A Web-based Lab for Distance Learning

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Abstract

This paper details a Web-based lab framework for supporting distance-learning courses. The architecture and implementation of a Web-based lab focusing on remote data acquisition and measurement, and industrial control and automation applications are illustrated. Laboratory experiments developed for a Web-based lab are outlined. Implementation of a remote AC motor control lab is also described.

I. Introduction

Many on-line software development systems such as WebCT, Blackboard, etc., are used by distance education instructors to develop and deploy non-technical courses. These software systems normally integrate such desired functions as design of presentation of the course, educational tools to facilitate learning, communication and collaboration page design, and administrative tools to assist the process of management and continuing improvement of the course. However, technological realities and lab hardware requirements/constraints of these software systems present challenges to educators who want to develop online technical courses in the fields of engineering or engineering technology with laboratory activities.

When the Department of Electrical and Computer Engineering Technology (ECET) decided to offer a Web-based Lab, which includes Web-based laboratories in electrical, electronics, measurement, and control for distance learning courses in 2000, we knew that we faced a serious design challenge and expected the following benefits [1]:

- Greater Scheduling Flexibility: with the availability of a Web-based Lab via the Internet, a technical course with lab activities would be available for students to access 24-hours a day, anywhere in the world.
- Cost Effective: this delivery method is cost effective for offering technical courses with a lab component, because it requires only one set of equipment while traditional labs require multiple sets of the same equipment.

- Broader Audiences: it not only assists students who need flexible schedules but also allows us to reach out to audiences that are looking for high-tech courses for their professional development or continuing education.
- Future Expansion: experience of developing Web-based Lab will enable us to convert the labs of many of our courses such as Introduction to Data Communications, and Introduction to Control Systems to asynchronous delivery.

This paper presents Internet and Web technologies needed for developing a Web-based Lab and summarizes the project experience that supports our distance learning courses. This paper is organized as follows: section II explores Web-based Lab system design issues, section III describes implementation and maintenance of the Web-based Lab system, and section IV provides some laboratory examples of a Web-based Lab.

II. Web-based Lab System Design

To gather the system requirements, the first question asked was what kind of laboratory experiments would this Web-based Lab support. We identified the following desired lab activities:
- Understanding of Web Server and Internet I/O Control
- Internet-Based I/O Monitoring with Visual Basic (optical Sensors, solenoids, etc)
- Using Visual Basic and legacy I/O modules for Web-Based Control Applications
- Visual C++ Programming for Internet Control Applications
- AC Motor On/Off Control through the Web
- AC Motor Control and Monitoring Using Visual Basic (temperature, motor voltage and current measurement, over load + time delay protection, and motor on/off control)
- Sequence Control
- Internet-Enabled Digital Multimeter Reading
- Web-Based Building Environment Monitoring (temperature, moisture, CO content, light)

