Modbus-Based SCADA/HMI Applications

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Abstract

This paper introduces design and implementation of Modbus-based supervisory control and data acquisition/human machine interface (SCADA/HMI) applications. In reaction to the severe problems such as incompatibility and complexity occurring in in the course of the selection of SCADA/HMI packet programs, controllers and instruments, a brief survey on SCADA programs produced by industrial automation vendors is presented and then two Modbus-based SCADA/HMI applications are designed and implemented via National Instrument (NI) Lookout program. Thus, obligation in harmony with same vendor's industrial automation products is eliminated for any SCADA/HMI system. In this study, Modbus-based SCADA/HMI applications have been developed using frequency-controlled inverter, programmable logic controller, and NI Lookout program in order to meet industrial and educational application needs.

Keywords

SCADA; Industrial Control; Control Engineering Education

Introduction

Supervisory control and data acquisition (SCADA) , the most important system in control and automation technology where researches and developments have gained momentum in recent years, possesses flexible and expandable functions due to its capability of control over real-time data acquisition (DAQ), storing and monitoring acquired data, alerting and warning events in the alarm window, managing with human-machine interface (HMI), interoperating wide and local area networks, and fieldbus communication protocols (Adamo et al., 2007; Chandra and Venugopal, 2012; Daponte et al., 2002; Dieu, 2001; Ertugrul, 2000; Faraco and Gabriele, 2007; Lazar and Carari, 2008; Sahin et al., 2010; Tellez-Anguiano, 2009). A typical SCADA/HMI system consists of physical phenomena, transducers, controller, server, and client processes shown in Figure 1. In this figure, physical phenomena are well known as controlled real plants. Overall system communication is established with suitable industrial communication protocols. Server process is made up of driver objects so that it controls and monitors variables of the real plants. In addition, to extend SCADA/HMI system, server and client processes are connected fully each other using Uniform Resource Locator (URL) address.

SCADA/HMI based systems and their applications require controllers with transducers and software program (Dieu, 2001; Faraco and Gabriele, 2007; Lazar and Carari, 2008; Mossin et al., 2009; Sahin et al., 2010; Tellez-Anguiano et al., 2009). The controllers can be chosen as microcontroller, programmable logic controller (PLC) and industrial personal computer (PC) and their transducers must be suitable (Dieu, 2001; Lazar and Carari, 2008; Mossin et al., 2009; Sahin et al., 2010; Tellez-Anguiano et al., 2009). On the other hand, HMI of such SCADA-based systems is generally programmed with graphical programming language (GPL) software packageswhich ensure some specific curricular and cognitive skills such as analysis of the process, implementation of GPL, station of program objects and SCADA/HMI applications (Adamo et al., 2007; Bejan et al., 2009; Coquard et al., 2007; Dieu, 2001; Gacek et al., 2001; Kleines et al., 1999; Mossin et al., 2009; Reynard et al., 2008; Sahin et al., 2010; Tellez-Anguiano et al., 2009).

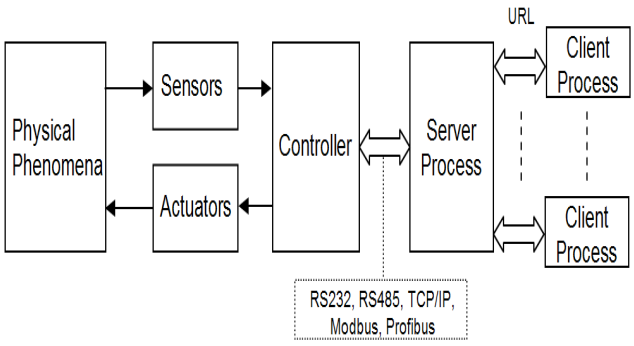


FIG. 1 GENERAL BLOCK DIAGRAM OF THE SCADA/HMI SYSTEM

In this study, the SCADA/HMI based applications are addressed as vital industrial applications and implemented for who want to learn these kinds of applications. In SCADA/HMI based applications, there are several important issues on their component

