtain maximum output to drive.

Using the HMI panels is a necessity in applications with PLCs because there is a lack of monitoring and controlling the realized program. With graphical interfaces help of the WEINTEK panel, the PLC CPU XC-101 can be controlled by operator without requiring the use of a PC.

With a minimal configuration of equipment (PLC, HMI, frequency inverters and sensors), can be built almost any automation, everything depending on the program designed in PLC.

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