Web-based Lab System Architecture. The desired Web-based Lab system is strongly focused on interactions between end-users the sensors, actuators, control and measurement systems located at the lowest end of the system. Figure 1 shows our Web-based Lab system architecture including the following features to enable collaboration among various legacy subsystems (both software and hardware):
- Open network communication (Ethernet and TCP/IP)
- Supporting distributed measurement and control application development
- Rapid system development that supports related technologies and legacy components (for example, an RS232 enabled digital multimeter, an Opto22 Web server, analog and digital I/Os, and legacy software
- Visual feedback through a Web camera
- Supporting a Web browser client, and other Web clients (Java Servlet, applets, Java RMI, Visual Basic clients, Visual C++ clients, etc).
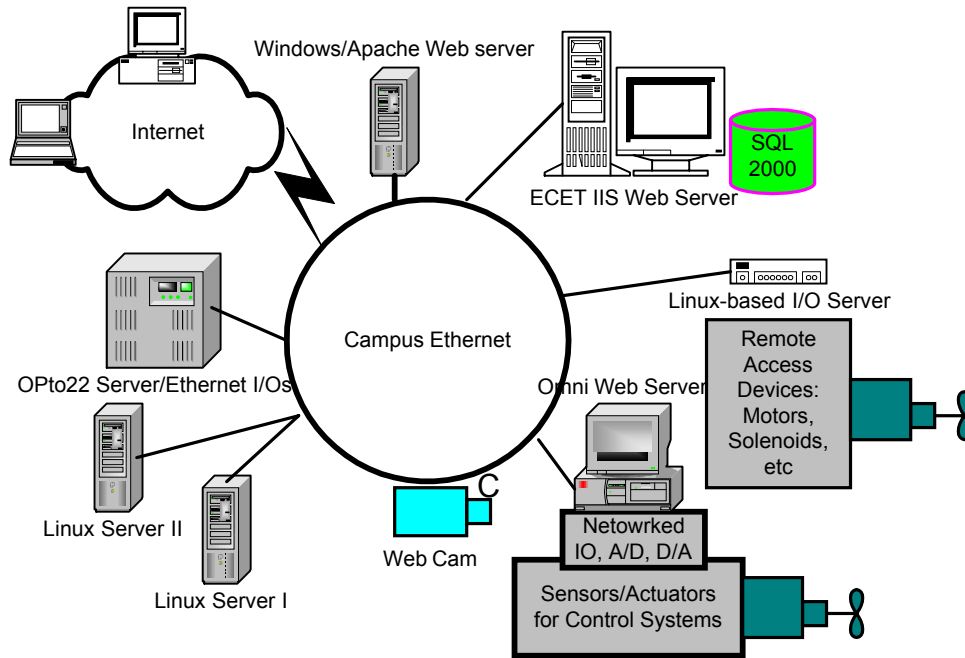
Figure 1. Web-based Lab System Architecture

III. Implementation

Web Server Configuration. The implementation of a Web-based Lab system is more than just writing Web pages, server-side CGI programs, it started from building a Web server, specifying hardware, building and testing lab circuits and control software. Configuring a Web server for publishing HTML documents is a major step in implementing a Web-based Lab. Figure 2 shows main directories of the Web-based Lab's main Web server. All HTML files located in C:\httpd\Htdocs are accessible to the outside world. The homepage of a server is normally named index.html, default.html, or welcome.html. To ensure the secured Web access, all lab users are authenticated through a login CGI program called protect.pl, which is located at C:\Httpd\Cgi-Bin. The protect.pl also generates a dynamic page, which allows all users to access the lab assignment pages. All lab files can be opened using Microsoft Notepad text editor or Interdev. Pictures of lab equipment and circuit diagrams are taken and saved in JPG or Gif file format for use with the Web page, and are located at C:\httpd\HtDocs\Picture\. Errorlog.dat is a file containing information about problems that occur during user logins. The login.dat file contains and accumulates user login information. The pwd.dat is a text file which includes password and login time/date information in the following format:

```
# This is the password file.
#====================================================================
# The format is:
#UserGroup::Username::password::LastDate::DayIn::TimeCheckIn::TimeCheckOut::/root
```

```
#
#Time format is: 10 to 11 in this file means 9 to 11 on real time
#              12 to 13 in this file means 11:00 A.M to 13:00 P.M
#=================================================================
```
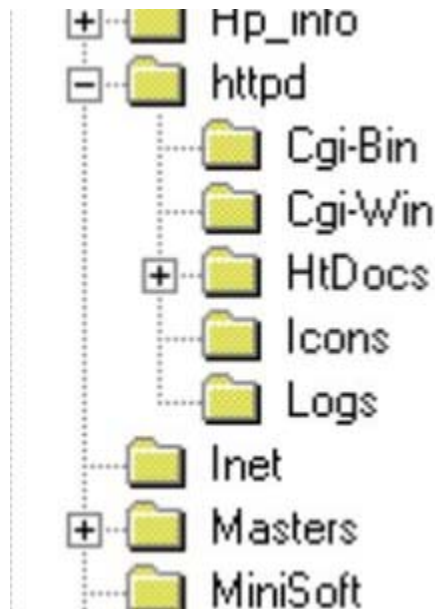

