Teaching Distributed Process and Manufacturing Control On Large System Trainers

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Abstract

Manufacturers are adding automation to meet the pressure for increased productivity, quality, and production flexibility. While the automation techniques used by central Pennsylvania companies varies, they have some common elements: a high degree of distributed control and increased use of programmable logic controllers and electro-mechanical devices. In addition, many companies require technology graduates to work on applied engineering problems. As a result of the these changes, the Engineering Department at PennState University Altoona Campus added a Bachelor of Science degree in Electro-mechanical Engineering Technology (BSEMET). An automation laboratory in a new Automation Technology Center was added to support three new controls courses taught in the last year of the BSEMET program.

The development of the controls laboratory presented some unique problems. The laboratory was required to support a standard laboratory class size of 16 students while delivering laboratory training over a wide range of manufacturing control problems. A laboratory system was required that permitted eight teams of two students each to have equal access to control and operation exercises on the single large manufacturing system. At the same time the laboratory system had to support fundamental control exercises on single machines and trainers. This paper describes the development of a controls laboratory system that permits student laboratory groups the opportunity to develop unique solutions for single large system trainers in the context of the standard laboratory class size.

Introduction

The PennState University Altoona Campus is one of 21 campuses in the PennState University system and a part of PennState's School of Engineering Technology and Commonwealth Engineering (SETCE). Located in central Pennsylvania, the college provides associate and bachelor degree graduates in Engineering Technology to industries located in the city of Altoona and five rural counties. The Altoona Campus offers two ABET accredited Associate of Science degree programs in Mechanical and Electrical Engineering Technology (MET/EET), and a new Bachelor of Science degree in Electro-mechanical Engineering Technology (BSEMET). The introduction of the BSEMET program was a result of changes in the engineering workforce in industry.

Changes in Industry

The genesis of the BSEMET program started from request from the industries the college serves. These central Pennsylvania industries have experienced the following changes in their manufacturing operations.

- *New production systems include a high degree of distributed control and information integration],*

The regional and national trend in manufacturing is to link the production machines in manufacturing cells and to integrate cells into production systems. The integration frequently includes hardware and software to make production and product quality information available to the design and production planning departments on a near real-time basis. These changes are driven by a need to become more competitive in the global market; as a result, the move toward integration in manufacturing will continue to accelerate.

- *Distributed control of discrete processes using programmable logic controllers (PLC) is increasing[2].*

The adoption of production work cells using computer controlled process machines, material handlers, material movers, automated storage and retrieval, and quality verification is a trend that started in the 1970's. Industries across the central Pennsylvania area are using PLCS for the discrete control of fixed and flexible production machines, cells, and systems. The increased use of PLCs for the distributed control of discrete production processes dictates that technology programs include education in distributed manufacturing control as a regular part of the technician training process.

- *There is a merging of the electrical and mechanical disciplines in the designing, manufacturing, and servicing ofproducts for the home and office[3].*

A study of products like the automobile, photo-copier, and most household appliances reveals a blend of electrical and mechanical technology. In the past, mechanical and electrical designers worked independently in their specialty area. Now, many companies in central Pennsylvania use concurrent engineering teams to solve design and production problems. Design excellence is achieved on a product when electrical and mechanical designers have cross knowledge of each others areas. Electro-mechanical concepts are also visible in the production machines and systems used to manufacture products. Primarily mechanical devices like material handlers, material movers, process machines, and storage and retrieval system have added electronic sensors and computers to improve operation and control. Therefore, technicians and engineers who work on these electro-mechanical production systems and assist in the design of the products should have knowledge that bridges these two technologies

- *In some industry sectors, technology graduates have job descriptions that include applied engineering.*

Small and medium size industries in the central Pennsylvania area are using technology graduates to perform applied engineering functions. This includes work in product and process design and in the design, modification programming, and advanced troubleshooting of production systems.