selection (e.g. package program, controllers, instruments, and communication protocols) resulting from the use of different vendor's products and programs. These issues give results in incompatibility, highly budget, and complexity problems (Bejan et al., 2009; Coquard et al., 2007; Gacek et al., 2001; Lazar and Carari, 2008; Kleines et al., 1999; Mossin et al., 2009; Sahin et al., 2010; Reynard et al., 2008; Tellez-Anguiano et al., 2009) because the SCADA/HMI system generally contains high-cost and sophisticated components. Therefore, this paper shows a way that these problems are overcome gradually. A brief survey on SCADA programs produced by industrial automation vendors is presented to choose a suitable one for any automation system. Modbus-based communication protocol is described in addition to two Modbus-based SCADA/HMI applications designed with flexible and feasible features. These applications have been done using Modbus-based components with inverter, PLC and National Instrument Lookout program excluding from specific vendors' components. As a result, proposed Modbus-based SCADA/HMI applications which are affordable and simple, meet industrial and education requirements.

The rest of the paper is organized in the following sections. A brief description of the SCADA system components, selection of the SCADA programs and Modbus communication protocol are given in "Modbus-Based SCADA/HMI System" Section. The Modbus-based SCADA applications with the programmed HMI and the designed hardware are explained in "Implementation of Applications" Section. The results of qualitative evaluations from students are given in "Evaluation" Section. The results and future directions are discussed in the "Conclusion and Future Directions" Section.

Modbus-Based SCADA/HMI System

Modbus-based SCADA/HMI system can be categorized as hardware and software groups. Hardware group is concerned with physical units such as industrial network, transducer, PLC, and HMI. While the other group software has a lot of measurements and control features such as real-time DAQ, storing and monitoring acquired data, alerting and warning events in the alarm window, managing with HMI, interoperating wide and local area networks.

Software Selection

In the literature, Siemens' WinCC (Bejan et al., 2009; Gacek et al., 2001; Kleines et al., 1999), Schneider Electric' Vijeo Citec (Coquard et al., 2007; Reynard et al., 2008), National Instrument's (NI) LabVIEW (Adamo et al., 2007; Chandra and Venugopal, 2012; Ertugrul, 2000; Faraco and Gabriele, 2007; Mossin et al., 2009; Sahin et al., 2010; Tellez-Anguiano et al., 2009) and Lookout (Dieu, 2001; Isler and Sahin, 2009; Lazar and Carari, 2008; Sahin, 2012; Tellez-Anguiano et al., 2009) are widely used as SCADA/HMI package programs for industrial automation systems. These programs are compared in view of their specifications given in Table 1 to select the most appropriate software program for the measurement and control applications.

TABLE 1 SPECIFICATIONS OF SCADA/HMI AUTOMATION PACKAGE PROGRAMS

	WinCC	VijeoCitec	LabVIEW	Lookout
Development Tools	Animate program execution, debugging	Animate program execution, debugging	Animate program execution, break point, debugging	Animate program execution, debugging
Toolkits	OPC server, Visual Basic scripts, control algorithms	OPC server, Visual Basic scripts, control algorithms	NI OPC server, Visual Basic scripts, C code gen., Math.func., control algorithms	NI OPC server, Visual Basic scripts, control algorithms
Communication	Profibus, Fieldbus, Profi Net, Industrial Ethernet (TCP/IP)	RS485, Fieldbus, Modbus TCP/IP, Modbus RTU	RS232, TCP/IP, UDP, VXI, GPIB, VISA	RS232, TCP/IP, Profibus, Modbus
Optional	Diagnostics, Safety, Security, Robustness	Diagnostics, Safety, Security, Robustness	Diagnostics, Robustness	Diagnostics, Robustness
Depending on vendor' products	High Level	High Level	Medium Level	Low Level

Minimum systems requirements for all the programs are CPU Pentium 4, 1GB RAM, 2GB disk space, Windows XP/Vista/7. All the programs have OOP language and measurement and control applications such as open and closed-loop control, observation and measurement, HMI, Telemetry, data analysis and storage, distributed alarms and events.

