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A WEB-BASED REMOTE LOAD CONTROL SYSTEM FOR INDUSTRIAL/COMMERCIAL CUSTOMERS

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ABSTRACT
In this paper, we present a web-based remote load control (WBRLC) system with automatic meter reading and demand control via programmable logic controllers (PLCs). In order to make a non-web-based PLC become web-controllable, we develop a graphical-control interface and utilize Internet techniques to implement our system. Based on the performance test conducted under the Laboratory environment, the proposed WBRLC architecture is cost-effective and suitable for industrial applications.

KEY WORDS
SCADA, Web-based control system, PLC

1. Introduction

The Internet is now providing a new and increasing important medium for distributing information world wide without time constraint, permitting information to be displayed numerically and graphically on any client platform. This has generated the concept of "Web-Based Remote Control System" to allow end users to access the real-time data and to control the instruments via a web browser. Medida, et al. [1] presented a Supervisory Control and Data Acquisition (SCADA) system on the Internet for Energy Management System (EMS), using Java applets and Java DataBase Connectivity (JDBC) APIs (application programming interfaces) to make SCADA database accessible and available to the Remote Man Machine Interfaces (MMIs) through web browsers. Georges and Aubin [2] presented a PLC-based system for on-line monitoring of power transformer to give access to a Web page where the current performances of the transformer can be monitored. Reference [3] presented a web embedded PLC, that had two key communication functions: embedded HTTP server and Ethernet TCP/IP connectivity, applied to substation automation, enabling the utility enterprise to access to PLC real-time data using standard browser technology. Kikuchi and Kenjo [4] presented a Web-based laboratory for remotely conducting experiments on Stepping Motors. Visual Basic (VB), ActiveX, and HTML were used in their implementation. Microsoft NetMeeting installed in both server and client was used to transmit/receive the live video.

For both utilities and industrial/commercial customers, the load supervisory control and data acquisition (SCADA) system is a critical function to their load management. Without a proper ELSAC system to monitor and control loads, industrial and commercial customers have to pay extra penalty fee for mis-managing their loads. Moreover, improper demand side management causes the increase of system peak load and decrease of spinning reserve, jeopardizing system security and raising the required installed generation capacity. For this reason most electric utilities install their own SCADA systems to fulfill functions of load control, energy management, distribution automation, and automatic meter reading. However, since the cost of building a SCADA system is expensive, most industrial/commercial customers don't have enough capital to build a regular-scale SCADA as the one for utilities. In this paper, a web-based remote load control (WBRLC) system with automatic meter reading and demand control via programmable logic controllers (PLCs) is presented for industrial/commercial customers.

The reason of using PLCs for collecting data and controlling loads is that they provide cheaper cost and superior control functions with respect to remote terminal units (RTUs). Besides, with the technology improvement, PLCs also offer unprecedented flexibility of sequencing and reliable control and have been widely used in most industrial applications [6] and power systems [7]. Especially, with an increasing emphasis on factory automation to cut the cost of production and/or increase product quality, the majority of manufacturing controllers now involves PLCs. However, each type of PLC has its own protocol and most existing PLCs are not equipped with Internet ability. To make a non-web-based PLC web-controllable, our approach is to use VB, ActiveX, HTML, and ASP (Active Server Page) to build graphical control interfaces, and to use ADO, RDS (Remote Data Service) for web database connectivity. The choice of VB, HTML, and ASP gives us simplicity of implementation and makes WBRLC browser independent.

2. System Architecture

WBRLC system is based on the client/server structure. Fig. 1 shows the system architecture for WBRLC. In this system, the server communicates with the PLC directly through RS-232 port; therefore, a program that deals with hardware service process and the connection requests from the clients to communicate with PLC is needed. This increases the design time but gives flexibility to the program for adding new features and the security to control the PLC.

In the system architecture, the non-web-based PLC is used to collect measurements from the digital power meter and to control loads through its output relays. The data transmission between PLC and the server is through RS-232 port. Furthermore, a ladder program for PLC is developed for automatic meter reading.