Figure 2. Directories of Main Server of the Web-based Lab

Multiple Web Servers. To increase the reliability and be able to support various Web-based Lab activities, multiple Web servers may be needed. The Web server software used in our Web-based Lab includes Apache server, Microsoft Internet Information server, and IBM WebSphere application server. Some Web servers were designed to use CGI programs (Perl, Visual Basic, and Visual C++) as external gateway interface programs to interface to databases, digital and analog I/Os. Other legacy Web servers with digital and analog I/Os are also connected to the Web-based Lab system. Apache servers are setup to work with Tomcat Servlet Engine, Java Servlet, and JSP for experimentation with Java technology. A Web-based Lab user can indirectly access the system through the course Web page or through the network diagram page as shown in Figure 3.
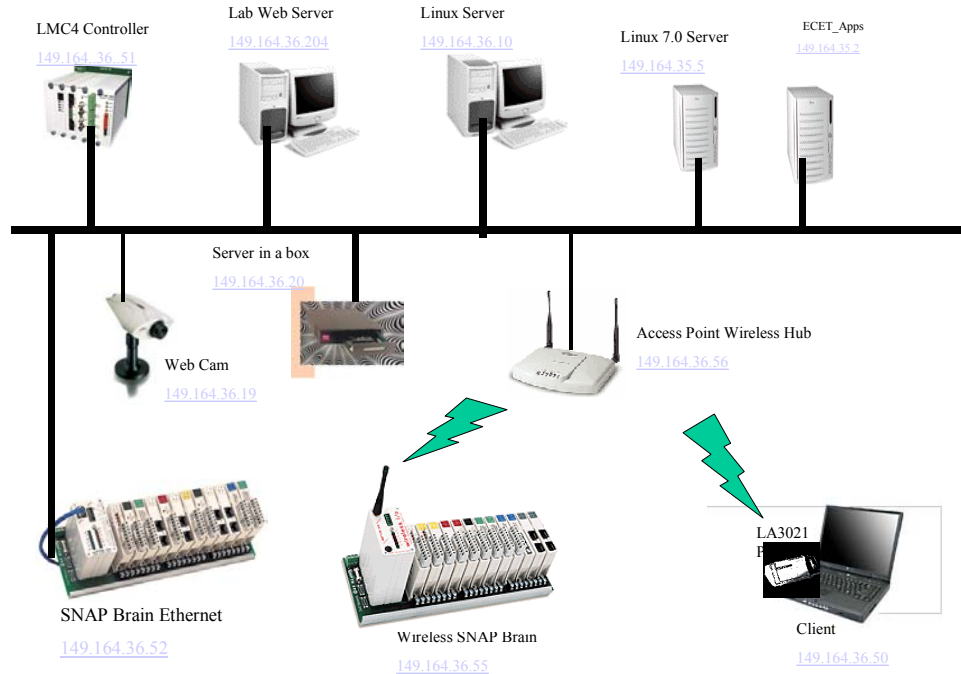
LMC4 Controller
149.164.36.51

Lab Web Server
149.164.36.204

Linux Server
149.164.36.10

Linux 7.0 Server
149.164.35.5

ECET_Apps
149.164.35.2

Server in a box
149.164.36.20

Web Cam
149.164.36.19

Access Point Wireless Hub
149.164.36.56

SNAP Brain Ethernet
149.164.36.52

Wireless SNAP Brain
149.164.36.55

LA3021

Client
149.164.36.50

Figure 3. Web-based Lab System Network Diagram Page

Integrated Software Strategies.
To support reuse and rapid development, we included existing Visual Basic and Visual C++
interfacing programs for interfacing to serial ports, parallel ports, and digital I/Os and
existing application programs for running RS232-based digital multi-meter and data
acquisition cards. These stand-alone programs can be converted to CGI (common gateway
interface) programs for remote access with minimum effort. Because of the low-level I/O
control requirement, we use CGI instead of Java for measurement control applications. A list
of programming languages used to develop applications and labs for our Web-based Lab is
[2]-[10]:

- HTML - for Web pages
- JavaScript - used in the client-side page for making dynamic pages, and performing
  some client side computations
- Perl - for writing server-side scripts to access and process login files, data files, and
  databases
- Visual Basic - for writing thick client applications and server-side CGI applications
- Visual C++ - for writing thick client applications and server-side CGI applications

In addition, other popular server-side programming tools such as ASP, JSP, Java Servlet, and
Visual Basic.NET, which can be found in [10]-[12], are also used to support some lab
activities.

