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PLC based Lab Automation

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***Abstract*--- Applying ever growing technological advancements in the automation sector to the education systems and with the intent to make the laboratories smarter and perform experiments in favorable conditions, an idea of PLC based Lab Automation was proposed. This paper represents the implementation of different modes as per the user's convenience. Special features of this design ensure the control of the presentation environment when the projector is in use and monitoring the availability of computers while entering the room. In this project, the aim is to have control over the electronic and electrical appliances as per the user's convenience either automatically by interfacing sensors with PLC or manually by human inputs. This is achieved with the help of an emerging communication protocol OPC Unified Architecture (OPC UA) in different ways mainly focusing on Client-Server application UaExpert and Android app Prosys. The main motive behind implementing this plan is to foster a better teaching-learning environment, save time and reduce human effort.**

***Index Terms*— Client-Server, Lab Automation, OPC-UA, PLC, PROSYS, UaExpert**

I. INTRODUCTION

Automation has seen rapid growth over recent years, with its increasing necessity in the industrial sector considering it not only reduces errors by minimizing manual interventions but also improves the safety, productivity and ensures optimum use of resources. Today, Programmable Logic Controller (PLC) is identified as one of the major revolutions in the automation sector contributing to the upgradation of conventional industrial processes. PLC is a versatile control unit due to its ability to be reprogrammed with user friendly programmable languages such as Ladder logic, structured text and many more to meet the changing needs of production and its diversity in the different sectors. Due to its robust nature, it is specifically designed to meet the needs of harsh environmental conditions in industries. Over the decades PLCs have expanded their networks by adapting to a variety of communication protocols and increased compatibility with peripherals. Contributing to the already existing applications and making the most out of the advancements for the education sector, the project of lab automation was proposed. This design mainly focuses on troubleshooting the problem of unnecessary energy consumption when it is not demanded and by dedicating our time solely for the lab activities. PLC and HMI along with other interfaced peripherals ensure the necessary control action for the system.

II. OVERVIEW

The proposed project is centered around a B&R X20-PLC module integrated with HMI that will control the electrical and electronic appliances. The tasks were to control the lamps and fans in the room, indicate the availability of computers and create a suitable environment for presentation when the projector is turned on. The complete system was categorized into 2 main modes of operation namely Automatic and Manual mode.

A] Automatic Mode:

Automatic mode is a mode where the software fully controls all appliances of the project. An ideal lab with lamps, fans, projector and a few PCs was considered. To automate these, a few sensors like proximity, LDR and temperature were used. The IR sensors are common to lamps and fans that is if any motion/presence is detected only then will the further instruction be executed. If the certain threshold value is detected for the sensors that is brightness in case of LDR and temperature for temp sensors then will the lamps and fans be actuated accordingly. These appliances will be actuated automatically till the user wants to switch to Manual mode which can be chosen on HMI.

B] Manual Mode:

In Manual mode, the user can operate fans and lamps by giving inputs from HMI and various communication platforms like UaExpert and Prosys. The UaExpert is a client-server application based on OPC-UA communication protocol and Prosys is an android application. HMI is also used as a display device wherein the indication of actuated appliances can be observed.

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C] PC Occupancy:

One of the special features of the project, PC Occupancy mode is for indication of availability of computers in the lab. IR proximity sensors placed under the computer desk will detect the presence of a person sitting there. Following the detection of the sensor, the timer of 10 seconds will turn on after which the status of the PC will be indicated as occupied on the HMI screen. If the person leaves the desk then the status will be updated to unoccupied after 10 seconds.

The Projector mode is intended for creating the environment suitable for presentation in the room irrespective of modes when the projector is turned on. This feature can be chosen from the option provided on HMI.