As shown in the Table 1, recommended system requirements, programming languages, development tools and applications are suitable for almost all industrial automation applications and training. However, toolkits of the LabVIEW are more appropriate for more complex applications, because they include many compilers, analysis, synthesis and advanced functions. In addition, because WinCC and Vijeo Citec programs require their own vendor's instruments, industrial communication protocol, and their security features, so they are expensive for ordinary industrial and educational applications (Bejan et al., 2009; Coquard et al., 2007; Gacek et al., 2001; Kleines et al., 1999; Reynard et al., 2008).

As for communication protocols, LabVIEW and Lookout programs provide more appropriate and low-cost solutions for industrial and educational applications because they needn't specific vendors' instruments (Adamo et al., 2007; Chandra and Venugopal, 2012; Dieu, 2001; Ertugrul, 2000; Faraco and Gabriele, 2007; Lazar and Carari, 2008; Mossin et al., 2009; Sahin et al., 2010; Tellez-Anguiano, 2009). Therefore, in this study, for the proposed Modbus-based SCADA applications, the reasons for the selection of Lookout program are listed as follows; i) it does not depend on industrial automation vendor's specific products, ii) it is suitable for Modbus-based application, iii) it has a user-friendly graphical user interface (GUI), i.e. it is easy to be used via HMI interface entries such as start, stop, indicator and controller, iv) the ideal software tool is selected with features such as modularity, compatibility and flexibility so on given in (Dieu, 2001; Isler and Sahin, 2009; Lazar and Carari, 2008; Sahin, 2012; Tellez-Anguiano, 2009), v) to achieve a minimal cost, and Lookout evaluation copy is used since it is free. In the light of these reasons, Lookout software might be chosen for Modbus-based SCADA/HMI applications.

Modbus Protocol

The Modbus communication protocol, a kind of serial communication standard , is widely used for industrial automation systems (Mackay et al., 2004; Tellez-Anguiano, 2009; Thompson, 2007)and requires serial communication parameters (e.g. baud rate, parity, and stop bits) and transmission modes for each terminal unit connected to the instrument. In this protocol, transmission modes are defined as American standard code for information interchange and remote terminal unit. In this study, Lookout software ensures Modbus drivers to establish communication links for the proposed application setups given in Figure 2.

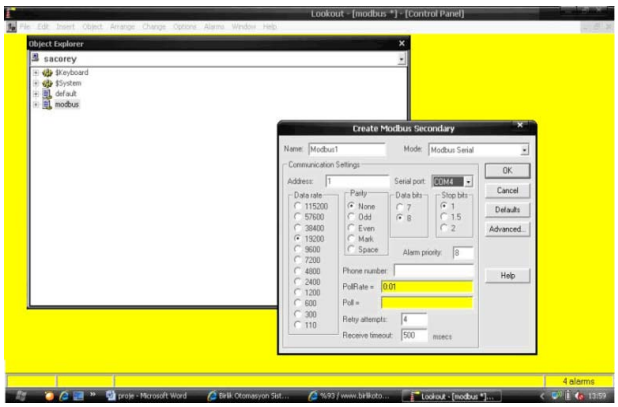


FIG. 2 MODBUS DRIVER CONFIGURATION IN LOOKOUT

Implementation of Applications

Modbus-based SCADA/HMI applications are defined as follows: i) Modbus-based inverter-controlled motor, and ii) Modbus-based PLC. Proposed applications equipped with two setups , each of which is composed of a PC, an application set, and software. The PCs with CPU DualCore2 3300 MHz processor and 2 GB memory are running with MS Windows XP Professional and Lookout 5 evaluation software. This Lookout software is used for HMI panel programming. The panel holds the graphical objects and ensures object-oriented programming (OOP). These features are useful for designing and running GUIs for the proposed applications.