Changes in Education

As a result of changes in the engineering work place, the Altoona Campus initiated a Bachelor of Electromechanical Technology program with an emphasis in production system design and control. In addition, the college received funding for an Advanced Technology Center (ATC) with laboratories to support the program[5]. The BSEMET program is designed to give students who complete a traditional two-year MET or EET program two additional years of study focused on concepts that bridge the disciplines. Courses in the final two years emphasize the design, prograrnming, optimization, and troubleshooting of control system at the machine and system level. The control course sequence, offered in the fourth year, includes EMET 410 Automatic Control Systems (Design of Feedback Control Systems by Stefani, Savant, Shahian, and Hostetter), EMET 430 Automatic Machine Control Technology (text selection not complete), and EMET 440 Electromechanical Project Design (text selection not complete).

Designing a Controls Laboratory

The development of the automation and controls laboratory in the ATC presented a major design and implementation challenge. The facility would have to effectively support classes of 16 students for laboratory exercises ranging from basic control concepts to the control of a large discrete manufacturing systems. The laboratory was designed (Figure 1) with Student Programming Laboratory Benches (SPLB) that support basic control exercises at the bench and exercises in control and programrning of the single large manufacturing system by students at each SPLB.

The SPLB concept was important because teaching students to work on the complex systems used in automated manufacturing is a two step process. First, students must master the operation of the hardware and programming of the software for the individual automation machines; second, they must learn how to integrate the machines into a production system. The eight SPLBS are designed to teach basic concepts that include: sequential and servo machine control, interfacing devices with programmable logic controllers (PLC), programming PLCs, robot programming, and CNC machine programming. Each SPLB has an Allen Bradley PLC, a microcomputer, and a sampling of the devices that are used on the larger automation system including: sensors, a bar code reader, lamps, switches, a servo robot, and a small conveyor[7]. The robot and conveyor are shared between two SPLBS through a quick disconnect interface illustrated in Figure 2. The interface is a patch panel to wire the PLC input/output (1/0) modules to the conveyor and robot 1/0. Connectors on the PLC side of the interface permit either SPLB to connect to the trainers. The wire jumpers on the panel permits students to wire the PLC interface and permits the introduction of faults.

The fundamental laboratory exercises include servo concepts, servo robot programming, sequential machine prograrnrning, PLC interfacing, and PLC programming using switches, lamps, and sensors. As a node on the Allen Bradley (AB) data highway, the microcomputer serves as a programming device for the AB PLCS through AB software. Using the QBASIC language and the serial ports, the same computers are used to teach robot programrning. In addition, the SPLBS support the programmingg of the lathe, mill, and laser engraver using the MasterCAM CNC programming software with the laboratory LAN as the link to the CNC machines

An automated manufacturing system is the second major component of the training system[8]. The layout of the automation system in Figure 1 identifies three major elements: 1) production and assembly cells, 2) conveyor and robot material handling hardware, and 3) machine and cell controllers. Figure 3 illustrates the interface between the SPLBS and the automated manufacturing system. This distributed control system links the eight Student Programming Laboratory Benches (SPLBs) to the automated manufacturing system. Information and data is moved between the SPLBS and automation system through an ethernet LAN and an Allen Bradley data highway. Three PLCS perform cell control fictions for the following hardware: CNC machines (mill, lathe, and laser), conveyor, and assembly cell. The PLCS use sensors, limit switches, bar code readers, and cell data to manage the sequential operation in each area.

The management and transfer of robot and CNC program files is accomplished by the system computer using Dmax cell controller software from Intellution Corporation. This higher level communication uses serial data lines and ARTIC cards to establish two-way program file transfers. The system computer has an interface with both networks, the Allen Bradley data highway and the laboratory LAN. This architecture gives the training laboratory flexibility in how manufacturing hardware is used in the exercises and will permit direct numerical control when the production machines have the capability to be nodes on the LAN.