III. HARDWARE LAYOUT

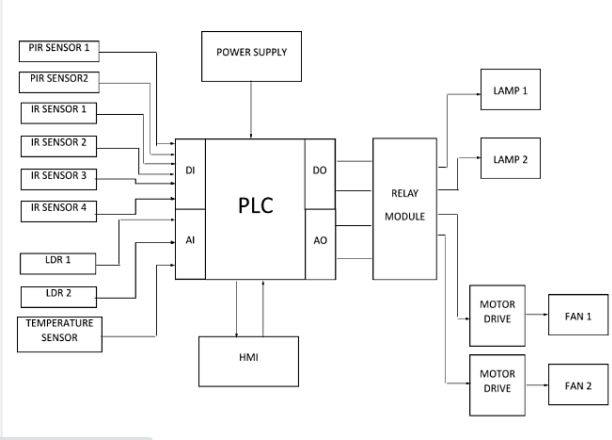

Fig 1. Block Diagram

The block diagram describes the ideal interconnection between the inputs, outputs and the controlling unit. HMI is designed for selection of a mode as per user's choice. The certain analog and digital inputs of PLC are connected to the sensors with specifications of sensing the intensity of brightness, motion detection and temperature parameters needed for specific modes of operation. Similarly, the digital and analog outputs of PLC are connected to Relays to further actuate the fans and lamps through drivers.

i. PROGRAMMABLE LOGIC CONTROLLER(PLC)

PLC is a main control unit having 12 digital inputs/outputs, 2 Analog inputs/outputs, X20CP0482 CPU, memory and several other function blocks that control the entire system. Its operating voltage is 24VDC.

The CPU has following specifications

- ARM Cortex A9-300 processor
- 128 MB RAM
- 1 GB built-in flash drive.

Sequential Function Chart, Function Block Diagrams, Ladder logic, Structure Text, Instruction list are the widely adopted programming languages for PLC.

The notable communication protocols used for automating the processes with plc are Modbus, Ethernet, RS-232, CAN bus, OPC-UA

ii. HUMAN MACHINE INTERFACE (HMI)

A Human Machine Interface is a user dashboard that acts as a bridge between a person and the system or device. HMI enables two-way communication that allows not only to observe the changes in the system but also to have control over it. The screen resolution used for this specific hardware is 1024*620. One of the main purposes of the dashboard in this design is to switch between the main modes of operation. Each mode has a dedicated page on the HMI screen used for monitoring the instantaneous changes in the system.

iii. MOTION DETECTOR

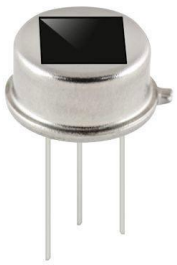

Fig.2 Passive infra-red sensor

These small and inexpensive sensors are used to detect the motion of a person in its range of sensing. They make use of their sensitivity to the passive infrared radiation for detection. It converts incoming change in IR radiations into the corresponding digital output levels 0 or 1. Considering this project design, in the presence of a person as detected by the sensor, based on the signals given by the LDR and temperature sensor, lights and fans will be actuated, respectively.

iv. PROXIMITY SENSOR

Fig.3 Infrared sensor

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An infrared sensor is a device that emits infrared rays to detect any object in its surroundings. It keeps emitting rays and if it doesn't get back the amount reflected, an obstacle is detected. Here, IR sensors are used to detect a person in front of the computers. As an output of this, availability of PC's is indicated on the HMI screen outside the lab. This feature is especially beneficial during exams when there is a need for PC's and shortage of time

v. LIGHT DETECTOR

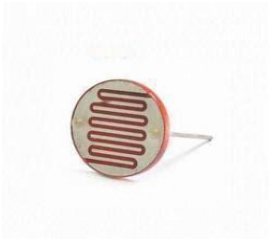

Fig.4 LIGHT DEPENDENT RESISTOR (LDR)

Light Dependent Resistors (LDRs) are light sensitive devices which when subjected to intense light give smaller resistance and in the absence of light have larger resistance i.e. the value of resistance across its terminals varies with brightness. LDR's are installed at particular spots in the room. According to the output received from the sensors the lamps in that part of the room would be triggered, improving the ambience of the room and conserving energy.

vi. ROOM TEMPERATURE SENSOR

Fig.5. RESISTANCE TEMPERATURE DETECTOR

Resistance Temperature Detector (RTD) is a device used for sensing the temperature, following the principle that change in the temperature causes a linear change in resistance. In this project the RTD will sense the room temperature and send the output to the PLC which will in turn control the operation of the fan.

