REMOTE SUPERVISION OF A DIDACTIC INTEGRATED MANUFACTURING PLANT

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Abstract. *Remote supervision of productive processes in real-time constitutes a fundamental part in the management of modern industrial processes. However, the viability of this supervision in the industrial context requires the analysis of specific functional parameters, such as the application response time, the monitoring frequency of process variables, and network latency. This paper presents the development and performance evaluation of a supervisory system monitored via Internet. This system has been used in the supervision of a didactic integrated manufacturing plant that distributes workpieces for a testing station.*

***Keywords**: Remote supervision, PLC, productive process*

1. Introduction

Real-time remote supervision of productive processes is essential to safe and efficient management of modern industrial processes. However, the implementation of such supervision system in the industry requires careful analysis and specification of parameters such as the application response time and the monitoring frequency of the process variables.

In the industrial context, the SCADA (Supervisory Control and Data Acquisition) technology is a well-established approach to the development of supervisory systems for industrial plants. SCADA provides several utilities that permit system interaction through the World Wide Web and the development of graphical interfaces that can be used to remotely monitor the system or to execute specific commands. As a consequence, users have a new form of operation and observation of the production system.

In this paper, we present the development and experimental performance evaluation of a supervisory system of an integrated manufacturing plant that can be monitored by the Internet. The manufacturing plant consists of a distribution station that transfers a workpiece between two different stations. The developed system allows an user to monitor and adjust the manipulation of workpieces by monitoring the status of sensors and changing the actuators states. The main objective of this work is to investigate if a remote monitoring system could be easily and efficiently implemented using such a framework. This paper focuses on the performance analysis of the implementation of this remote monitoring system in a real scenario.

2. Implementation of a web-based supervision system

To implement the control and supervision application, it was used a distribution station of cylindrical workpieces available at CIMATEC. The purpose of the distribution station is to separate a workpiece from a feed magazine and to make the workpiece available for a subsequent process. The distribution station is composed of two subsystems: the feed magazine module and the transfer module. This distribution station is part of the Modular Production System (MPS) manufactured by FESTO Automation. This manufacturing plant is controlled by a Programmable Logic Controller (PLC) manufactured by SIEMENS. In the next sections, we describe the steps concerning the design decisions and development details of the supervisory software.

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2.1. System description

The manufacturing system is composed by a didactic distribution station composed of pneumatic and electrical actuators and sensors, as shown in Figure 1. The objective of the distribution station is to pick up a workpiece in the feed magazine and to transfer it to the next station of the manufacturing plant. The workpieces are fed in FIFO (First In, First Out) order to the next station (Festo, 1999).

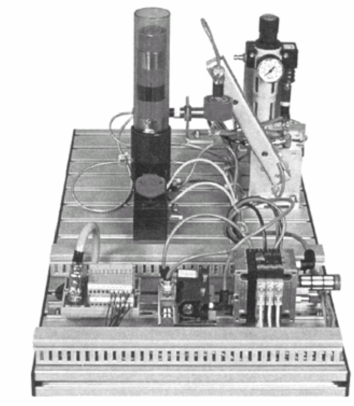

Figure 1. MPS Festo Distribution Station

The feed magazine separates the workpieces stocked in the pile. A pneumatic actuator (also called pusher) pushes the workpiece that lies on the base of the pile to the a position where it can be picked up by the transfer module. Two proximity sensors identify the current position of the actuator: advanced or retracted. An optical sensor identifies the presence of workpieces in the base of the pile.

The transfer module is composed by a pneumatic actuator, also called manipulator. The workpieces are picked by a vacuum suction cap and are placed on the next station by a handling device. Two contact sensors identify the position of the actuator: 0º when the manipulator is in the feed magazine and 180º when it is in the next station. A pressure sensor identifies the presence of a workpiece held by the suction cap.

To control the distribution station, the manufacturer suggests the following control steps:

1 – Move the manipulator to the 180º position
2 – Push the workpiece
3 – Move the manipulator to the 0º position
4 – Turn the vacuum on
5 – Retract the pusher
6 – Move the manipulator to the 180º position
7 – Turn the vacuum off
8 – Move the manipulator to the 0º position
9 – Restart the cicle

The main difficulty in programming a PLC to control the distribution station as stated above is that the transitions of some of the steps above are related to the same sets of events. To simplify system development, the control sequence of the distribution station was modeled using a finite state automaton, in which each step suggested by the manufacturer is represented by an automaton state. A simplified version of the automaton is depicted in Figure 2. Each automaton state defines a set of output signals to the PLC controlling the distribution station and the state transitions are triggered by the sensors readings (Fabian e Hellgren, 1998). At the end of the sequence, if the automatic control is selected by the user, the systems goes to state 1 and waits for a piece in the base of the pile. If the user selects manual control, the system goes to state 0 and waits for the start button to be pressed.

