Data Acquisition System Based on a Programmable Logic Controller

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Abstract — The data acquisition process has the role of transposing physical phenomena from the real world into analogue and digital electrical signal for further processing, analysis and storage of the measurement data. This paper proposes a data acquisition system based on a Programmable Logic Controller (PLC) for voltage and current monitoring in a DC circuit. Two interfacing methods are presented. The first method consists of interfacing the system by means of a specialized graphical terminal. The second method is realized by connecting the system to a PC terminal through the serial RS-232 interface.

Keywords — data acquisition, system, programmable logical controller, monitoring, interfacing

1. INTRODUCTION

Data acquisition systems consist of sensitive elements, conditioning and conversion circuits, hardware and software equipments, processing units and user interfaces.

![Data acquisition system structure](image)

Implementing a data acquisition system based on equipments designed for industrial applications (PLCs, industrial processing units) allows these systems to be used in media that present exceptional conditions regarding the environment, as well as the length of the operation duration. [1]

Programmable Logic Controllers (PLCs) are digital processing units used in process automation. Unlike general purpose computers, the PLCs are designed and built to run in special environmental conditions: extreme temperatures, electrical noise, vibrations and mechanical shocks, media with dust, impurities and high humidity. Depending on the model and the manufacturer, PLCs have several analogue and digital inputs and outputs. The inputs are used for the connection of the sensitive elements, and the outputs are used to command the active elements of the control system. A data acquisition system based on a programmable logic controller is a real time system, therefore the data being read at the inputs must be processed immediately and the results must be sent towards the outputs as soon as possible.

The programmable logic controller’s design and structure allows extension modules to be attached to the main unit. The extension modules are designed for specific functions: extending the number of inputs and outputs, analogue to digital conversion, digital to analogue conversion, communication with other devices by means of specialized communication protocols. Given the multiple extension and connection possibilities, data acquisition systems based on programmable logic controllers show a multitude of usage and integration opportunities. [8]

2. EXPERIMENTAL SYSTEM

This paper proposes the design and implementation of a data acquisition system for the monitoring of voltage and current in an DC circuit, using the Mitsubishi FX3U-16 PLC as the main processing unit.

The programmable logic controller used in the system has 8 inputs and 8 outputs. Programming the device is achieved through the vendor supplied development software (GX Developer, GX IEC Developer). The software which is prewritten in the PLC’s memory has a list of 238 instructions which can be launched into execution by the program written by the user in the controller’s temporary memory. Depending of the type of operations called by the program (mathematical, logical, input read, output

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write), the PLC can execute up to 3000 operations per second. The controller’s base memory is 64 MB and it can be extended up to 128 MB.

The sensitive elements of the system are the voltage and current transducers LA-55P and LV-25P. The transducers are built to work in industrial environments, having a measuring range of 0…50 A and 0…500V respectively. Both transducers have the Hall Effect as their working principle, therefore the galvanic insulation of the measurement circuit is solved.

The transducers have analogue current outputs. The signals read from the transducers’ outputs need to be converted in numerical values in order to be processed by the programmable logic controller. [4]

The analogue to digital conversion is made by the Mitsubishi FX0N-3A extension module. The module has two analogue voltage inputs (0…10V) and two current inputs (4…20mA). The analogue to digital conversion is done by conversion circuit with an 8 bit digital resolution. The module is connected to the PLC via the main unit’s communication bus. [5]

The data acquisitioned on the two input channels of the extension module are stored in its transfer registers which are interrogated by the PLC through the RD3A instruction. [6]

The data sent to the PLC in digital format can be presented in real time by means of specialized graphical terminals, or it can be sent to a computer in order to be presented or stored for further calculations and analysis. Furthermore, the programming routine of the PLC can contain data comparison sequences. The acquired data can be compared to preset values and the result of the comparisons can determine a change in the PLC’s outputs state, therefore acting upon the system’s active elements placed within the monitored process in order to modify the values of the concerned parameters.

![Fig. 2. The interrogation sequence.](image)

The first interfacing method is realized by means of a specialized graphical terminal. The terminal hosts one or more graphical interfaces which can be configured by the user to best suit the applications for which the interfaces are intended.

The second interfacing method proposed in the paper is based on the data transfer from the PLC to a PC via the RS-232 interface. Using the RS-232 interface to connect the data acquisition system to a PC terminal offers a stable and fast enough connection method. Therefore, interfacing the data acquisition system with a PC terminal via the RS-232 standard results in a real time monitoring and control system, suitable to work in various environments. [3]

3. RESULTS

In order to present the multiple interfacing possibilities of the proposed system two interfacing methods have been implemented: interfacing the system by means of a graphical terminal and by sending the measurement data to a PC terminal via the serial interface. The system’s connection possibilities are numerous and can be implemented by attaching extension modules to the PLC in order to establish communication links via specialized communication protocols used in automation.

The graphical terminal used in this paper is a Human Machine Interface (HMI) GT1155, which is specially designed for Mitsubishi PLC interfacing. The device is powered by a 24V DC power supply and it can be connected directly to the voltage source of the PLC. The HMI is connected to the PLC via the RS-422 serial interface and the programming of the terminal is done by connecting it to a PC equipped with the development software via USB or the RS-232 interface. This type of terminal has a 256 colors touch screen that can be entirely configured using the development software provided by the manufacturer.