In operation, the SPLBS and automated manufacturing system fiction as follows:

- Each team of two students uses the computer and the Allen Bradley PLC at the SPLB to develop a program for the control of one element in the automated manufacturing system (i.e. the movement of pallets on the conveyor).
- When the program is ready the team transfers the code file over the AB data highway to the PLC on the automated manufacturing system.
- The team tests the code on the manufacturing system (i.e. conveyor).
- If the solution works, they move back to the SPLB to work onto the next part of the system control problem. If bugs are identified, they return to the SPLB and correct the problem.
- Another team moves their solution over the automated system and processes is repeated.

The program development time is greater than the verification time so one automated manufacturing system will support the eight SPLBS.

A similar technique is used to teach the programming of the CNC lathe, mill, and laser and the material handling robots. Students create programs for the robots using QBASIC on the SPLB computers and create CNC machine code using MasterCAM software at the SPLBS. The transfer of the production machine code from one SPLB to the automation system is supported by the laboratory LAN and the cell control software. The LAN permits the program to be transferred from the SPLB to the cell controller, and cell controller acts as a direct numerical control (DNC) system for the CNC machines and robots. After transferring files to the CNC machines or robots, the students test the code on the automation system. The use of three different PLCS and the individual CNC and robot controllers permits simultaneous student projects on each of the these systems.

Conclusion

The changes occurring in manufacturing dictate that technology graduates must play a bigger role if these industries are going to be competitive in global markets. Graduates of four-year engineering technology programs will be asked by manufacturers to work in the applied engineering area; therefore, the curriculums must prepare them with control training at both the machine and system level. A strategy for delivering laboratory control exercises at the machine and system level to standard laboratory section sizes has been presented.