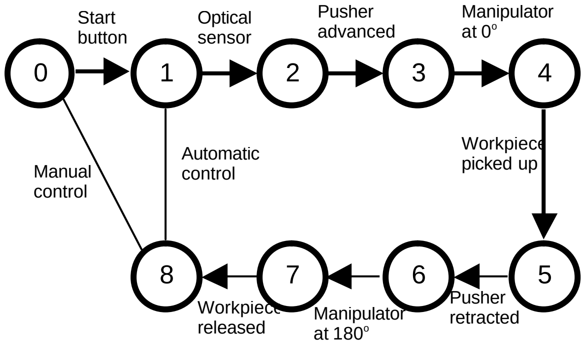

Figure 2. Finite state automaton for the distribution station

2.2. Application development scheme

The application development scheme is represented in Figure 3. The distribution station is connected by a serial port to a PC that acts as a control unit and a web server. A second PC acts as a web client. Both PCs are connected to a 10/100Mbits Ethernet corporative LAN. The server is an Intel Pentium III running Windows 2000 Advanced Server, including an Internet Information Service (IIS) web server. PLC programs in the server are written using Indusoft Web Studio and STEP7 development environments. The client runs Windows 2000 Workstation with Internet Explorer 6. The PLC is a Siemens Simatic-300 controller with a 314 CPU model, 16 digital outputs, 16 digital inputs, 3 analog inputs and 1 analog output.

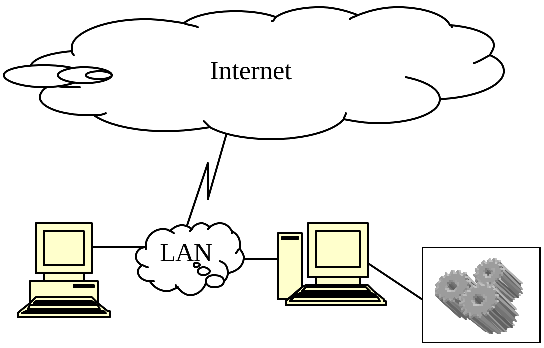

Figure 3. Application development scheme

2.3. Distribution station supervision and control application

To develop SCADA applications to control the distribution station we used the InduSoft Web Studio suite. This framework contains two basic modules: the Development Module and the RunTime Module. These modules communicate using a TAG's DATABASE.

The Development Module is used to create the screens, symbol libraries, tasks lists, communications, databases and security systems, in order to represent the real system. The RunTime Module shows the interface screens, executes the background tasks and communications (TCP/IP, OPC and DDE) and controls logon and logoff.

Initially, we developed the main screens that deal with process control. For that, we designed three screens. The first screen (Figure 4) is a presentation screen that shows the current stations of the manufacturing plant, the state of each station and control buttons used to start and interrupt the operation of the plant. Also, this screen provides links to other stations such as the testing and stock station. Since the controllers for the other stations had not been implemented yet, only the shortcut of the distribution station is enabled.

Figure 4. Main screen for the manufacturing plant web interface

The second screen (Figure 5) shows the distribution station. An animation, updated in real-time, represents the real state of the distribution station. A control panel with push-button like controls allows the remote operation of the distribution station.

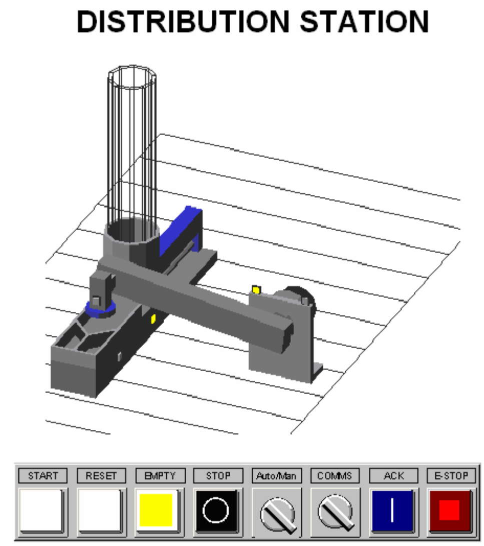

Figure 5. Distribution station screen.