Electrical/Electronics Hardware for Web-based Lab. The architecture of the Internet-
Based Monitoring and Controls for HVAC Applications [14] was slightly modified and used
as a reference for Web-based Lab development. As shown in Figure 4, major

hardware/software modules including sensors, I/Os, data acquisition, signal conditioning, modules and software CGI program are pre-configured and can be accessed through prewritten Web pages and CGI programs.
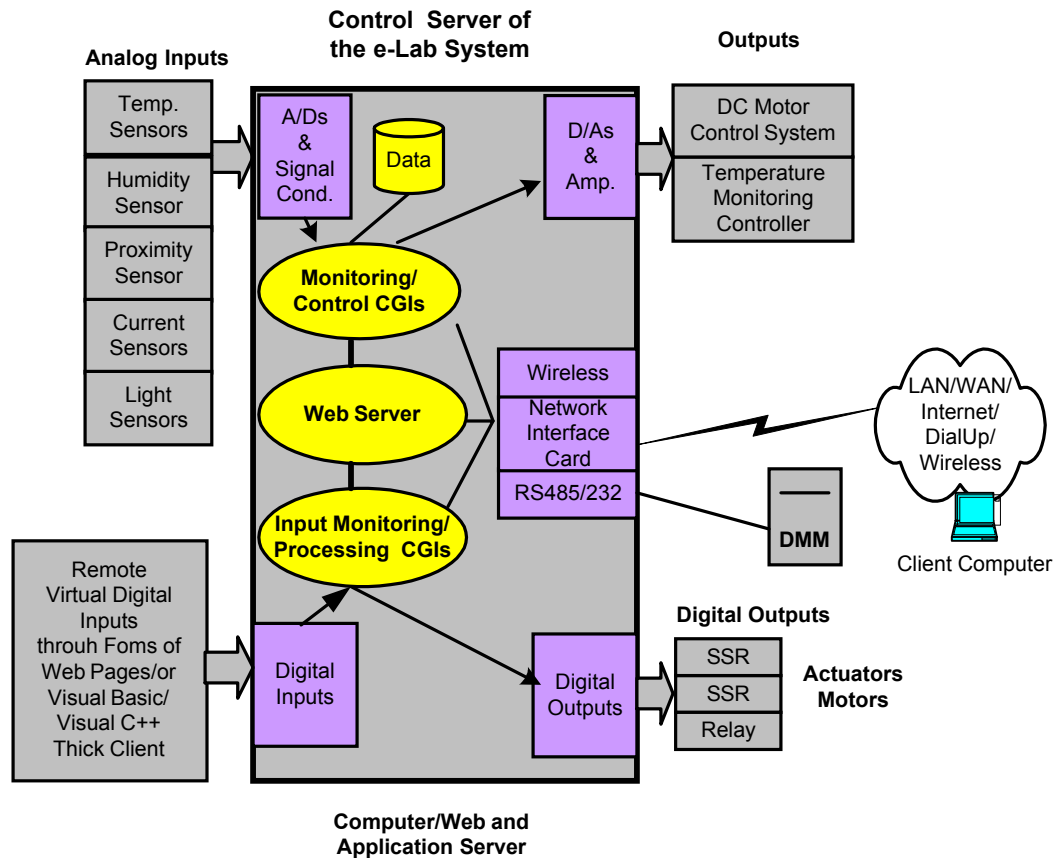

Figure 4. Control Server of the Web-based Lab

Web-based Lab Access Processing. The login page (homepage1.shtml), as shown in Figure 5, was designed to authenticate users for using a Web-based Lab. Login as Professor is granted to access the system without date and time restriction. Students are asked to reserve their time slots through the schedule link on this page before they can access the Web-based Lab. When a user clicks on the Web Cam on the login page, it displays the camera Web page, as shown in Figure 6 which includes a light ON/OFF control option so that any user can view the lab setups even when the ceiling light of the lab room is off.
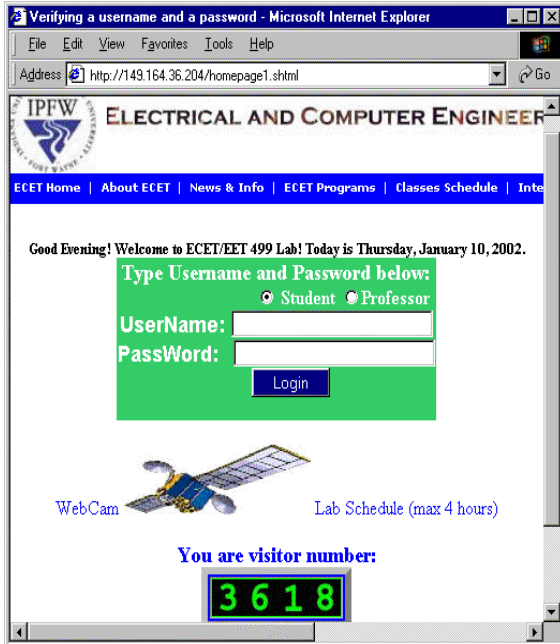
Figure 5. Login Page for Web-based Lab Looking