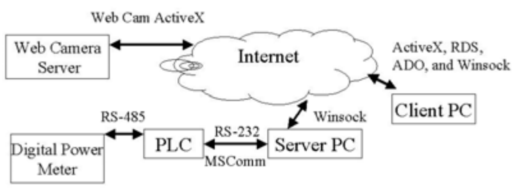

Fig. 1. WBRLC architecture

Since WBRLC system has to provide clients the function to monitor on-line load curves that can be shown on their browsers, the server needs a database management system for these measurements. In our implementation, Microsoft RDS/ADO/ODBC technologies are used for this purpose. The server collects real-time data from the digital power meter through the PLC and saves them into files. To plot the trends of measurements on the client browser, an ActiveX control embedded in the ASP program for the client is developed for reading the latest 100 measurements from files. This will reduce the data transmission time between the server and the client.

The graphical control interface is written in Visual Basic (VB). VB is based on an event-driven programming model and supports a number of features that make it an excellent language for quickly creating full-featured solutions, taking advantage of the graphical user interface in Microsoft Windows. These features include data access, ActiveX technologies, Internet capabilities, rapid application development (RAD), etc. It can also use system-provided APIs or external DLL/OCX to extend its functionality. For instance, we can easily use winsock.ocx (Winsock control) to develop an Active X control in the ASP program that gives the Internet accessibility to the server and the client.

The WBRLC system provides easy access to the user. All the user has to do is to access the WBRLC web site and to start the client window at the press of a button. By clicking the command button icons on the client window, the user can control on/off switches of the loads and view the trends of measurements. The user can also observe the live video of load operations through a web camera that is implemented on the load site.

3. Software Design

Figures 2 and 3 show the software functions for the server and client for the system shown in Fig. 1, respectively. In the server, the database management system is to collect measurements from the digital power meter and then to show them on the client's window. VB uses ADO through ODBC method to access the database on the server side. Fig. 4 shows the ADO relationship with VB, ODBC, and the database [8]. The server program also needs to use MSComm control [9] to monitor/control PLC through RS-232 port.

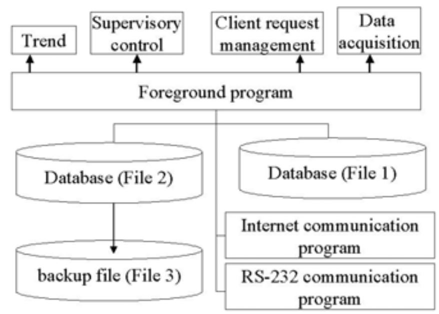

Fig. 2. Software functions of the sever

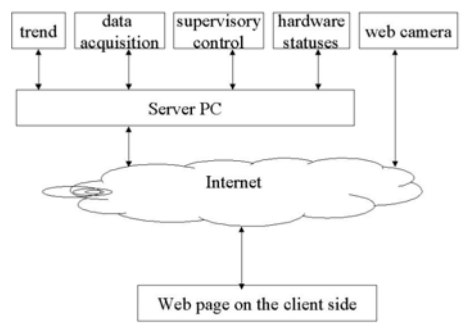

Fig. 3. Software functions of the client

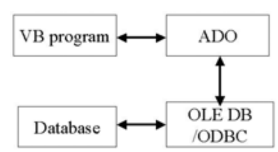

Fig. 4. ADO relationship with VB, ODBC, and database

Fig. 5 shows the relationship among VB, ADO, RDS, and IIS/PWS. The pre-process to establish RDS connection is as follows.

1. Install PWS or IIS. In this paper, PWS is used.
2. Install MDAC version 1.5 or higher version.
3. In PWS, set up a virtual directory for MSADC with the right to execute application program.
4. Open msdfmap.ini file under windows directory and edit the parameters for [connect] and [sql] to define the user's access right to the database.

On the client side, an ActiveX control is developed and embedded in the web page to directly communicate with the server. It needs to perform supervisory controls of hardware and to plot the trends of measurements using RDS. Since ADO only allows the VB program to access the database on the same computer, RDS and IIS (Internet

Information Server)/PWS (Personal Web Server) techniques are needed for the VB program on the client side to access the database on the server side. Through this ActiveX control, the on/off statuses of these DIs/DOs can be monitored and the loads connected to DIs/DOs can also be controlled by the remote client. The visual image of the load operations can even be seen through the ActiveX control of the Web Camera server installed on the load side.