The third screen deals with system maintenance (Figure 6). It is used to diagnose and correct problems in the station. This screen enables the user to visualize the current state of each sensor and send commands to the actuators by individually turning them on or off.

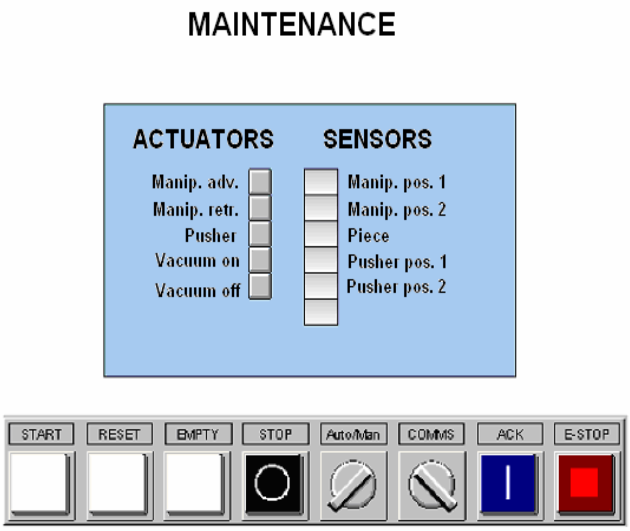

Figure 6. System maintenance screen

Each element on the screen is associated to a *tag*, that is, an object whose value reflects what happens in the manufacturing plant. Besides storing a specific value, a tag has a series of attributes and methods, similarly to classes of an object-oriented programming language. All tags of a control application are stored in a database provided by Indusoft Web Studio. To share the value of a tag with the CLP, a communication driver is used. This driver abstract the details concerning the communication between the CLP and the PC.

If more than one user is connected to Indusoft at the same time, the program sends to the CLP the commands in the order that they are received, and refreshes the status screens to the other users.

To allow remote access to the application screens via Internet, Indusoft Studio provides a TCP/IP server that listens to incoming request on a specific TCP port. In this work, we used port 5000 as the communication channel with the application. The TCP/IP server makes it possible to run the control application and the web server on two different machines. This increases flexibility because users can use machines with different setups. Another advantage is that it is easy to publish relevant pages on a corporative web server using parts of an institutional web site. However, this distributed coordination must be carefully implemented as it can decrease the system responsiveness, depending on the network traffic and bandwidth available between the control and web servers. The machine which runs the control application has a fixed IP address. In this work, both the control application and the web server are running in the same machine.

To provide remote access to the control application, we used the Internet Information Service (IIS), which is part of the Microsoft Windows 2000 Server setup. This server is configured by default to listen to HTTP requests on port 80. The HTML pages which interact with the application are generated automatically by Indusoft Studio. To increase the security preventing unauthorized user access to the manufacturing plant, the control application requires a user login and password.

3. Performance analysis

To analyze the system performance, this work basically focused on measuring the overall system response time, considering three different scenarios. The basic operation was to move a workpiece from the feed magazine to the next station. In the first scenario the operator uses the computer directly connected to the PLC through the serial port. Figure 7 shows the measured times for scenario 1.

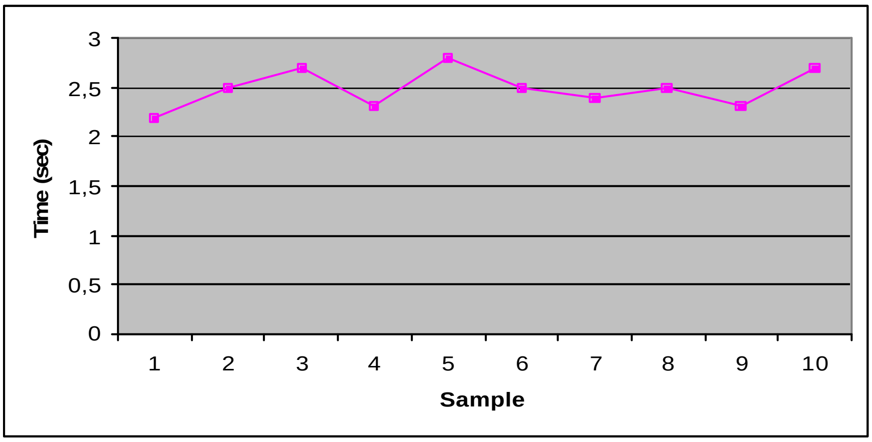

Figure 7. Response times for a PC directly connected to the PLC

In scenario 2, we measured the response times when accesses are made through a second PC that acts as a web client. The PC server is physically connected to the PLC as in scenario 1 and acts as a web server. Both the PCs are on a corporative 100Mbits Ethernet LAN. To analyse real conditions, these tests were conducted during commercial time, ensuring that the intranet is in its normal usage. The performance results are presented in Figure 8.