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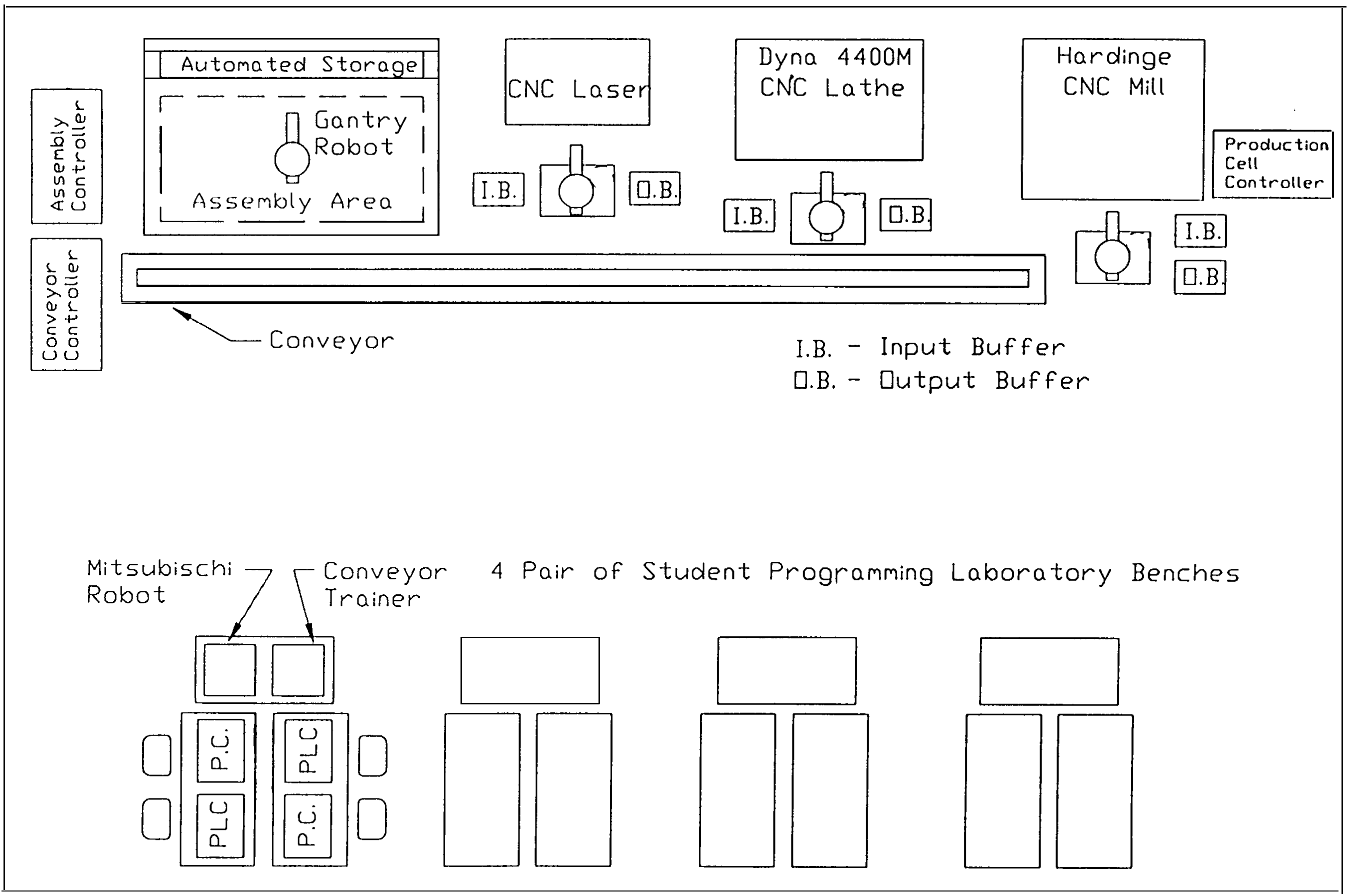
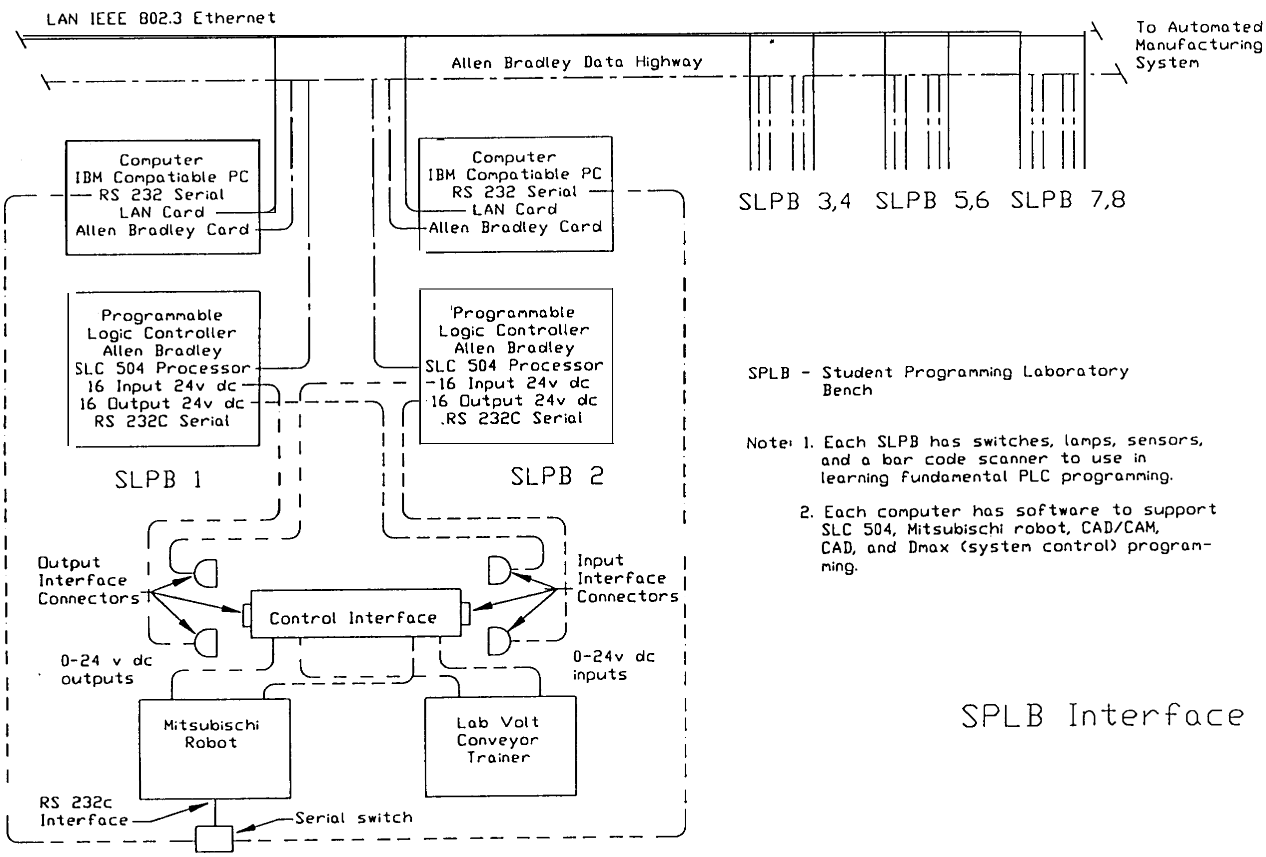

