Engineering Technology Students Gain Insight into Real-World Engineering Problem Solving by Providing Solutions to Industry Provided Senior Design Projects in Industrial Control Systems

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Abstract ¾ At Northeastern University, students are learning how to solve real life engineering problems as they provide hands-on solutions to industrial control systems problems in a real time engineering environment. Students are required to team-develop solutions to real life problems as provided to them by industry professionals in a simulated engineering scenario. Through the application of the team design concept, students work together to provide "complete" solutions to presented problems. This paper chronicles an assigned project from initial definition to a student team's final report including hardware and software solution. Students are treated as engineers throughout and are expected to compile necessary information on their own to solve presented problems. This project brings together many of the courses and cooperative work experiences that students have had during their college tenure.

Background

At Northeastern University's School of Engineering Technology, electrical engineering technology students (Juniors and Seniors) are now required to take the newly developed "Industrial Control Systems I" course. The focus of this course is to provide students with a close approximation to what they will encounter in real-life engineering environments including dependencies on others and the responsibilities that are required in such positions. This industrial control systems lecture-laboratory course attempts to emulate these real-life environmental functions as close as possible.

In an effort to realize this scenario, industry partners were consulted and ideas were brainstormed between this author and the industrial advisors. Once these ideas were solidified, a formal specification was developed and used as a "final project" model for students taking this class. Upon completion, industry advisors reviewed the resulting student reports and comments were accepted. The utilization of industry advisors is vital to the success of this course as the original premise was to develop a course that would emulate industry as closely as possible. The evolution of this course has already been described elsewhere [1,2,3,4].

Setting The Stage - Preparation

To preserve and replicate a true engineering environment, students were divided into "engineering design teams" of no more than two students each. The entire class is then treated throughout the term as independent "engineering design groups" who have been hired to work for "this author" who will act as their engineering department manager. The important thing to keep in mind is that these groups must be treated, not as students, but as engineers. Students have acquired a lot of education to this point and will be required to put that expertise to work here.

This teaching transition style may be difficult for some to overcome but it is none-the-less necessary. Students must be treated as real engineers with real responsibilities if this course is to be successful.

Throughout the term all of the student design team groups will be given several small design assignments. Each of these small design assignments will ultimately be utilized as elements in the overall design of their final projects. All groups are given the exact same smaller design projects to work on. These design projects are given out in a fixed specific order. (same order to all groups). Through experience it has been determined that no two groups will ever complete their designs at the same time. Although there is plenty of time for these groups to complete their assignments, time is limited since the last three classes (nine hours) must be devoted to their working on their final projects. This is a good thing since student groups can be graded on their ability to utilize newly acquired information from lectures in this class in concert with previously acquired material from earlier classes. The fact that groups will complete assigned projects at different rates allows the instructor to see which teams may be weak in their overall design and organization skills.

Included in the specifications of these small incremental designs is the requirement that each group "paper design" their designs prior to committing them to a computer simulation scenario. This concept was suggested by one of the industry advisors who claimed that design engineers usually "jump" directly to the computer simulator without ever putting pencil to paper. This advisor claimed that without initial preparation and forethought, designs take longer. It was also said that this longer design time made for unnecessarily expensive mistakes and was more costly to the engineering firm in the long run.

Another requirement of the design team groups is that they must thoroughly document each design. Industry advisors made this a requirement since engineers in real life quite often move from project to project or group to group and sometimes company to company. It is then quite logical, that if a new person were to take over and be required to fix an existing system problem or make programming additions to the existing system, how would that new engineer be able to perform this function without proper documentation? This may be very difficult or even impossible to do. Again, this may impose a costly scenario to the engineering firm.

Final Project Design Specification

The following represents an actual design specification given in the EET 1368, Industrial Control Systems I course. This final project design utilized all of the elements of the smaller incremental designs performed to this point. Some of the concepts learned and required for the final project are:

- Understanding PLC architecture
- How to apply PLC timers properly
- How to apply PLC counters properly
- How to apply PLC Shift Registers properly
- How to write and structure PLC ladder diagrams properly
- What is a "Pick & Place" mechanism?