Figure 6. A Snap Shot of Web Cam at the Lab Equipment

The main page of the Web-based Lab including the laboratory assignment page is as shown in Figure 7. This HTML page is design to include the following features:

- Links to all available lab assignment pages
- Links to show graphic diagrams of circuits and equipment that relate to each lab
- Links for users to invoke CGI programs to exercise control and measurement systems.
- Upload links for students to turn in their homework assignments
- File/program download links
- A secured homework, lab, and test grades display page for instructors and students
- Access to the Web-based Lab Web camera and other useful links
- e-Mail links for students to communicate with the instructor

We devoted one and half persons working full-time for 2 months during the summer 2000 on initial design of hardware/software and laboratories, followed by one semester to fine tune laboratory experiments.
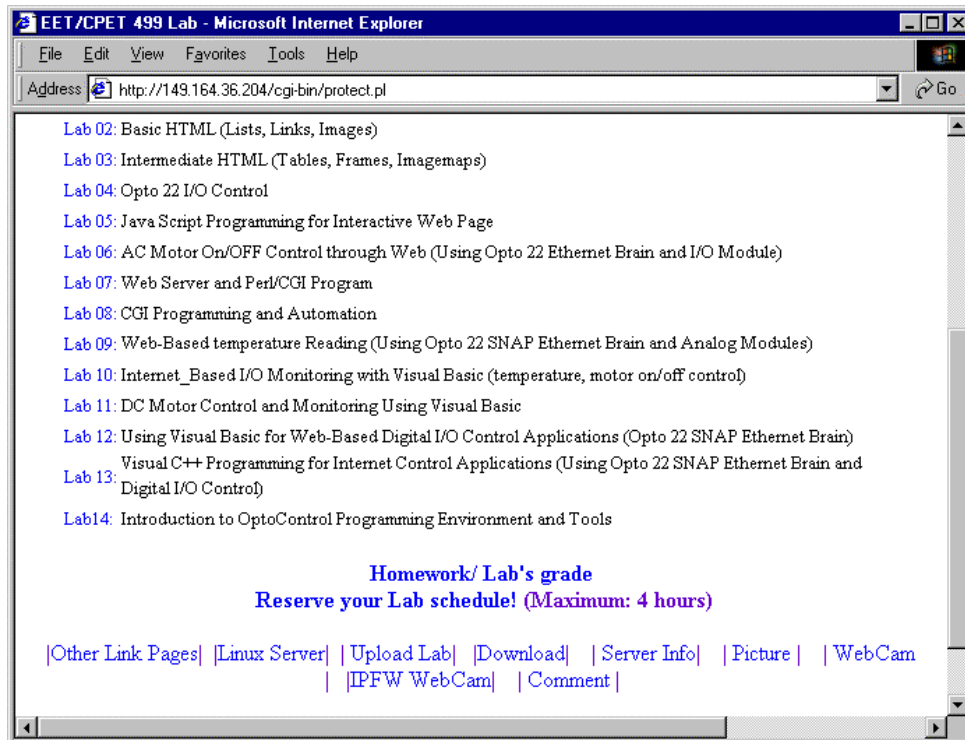
Figure 7. Web-based Lab Assignment Page

IV. A Laboratory Example

In this section, we describe two laboratory experiments: an AC motor control application, and a Web-based temperature measurement. Each lab is associated with a lab assignment page, which includes the following information:

- Lab title
- Introduction to the lab
- Equipment with links for showing pictures
- Links to CGI programs for interacting with hardware systems
- A procedure with a description and link for user interaction
- Questions
- Other appropriate links to additional information, circuit diagrams, and supplementary Web sites.