Automated Storage
Gantry Robot
Assembly Area
CNC Laser
Dyna 4400M CNC Lathe
Hardinge CNC Mill
Production Cell Controller
Assembly Controller
Conveyor Controller
I.B.
O.B.
Conveyor
I.B. - Input Buffer
O.B. - Output Buffer
Mitsubischi Robot
Conveyor Trainer
4 Pair of Student Programming Laboratory Benches
P.C.
PLC

Figure 1



LAN IEEE 802.3 Ethernet
Allen Bradley Data Highway
To Automated Manufacturing System
Computer
IBM Compatiable PC
RS 232 Serial
LAN Card
Allen Bradley Card
Programmable
Logic Controller
Allen Bradley
SLC 504 Processor
16 Input 24v dc
16 Output 24v dc
RS 232C Serial
SLPB 1
SLPB 2
SLPB 3,4
SLPB 5,6
SLPB 7,8
SPLB - Student Programming Laboratory Bench
Note: 1. Each SLPB has switches, lamps, sensors, and a bar code scanner to use in learning fundamental PLC programming.
2. Each computer has software to support SLC 504, Mitsubischi robot, CAD/CAM, CAD, and Dmax (system control) programming.
Output Interface Connectors
Input Interface Connectors
Control Interface
0-24 v dc outputs
0-24v dc inputs
Mitsubischi Robot
Lab Volt Conveyor Trainer
RS 232c Interface
Serial switch
SPLB Interface