Modbus-Based Inverter-Controlled Motor

The first application designed for a real-time controlling and observing inverter-controlled motor system, consists of an asynchronous three phases motor (Gamak AGM-80-2b), frequency-controlled inverter (Delta VFD015E43), and GUI in Figure 3. The motor can be controlled and measured by frequency controlled inverter via own GUI. Modbus communication rate is 19200 bps. The application is presented in the following items: i) Modbus driver is generated with virtual object in Lookout, ii) inverter Modbus address is determined from the inverter data sheet (for example, in this application, 2102 hex address is used for frequency command in Delta VFD015E43A inverter. This address can be converted to decimal address as 8450, and then "Tuning Frequency" virtual knob can be configured at GUI as Modbus1.48450), iii) controlling inverter frequency for motor via "Tuning Frequency" knob at GUI programmed Lookout iv) measurement on GUI

received current and voltage data from the electrical motor.

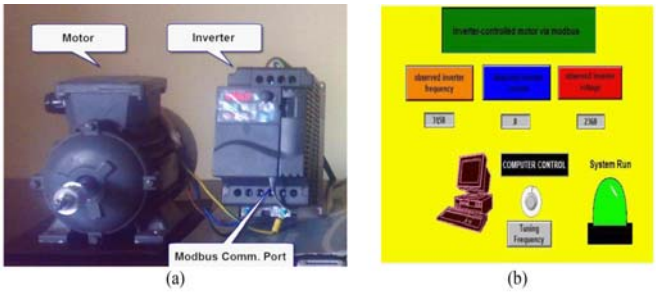


FIG. 3 MODBUS-BASED INVERTER-CONTROLLED MOTOR APPLICATION (a) THE HARDWARE SETUP; (b) THE GUI OF SCADA/HMI

Modbus-Based PLC

The Modbus-based PLC application consists of a PLC (Delta DVP14SS11R2), buttons, indicators, and GUI in Figure 4. The PLC can be controlled by virtual buttons and indicators on the GUI. Likewise, the GUI of the SCADA/HMI on PC can be controlled by real buttons and indicators via PLC input and outputs. The application is presented in the following items: i) Modbus driver is generated with the virtual object Lookout program, ii) Modbus addresses of the buttons and the indicators are determined from the PLC data sheet (for example, M1 button Modbus address is given as 0801 hex address in Delta DVP14SS11R2 PLC Modbus address list. This address can be converted to decimal address as 2050, and then the M1 switch can be configured at GUI as Modbus1.42050), iii) controlling and observing PLC via GUI, iv) monitoring on GUI received buttons and indicators data from PLC.

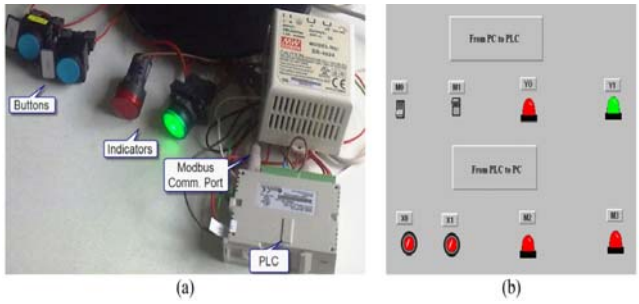


FIG. 4 MODBUS-BASED PLC APPLICATION (a) THE HARDWARE SETUP; (b) THE GUI OF SCADA/HMI

Evaluation

The success of the proposed applications for Control and Automation laboratory is evaluated in this section. A five-question survey was given at the end of the laboratory applications in order to evaluate the performance to obtain a qualitative evaluation. The answers are grouped using a Likert-scale of (Very poor, Poor, Average, Good, and Excellent). The questions are listed in the following:

Q1) Do you think these laboratory applications are easy to use?

Q2) Do you think these laboratory applications ensure a deep understanding of, and experience in, the subject of interest?