AC Motor On/Off Control. This lab illustrates how to create a customized Web page using the SNAP Brain Ethernet to interact with an AC motor control circuit. We can turn the motor On/Off using built-in CGI programs of Opto22 SNAP Brain Ethernet Web server and its digital I/Os. Since the SNAP Brain Ethernet has a limited memory space, it is necessary to use a regular editor to create raw HTML code to create control Web pages for uploading to the SNAP Web server. After creating this HTML control page, the file can be uploaded to the SNAP Web server for testing. Again, we pre-configured the AC motor on/off control circuit and also prepared the schematic diagram in a JPG format as shown Figure 8 for viewing

through the hypertext link in the lab page, as shown in Figure 9. The lab page includes all necessary links to run CGI-programs that turn motor on and off.
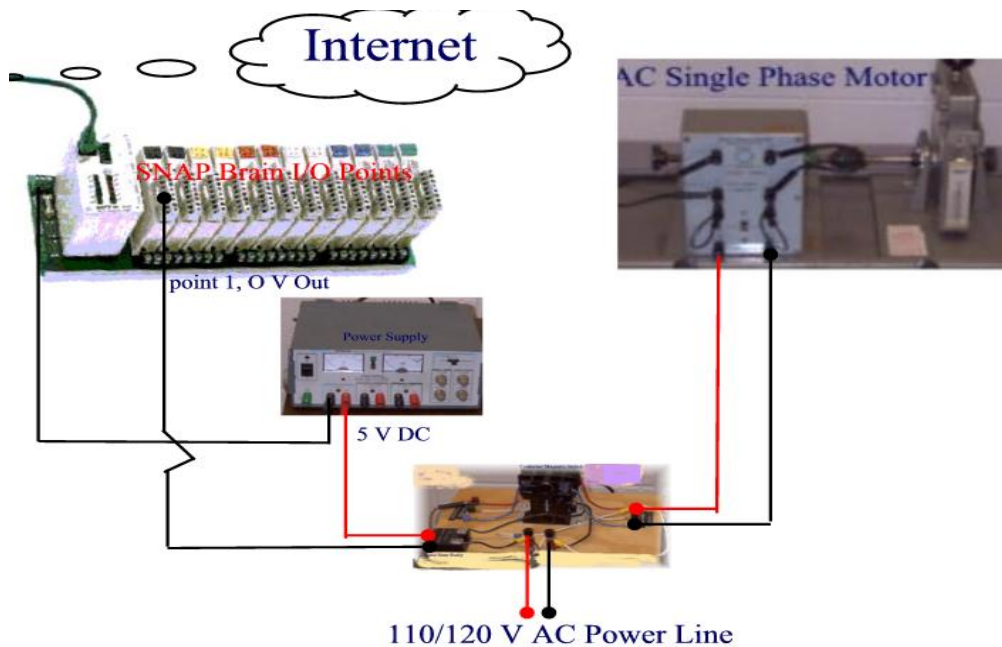

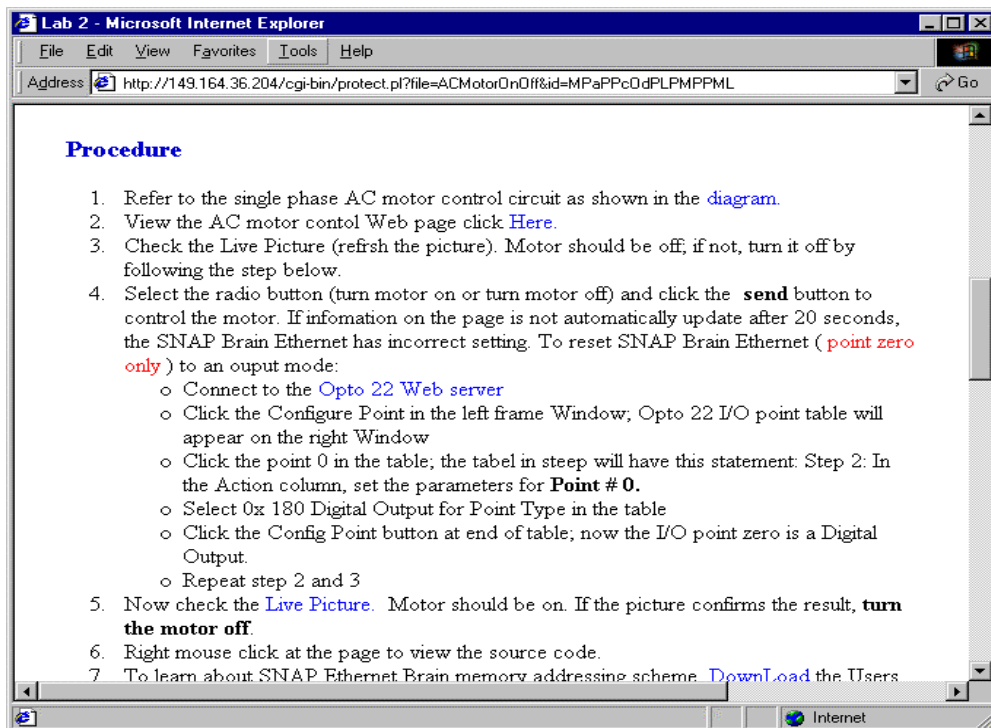Figure 8. Diagram of the AC Motor On/Off Control Lab