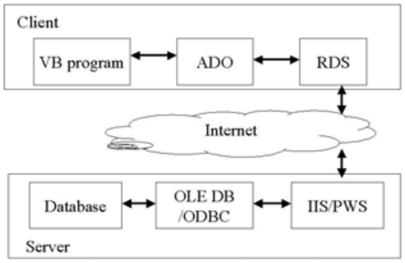

Fig. 5. RDS relationship with ADO, VB, ODBC, and database

4. Implementation and Example

The proposed WBRLC system was implemented in a laboratory environment to demonstrate its performance. In this WBRLC, the following equipment is used:

1. One server PC with Pentium III 550 MHz CPU and 128MB RAM running Windows 98 operating system with PWS installed,
2. One client PC with Pentium III 300 MHz and 64MB RAM running Windows 98 operating system,
3. One non-web-based PLC,
4. Two loads: An electric fan and a lamp,
5. One digital power meter,
6. One web camera server and one CCD.

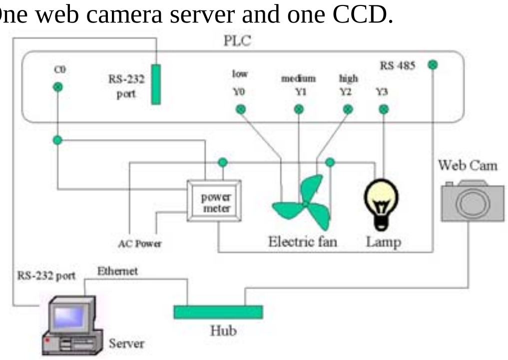

Fig. 6. Connection diagram of WBRLC

Fig. 6 shows the connection diagram of the tested WBRLC system. The loads are controlled by 4 DOs of PLC: one DO (Y3) for controlling the on/off switch of the lamp, the other three DOs (Y2, Y1, and Y0) for controlling high/medium/low speeds of the electric fan. The control commands for these DIs/DOs are sent by the server through MSComm.ocx. A digital power meter is also connected to the loads to measure voltage, current, real/reactive power and some other electrical data. These measurements are then transmitted and stored in the registers of the PLC. A PLC ladder program was designed to automatically read these data into the PLC from the digital power meter. The server then reads in these data from the PLC using MSComm control.