IV. SOFTWARE

A] AUTOMATION STUDIO

This software enables the users in logic building, modeling and simulation. This is principally used for ladder programming where the attributes of the ladder logic are associated with particular tasks and the in those values can be monitored at the backend changes. The distinctive feature of this prototype is that it is programmed in such a way that the ladder logic itself serves the purpose of continuous monitoring and further controlling process. Automation Studio and VNC viewer together were used for HMI designing. The particular variables were assigned in the ladder program to represent the elements in the HMI visualization and change in the values of variables will change the occurrence of events accordingly.

- LADDER LOGIC

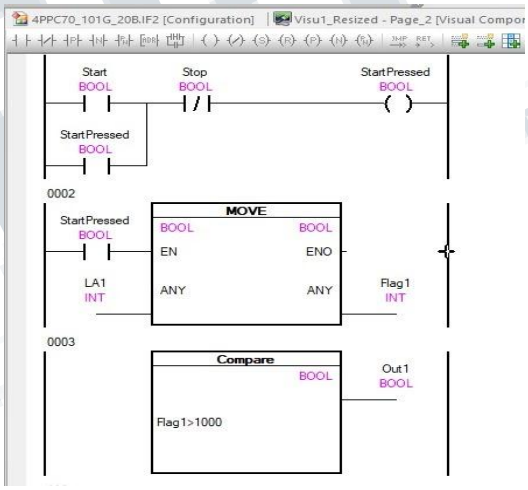

Fig.6(a) Ladder Logic

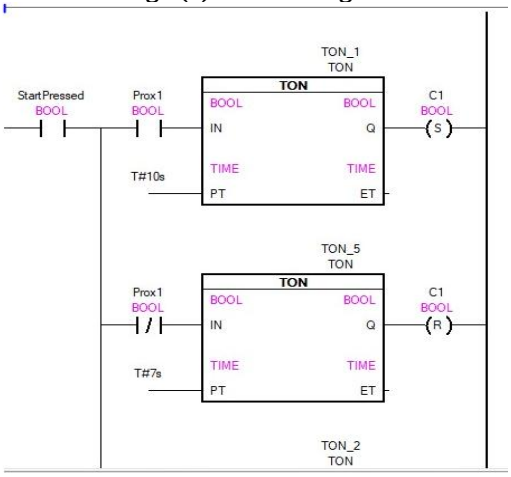

Fig.6(b) Ladder Logic

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Ladder logic is one of the predominant methods for programming PLC's. Individual program units forming circuits are connected to the two power rails also referred as rungs on either side of program space. Such series small circuits or racks horizontally connected between two rails build up the entire program to be loaded into the program memory of PLC. NO/NC contacts and output coils are core elements in this programming method. Timer/counter, comparator blocks also serve as vital elements that allow the system to perform timing and comparison operation respectively. It becomes very easy to read and track the flow of connected components to analyze the entire program. Compute blocks performing arithmetic and logical operations and programmable function blocks add extra value that makes the ladder logic a possible option to operate almost any kind of industrial machine.

B] PROSYS

It is an application that helps to harness maximum benefits of the OPC UA technology. The system can be controlled by changing the variable values on mobile through Prosys app by connecting it on the same Wi-Fi network to which PLC is connected. Variables used for the working of the device must be assigned on the software.

C] UaExpert

The UaExpert is a OPC UA client which shows various features of OPC UA technology. It provides another platform for remote operation of the system. In this software when connected to the server, the user can change as well as observe the values of variables assigned in the ladder program. With the help of this, the lamps and fans can be controlled without accessing the hardware and the simulation software.