Figure 9. Lab Page for AC Motor On/off Control

V. Summary

An Web-based Lab system, consisting of multiple Web servers, legacy Web servers, I/O, hardware and sensor modules was designed and used to support the distance learning course entitled Web Programming for Industrial Applications for the past three semesters. This Web-based Lab provided students with an opportunity to acquire new knowledge that might help their careers and prepare students for jobs in challenging areas of the Internet, computer networking, Web programming, and industrial control and automation. Students were able to learn Web control technologies and complete projects in their areas of interest. Some student projects were:

- Web Enabled Factory Ventilation Control
- The Internet Counter Controller
- Web Database Access using Java Servlet (one ECET student and three CS students)
- Industrial Control Applications Using the Opto22 Factory Floor
- Home Security System (remote monitoring and control) using Ethernet I/O and Programmable Logic Controller
- Device and Appliance Control Over the Internet
- ASP Database Application: Data Time Clock
- Website Interface Controller and Database
- A Web Enabled Intelligent Traffic Monitoring System (civil engineering graduate students)

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Biographies

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Paul is Associate Professor and Chair of the Electrical and Computer Engineering Technology, at Indiana University - Purdue University Fort Wayne. He has been with Purdue University since 1985 and is a registered Professional Engineer (EE) in California and Indiana. Prior to joining IPFW, he taught in the Engineering and Technology Department of Dutchess Community College (NY) for three years; in the Electrical Engineering Department of National Taipei Institute of Technology for two years; and worked in industry for 8 years. He was a Visiting Associate Professor in the Electrical Engineering Department of National Taipei Institute of Technology, from January-July 1995, and the Conference Vice-Chair of the 1995 IEEE International Conference on Industrial Automation and Control at Taipei. He is a senior member of IEEE and was the Chairman of the Manufacturing System Development and Application Department of IEEE-Industry

Applications Society from January 1998 to December 1999. Lin's current interests include Web engineering, distributed intelligent control of embedded real-time systems, and sensors in industrial control applications.

HAROLD BROBERG
Hal taught EE for 3 years at the U.S. Naval Academy and, after retirement from the Marine Corps as a Lieutenant Colonel, chose to continue teaching. He received his PE license in Indiana in 1988 and his PhD in Engineering (EE) in 1993. His research area is servo systems and he has consulted and worked for ITT (Aerospace-Communications) on weather satellite servos for the past 10 years. He is currently an Associate Professor of EET and Interim Associate Dean of the school of Engineering, Technology, and Computer Science at Indiana Purdue University Fort Wayne, IN, a senior member of IEEE, and a program evaluator for IEEE with twelve TAC/ABET accreditation visits completed.

AIK MON
Aik Mon received his B.S. in Electrical Engineering Technology from Purdue University, Fort Wayne Campus. He is a Systems Engineer at GE Industrial Systems, Fort Wayne. His main responsibility is to maintain and support TIES (Transformer Integrated Engineering System) for designing new products, providing bill of materials, and estimating the cost of the product. He also serves as a database administrator, a Web developer, a Visual Basic developer, and a database front-end and back-end developer.