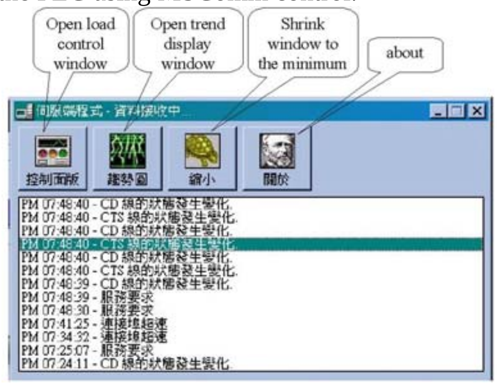

Fig. 7. Main interface of the server program

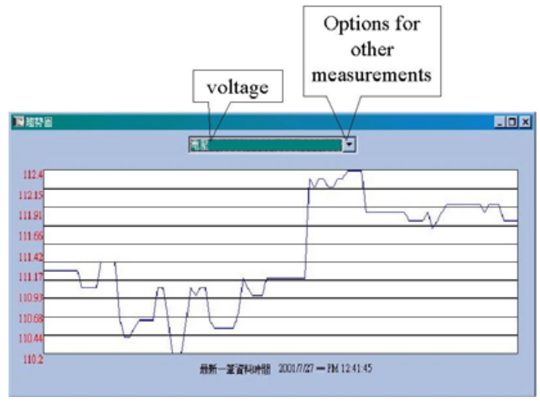

Fig. 8. Trend display window

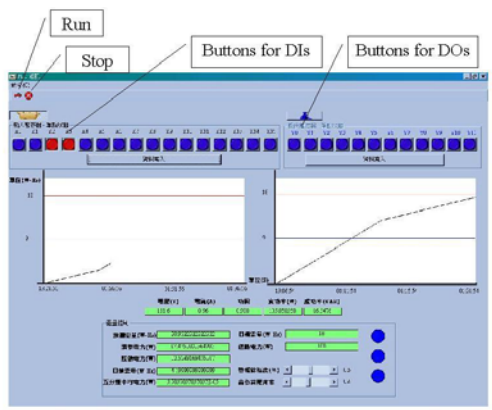

Fig. 9. Load control window

Fig. 10. Web page seen by the client

Fig. 7 shows the main interface of the server program. This interface can process the connection and service requests of the client, display the statuses of these requests, and open trend display windows and the load control window. Fig. 8 shows one of the trend display window in which the voltage curve is plotted. Fig. 9 shows the load control window. In the top portion of Fig. 9 the statuses of DIs/DOs of the PLC are monitored by the color of their button icons. The DIs/DOs can further be controlled by clicking these buttons. Two demand curves are also plotted in Fig. 9: the one on the left side showing the current demand curve with demand interval of 15 minutes and the one on the right side showing the last 15-minute demand curve. In the bottom portion of Fig. 9, the measurements from the digital power meter are displayed and some other parameters are calculated for demand control purpose. Preventive load shedding actions are implemented to avoid demand contract violation. There are also two icons (run and stop) at the top left corner of Fig. 9 to run and stop PLC. Fig. 10 shows the web page seen by the client when it logins the web site of the server. There are five buttons in this web page: one to turn on or turn off of the lamp, one to turn off the electric fan, and the other three to control the speed (high/medium/low) of the electric fan. There is a live video embedded in this web page to watch the load operations. There are also two links to plot trend displays for voltage and current. Figures 11 shows the trend displays for voltage. The live video image captured in the Fig. 10 shows that the lamp is on and the electric fan is off. If the client clicks the high-speed button, the electric fan starts running with high speed as seen in Fig. 12.

5. Conclusions

In this paper, a web-based remote load control (WBRLC) system with automatic meter reading and demand control via programmable logic controllers (PLCs) has been presented. The presented system integrates VB programs, ActiveX controls, HTML, ADO, RDS, and ASP to provide graphical control interfaces to the client with the ability to monitor/control loads remotely through the Internet. The presented system is simple and easy to implement and is flexible for adding new functionalities. With the increasing use of PLCs in industrial automation, this PLC-based WBRLC can be easily implemented for the load management in industrial/commercial customers.

Fig. 11. Trend display for voltage

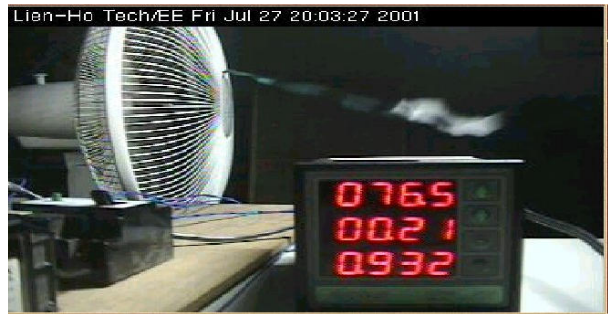

Fig. 12. Live video: the lamp is on and the fan is running (high speed)

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References:

[1] Srinivas Medida, N Sreekumar, Kishna V Prasad, SACDA-EMS on the Internet, *Proc. of the international conference on Energy Management and Power Delivery*, Vol. 2, 1998, pp. 656-660

[2] Bruno Georges and Jacques Aubin, Application of PLC for on-line Monitoring of Power Transformers, *IEEE PES Winter Meeting*, Vol. 2, 2001, pp. 483-486

[3] Schneider Electric, Web Embedded PLC Applications in Substations, #40293318, *IEEE PES Winter Meeting*, Vol. 2, 2001, pp. 487-488

[4] T. Kikuchi and T. Kenjo, Distance Learning Applied to a Small Motor Laboratory—Insight into the Stepping Motor, *IEEE International Conference on Systems, Man, and Cybernetics*, Vol. 2, 1999, pp. 259-264

[5] H. Shen, Z. Xu, B. Dalager, V. Kristiansen, O. Strom, M.S. Shur, T.A. Fjeldly, J.-Q. Lu, and T. Ytterdal, Conducting Laboratory Experiments over the Internet, *IEEE Transactions on Education*, 42(2), 1999, 180-185

[6] M.C. Zhou and E. Twiss, Design of Industrial Automated Systems via Relay Ladder Logic Programming and Petri nets, *IEEE Transactions on Systems, Man, and Cybernetics, Part C,* 28(1), 1998, 137-150

[7] R. Roman and R. Wilson, Commercial Demand Side Management Using a Programmable Logic Controller, *IEEE Transactions on Power Systems*, 10(1), 1995, 376-379

[8] K.J. Wang, *Visual Basic 6.0 Database Design*, (Chi-Biaw Book Company, 1999)

[9] M.F. Russo and M.M. Echols, *Automating Science and Engineering Laboratories with Visual Basic* (John Wiley & Sons, Inc., 1999)