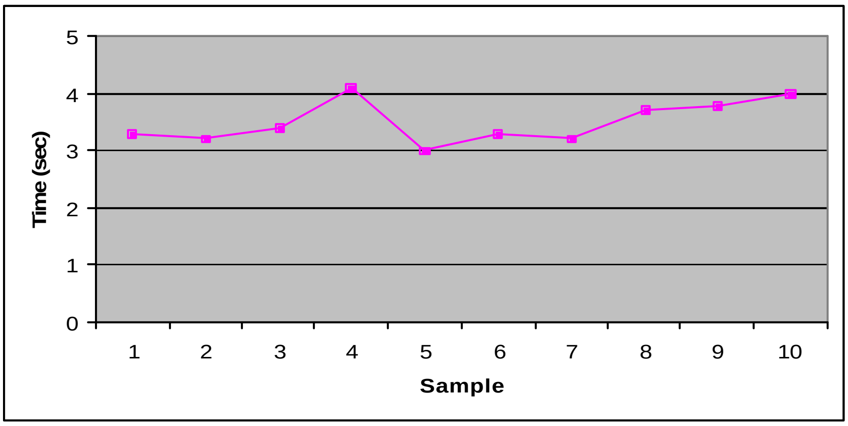

Figure 8. Response times for a PC connected to the local Intranet

In the third scenario, the web client accesses the web server through the Internet using a Broadband connection. Note that the web client is not directly connected to the corporative local network. Figure 9 presents the results obtained in this situation.

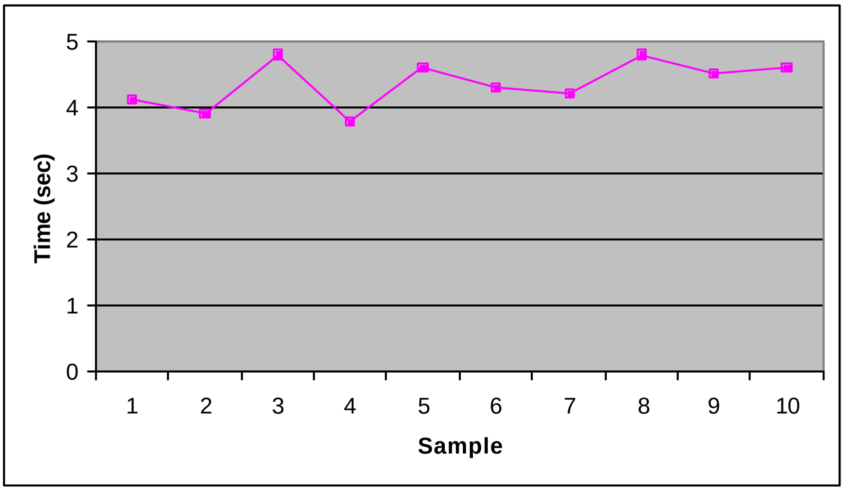

Figure 9. Response times for Internet web client accesses

4. Conclusions

In this paper we presented the design and development of a manufacturing plant supervisory system and its integration to the Internet. This system was used to control a didactic manufacturing plant using a workpiece distribution station. First, the plant functionality was modeled using a finite state automaton and then implemented using a PLC programming module. Then the application interface to the system operator was developed and the screens were integrated to the control variables monitored by the PLC. The analysis of the response times obtained through experimental tests suggests that the use of such a remote monitoring system is an adequate alternative concerning the supervision and diagnosis of manufacturing plants. It is important to note that critical actions requiring very low response times should not be realized through the Internet, since the corresponding response times would easily be prohibitive for controlling critical systems. However, monitoring variables and actions that do not require low response times (such as starting the manufacturing plant) are correctly handled by remote monitoring facilities.

Remote monitoring is especially useful since it allows the company to easily employ differently skilled human resources (*eg*, managers, engineers, operators) to analyze the industrial plants. Also, correcting system failures can be performed without physical presence of the plant operator and it can be triggered anywhere by using devices such as a portable computer or a cell phone.

5. Acknowledgements

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6. References

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7. Responsibility notice

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