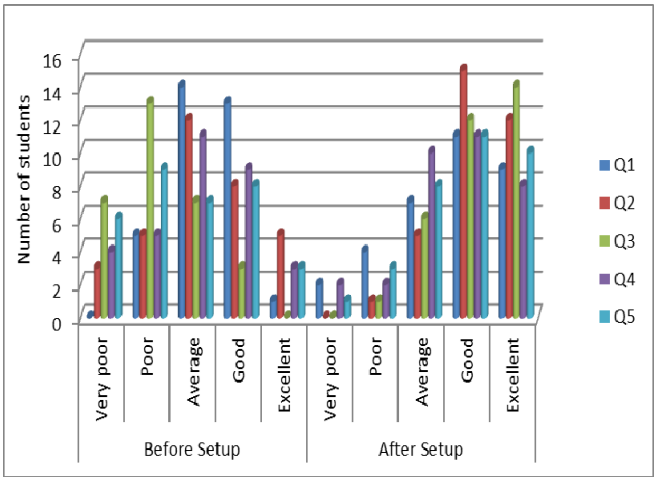
Q3) Do you think the laboratory materials used in the laboratory applications are sufficient?

Q4) How do proposed laboratory applications affect your motivation to continue your education in the field of control and automation?

Q5) How useful do you find proposed laboratory applications for your control and automation education?

The questions targeted the students who had been attending System Analysis and Design course in the second year spring semesterfor two times (before and after the use of the applications setups) in order to evaluate students' circumstances and insights. The first questionnaire outcomes represent students' responses madebefore the proposed applications, in which they used only software simulation mode for the proposed applications in Lookout without the hardware setups. The other questionnaire outcomes represent same students' responses made after the proposed applications, in which they used real-time simulation mode for the proposed applications in Lookout with the hardware setups. Both before and after questionnaires results are given in Table 2.

TABLE 2 EVALUATION RESULTS OF QUESTIONNAIRES ON BOTH BEFORE AND AFTER SETUP APPLICATIONS



The answers of the first question show that the students all agree that the proposed applications are easy to use, both before and after the setups. The

answers of the second question show that the students all agree that the laboratory applications gave them good comprehension and experience, after the application setups. In the third question, most of the students thought that the laboratory materials used in the laboratory applications are very good, after the application setups. In the fourth question, students mentioned that the proposed laboratory applications highly motivated them in the field of control and automation technologies, after the application setups. As for the last question, it is clear that students evaluated the proposed applications as a whole and found it satisfactory. The answers to the last question are very similar to the second and the fourth questions. These three questions show that the motivation and self confidence of the students are very high, after the application setups.

Discussion and Conclusion

This study summarizes concepts of selection SCADA system components, establish modbus-based applications, as well asprogramm the commercial software Lookout for industrial SCADA systemsand obtain experimental experiences of the proposed applications by means of two setups to integrate the industrial SCADA solutions.

industrial SCADA applications and hardware devices are unaffordable for control and automation laboratories Similar setups of the proposed applications value approximately $5,000, in contrast to the proposed setups worthy of $600. An evaluation copy of the selected software, Lookout, has been used in the study to achieve minimal-cost. As a result, the proposed applications seem a good alternative to commercial ones. In addition,, these applications are suitable for laboratories that cover control, automation, and SCADA applications. Therefore, they can be availabe for the related laboratories of departments of engineering institutions and vocational schools.

In conclusion, before the proposed applications, the students' answers generally were average or negative because they had not used real industrial SCADA applications. Nonetheless, after the proposed applications, almost all the students' feedbacks were affirmative because the proposed applications aroused students' interests for real SCADA systems.

Proposed Modbus-based inverter-controlled motor and Modbus-based PLC were developed in the laboratory of Control and Automation Technology of Ege Technical and Business College at Ege University in Izmir, Turkey. Details of the applications (e.g. Lookout program notes, theoretical and experimental knowledge and applications materials) have been given to students in System Analysis and Design Course, by which students can develop their own sophisticated SCADA/HMI automation systems for their professional life. Possible extensions of the presented work are at three directions, i) one can develop another industrial automation applications which might be modbus-based systems, ii) one can enhance the proposed applications by adding novel features in order to meet some specifications on desired SCADA systems, and iii) one can design the proposed modbus-based applications with microcontrollers to reduce cost.

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