The software allows the user to define multiple interest areas within the surface of the touch screen. These areas can be given a display-only function or they can be configured in order to be touch-sensitive, allowing the operator to interact with the system through the graphical terminal. Besides the display and interaction functions, the graphical terminal offers a data storage function. The process acquisitioned by the system can be stored on a removable memory card and can be transferred to a specialized processing unit for further processing and analysis.

The program written in the HMI’s memory can contain more than one graphical interface, therefore making it possible for the operator to monitor different processes connected to the data acquisition system, using the same HMI terminal. [7]

The HMI’s development software allows the user to define limit values for the monitored parameters. Given the case that the acquisitioned values do not fit within the preset intervals, the terminal can alert the operator by graphical and acoustical means. Also, the
user can choose in the developing phase of the graphical interface weather to log separately the unusual events, or to send alarm messages to other terminals connected to the data acquisition system. Furthermore, if the programming routine specifies it, the HMI can terminate the process in order to prevent hazardous situations.

A graphical interface for voltage and current monitoring in a DC circuit has been developed and is presented in this paper. The values recorded from the circuit are displayed in real time in decimal format and their evolution in time is graphically presented. Three touch sensitive areas have been defined in the graphical interface, which allow the operator to start and stop the data acquisition on the two channels and to activate or deactivate the serial data transmission towards the PC terminal.

Interfacing the data acquisition system with the HMI terminal gives the user a series of advantages: real time access to the data collected from the monitored process, the possibility of intervention upon the system via the touch screen, explicit warnings in case of exceeding values of the monitored parameters and the possibility of storing the data acquisitioned by the system.

The second interfacing method is implemented by transmitting the data collected from the process to a processing unit. The data taken from the sensitive elements placed in the monitored process is converted into ASCII characters by the PLC and is then transmitted to a computer. The data conversion from binary values to ASCII characters is done using the PLC’s BINDA command. The data resulted after the conversion is stored in the PLC’s memory locations and is awaiting transmission towards the PC via the serial interface. The programming sequence written in the PLC’s memory also generates and transmits other ASCII characters (“U”, “I”, “V”, “A” and “=” ) in order to make the displayed collected data as accessible as possible.

When configuring the graphical interface, limit values have been preset for the monitored parameters. The development software gives the possibility to redefine visual and acoustical warnings in case the monitored parameters’ values exceed the preset limits. Therefore, in case of a voltage higher than 150V, or a current over 3A, the displays on the interface change their color in order to warn the operator about the undesired value. Figure 5 presents the aspect of the interface in the case of higher values than the ones preset by the programmer.

The data is transmitted via the RS-232 interface, using the RS command available in the PLC’s language. The data stored as ASCII characters in the programmable logic controller’s memory locations are transmitted towards the PC terminal. The operator can see the data received at the PC side of the system in real time.

The data received on the PC terminal can be stored in a “.log” file, making them available for later display or usage in the monitored process’ analysis. The data can be stored on the terminal towards it has been transmitted, or it can be further sent to a dedicated storage terminal, connected to the data acquisition system.
The data stored in the “.log” files can be used at a later time for calculations concerning the measurements taken from the monitored process. The value arrays in the “.log” files can be easily read by specialized calculus and data acquisition software (Mathlab, Excel, LabVIEW).

Fig. 8. Data stored in the “.log” file.

By attaching additional extension modules to the programmable logic controller, the collected and converted data can be sent via dedicated automation networks which use specialized protocols, or it can be sent via GSM or via the Internet.[6]

4. CONCLUSIONS

This paper presents a data acquisition system based on the Mitsubishi FX3U-16M programmable logic controller equipped with the Mitsubishi FX0N-3A analogue to digital conversion module. The system allows the monitoring of a wide range of voltage and current values because of the used transducers, which have wide measuring domains. The transducers can be used in AC as well as in DC circuits, their output signal having the same nature as the input signals.

The system presented can operate autonomously from a PC terminal, the operator interaction with the system being possible through a HMI terminal with the appropriate graphical interface written into the HMI’s memory. Such an interface can be configured for real time monitoring of a series of parameters taken from the process by the data acquisition system. The graphical interface’s configuration routine also allows presetting limit values for the parameters and operator alerts in case the preset limits are exceeded.

The operator can easily act upon the system via the configurable areas on the HMI’s screen surface. If the monitored process is controlled by the same PLC, the operator can also intervene on the active elements which are connected to the PLC via the HMI. Access via the HMI terminal can be extended to other PLCs connected with the data acquisition system.

The data acquisition system can be easily connected to state of the art processing units via a multitude of connection technologies, therefore creating a basis for advanced systems of monitoring, analysis, command and control of complex processes.[2]

Because of the numerous connection possibilities of such a system, the authors propose the integration of the system within a complex network for monitoring and control purposes. The other nodes of such a network could be represented by programmable logic controllers equipped with extension modules specialized for communication in automation networks, using different communication protocols for specific applications. All the nodes of the network should be connected to a central unit for monitoring and controlling the process in real time.

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