Figure 2

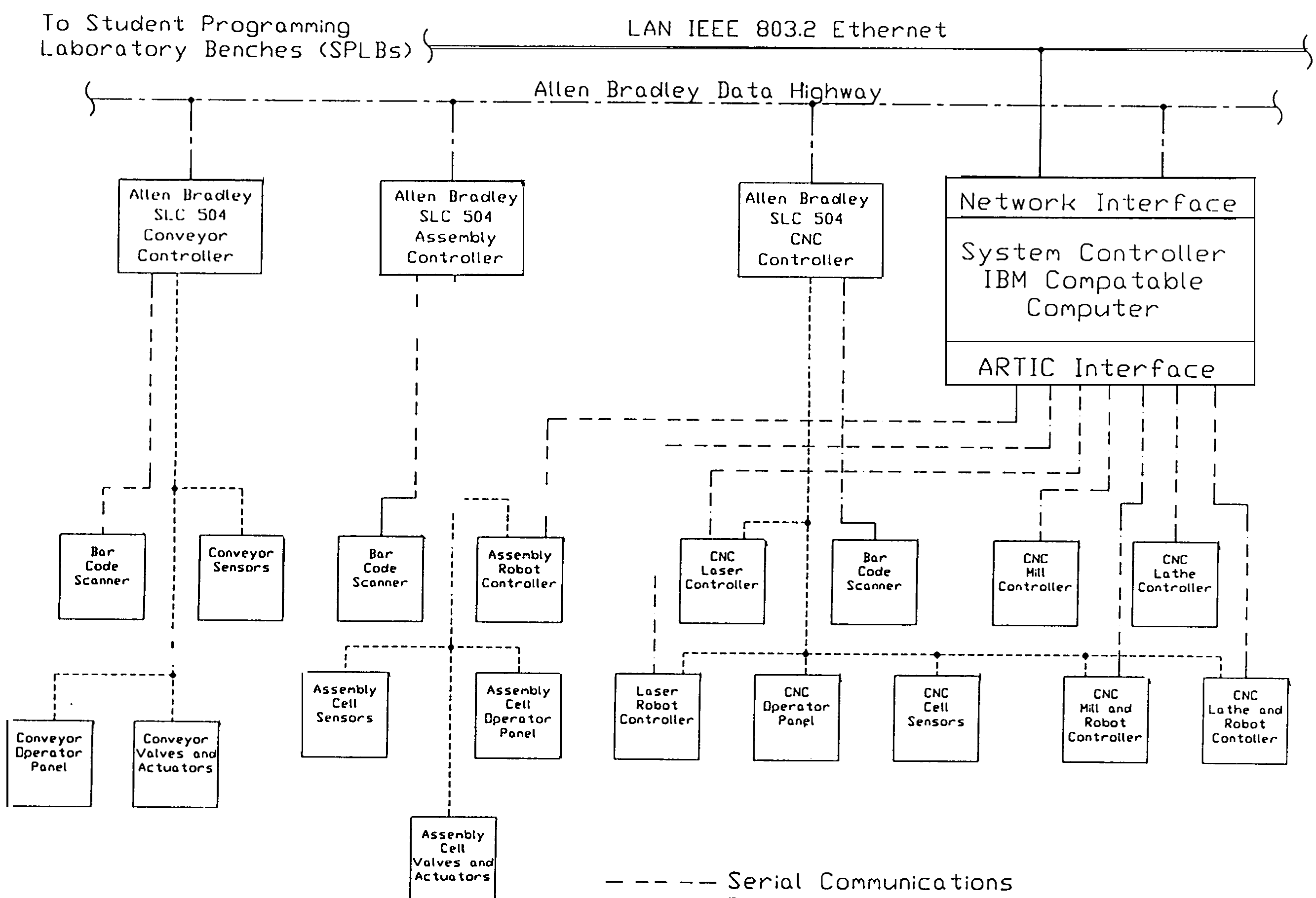

To Student Programming Laboratory Benches (SPLBs)
LAN IEEE 803.2 Ethernet
Allen Bradley Data Highway
Allen Bradley SLC 504 Conveyor Controller
Allen Bradley SLC 504 Assembly Controller
Allen Bradley SLC 504 CNC Controller
Network Interface
System Controller IBM Compatable Computer
ARTIC Interface
Bar Code Scanner
Conveyor Sensors
Bar Code Scanner
Assembly Robot Controller
CNC Laser Controller
Bar Code Scanner
CNC Mill Controller
CNC Lathe Controller
Conveyor Operator Panel
Conveyor Valves and Actuators
Assembly Cell Sensors
Assembly Cell Operator Panel
Laser Robot Controller
CNC Operator Panel
CNC Cell Sensors
CNC Mill and Robot Controller
CNC Lathe and Robot Contoller
Assembly Cell Valves and Actuators
Serial Communications
Discrete Input/Output (24vdc)

Figure 3