D] VNC VIEWER

Virtual Network Computing (VNC) protocol is used in RealVNC client-server-based software. By connecting to the VNC server, one computer (client) can control a program running in another computer (server) remotely. B&R VNC viewer provides an easy interface to the VNC Server running on another computer for remote operation. In this project, it was used particularly for HMI designing. By connecting to the server, it was easy to monitor the changes made in programming on the computer acting as a virtual HMI.

V. HMI NAVIGATION

Fig.7 HOME PAGE

Fig.8 MANUAL MODE

Fig 7 is the home page that displays options for navigation to the respective pages of different modes of operation. The button at top right position is used to toggle between two primary modes of the system.

Fig 8 represents the manual mode page. The lamps and fans are actuated with the help of the assigned switches. The picture of a lab also shows the status of actuated lamps in the room to make it look more presentable. The button situated at the top left corner shows the option to switch to the projector mode after which the lamps in the room will be turned off automatically.

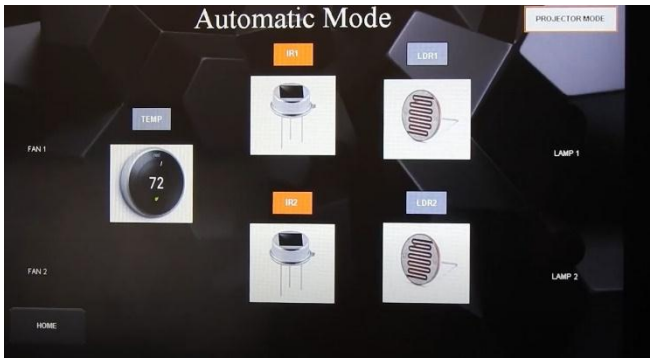

Fig.9 AUTOMATIC MODE

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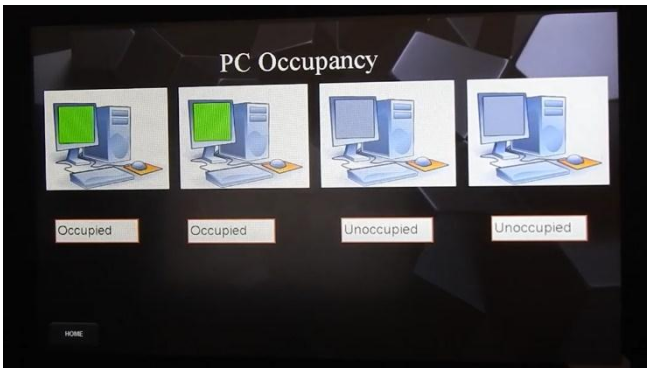

Fig.10 PC OCCUPANCY

Fig 9 represents the manual mode page. The lamps and fans are actuated with the help of the assigned switches. The picture of a lab also shows the status of actuated lamps in the room to make it look more presentable. The button situated at the top left corner shows the option to switch to the projector mode after which the lamps in the room will be turned off automatically.

Fig10 This page indicates the status of availability of computers in the lab.

The animation of the PC's shows two conditions-

- The green color with status as occupied shows that the PC is already engaged.
- Grey color with status as unoccupied indicates that the PC is available to use

VI. FUTURE SCOPE

- Attendance monitoring: Considering the amount of time devoted to keep a track of attendance, a scan-based attendance monitoring can be introduced which will scan the identity card and update the record in the system.
- Emergency alert: This system can also be used with smoke detectors and fire alarms-In case of any emergency situation, the alerts can be generated with the help buzzer
- Automatic PC ON/OFF: Here with the help of sensors, an idea is to have control over the PCs that is to turn it ON or OFF when the person's presence is sensed or else ways accordingly.
- Lab schedule display: As an additional feature, we aim to design a window on HMI where the students and the faculty can view and enter the schedule for the day so that one can have a track on the availability of a lab.
- Auto-Manual mode: In this design, the user has to switch between the main modes that are either automatic or manual. In future, this system can be made auto-manual where one doesn't have to mention specifically about mode but is programmed in such a way that purpose is served in the backend.

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