- Understanding the operation of multi-station "Rotary Index Tables"
- Understanding how to properly organize sequential process operations
- Understanding the principle of Variable Frequency Drives (VFD)
- Setting correct parameters in Variable Frequency Drives
- Understanding the concept of production "line rate"
- Understanding the concept of modular equipment design
- Understanding the application of Limit Switches, Photo-Electric, and Proximity Sensors
- Understanding "Safety" issues in equipment design

Final Project Specifications and Requirements

The following material, starting with Figure 1, represents the actual specification sheets given to the students. It spells out in clear engineering terms what is required by "the customer."

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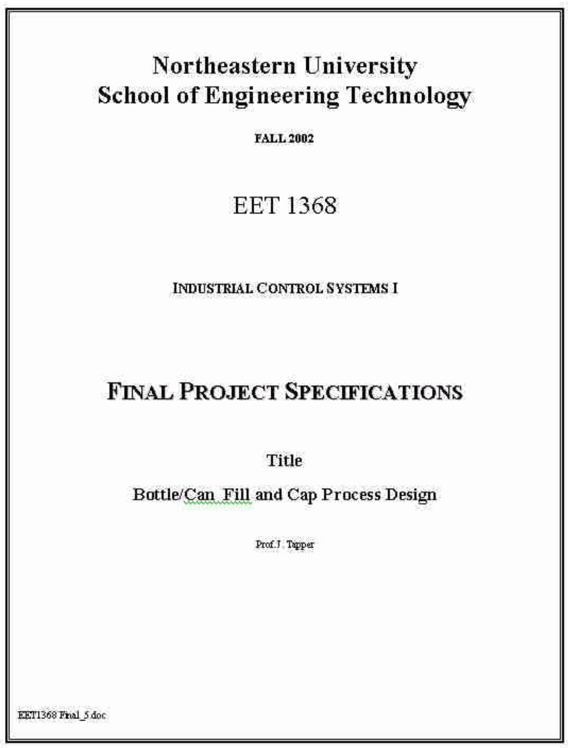
Northeastern University
School of Engineering Technology
FALL 2002

EET 1368

INDUSTRIAL CONTROL SYSTEMS I

FINAL PROJECT SPECIFICATIONS

Title

Bottle/Can Fill and Cap Process Design

Prof. J. Tapper

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Figure 1 Final Project Specification Formal Cover

Needs:

It has been determined that a need exists at a major manufacturer of soft drinks. The need has been determined to design and build a manufacturing process system that can process cans and bottles on the same manufacturing line. The process consists of ***filling and capping*** (applying caps or lids) to either ***bottles*** or ***cans*** within the same process equipment. The constraints are as follows:

Constraints and Requirements:

1. Bottles and cans are being fed via conveyor (see attached diagrams – Figures 2 & 3) randomly to an eight station "rotary indexing" table.

2. Upon reaching the end of this conveyor, a robotic "pick and place" mechanism reaches out to "grab" a product. At that instant, the robot reads a bar code attached to the product. This bar code will tell the robot and hence the system controller logic what type of product it actually is; bottle or can.

3. The "pick and place" robot now changes position and places the product into a waiting "station" on the rotary table, which is at stop.

4. The "rotary table" now increments one position clock-wise. As the table increments, the identity of the product travels with that product to this incremented position. Process will not continue until table has stopped.

5. As this process continues, product will reach the "bottle-cap & fill" station. If the correct product (a bottle) is under the station, that product will get filled and caped. If not, that product will be ignored.

6. The same process repeats as the table is now filling up with product randomly (cans and bottles).

7. When product reaches the "can-cap and fill" station, that product will be filled and caped only if it is a can. If not, that product will be ignored.

8. If by accident, the "pick and place robot" at position 1 misses and does not pick any product up, "neither" fill and cap station will activate when an empty station passes under any of these stations.

9. When product finally reaches position "5", a new robotic "pick and place" mechanism will reach onto the table and grab the product (only if it is a bottle) and place it onto an exiting conveyor which will ultimately send this product to the "next" process. (Packaging) If this product turns out to be a "bottle," a counter should be incremented to keep track of the "production-rate" for "bottles."

10. When product reaches position "6," a new robotic "pick and place" mechanism will reach onto the table and grab the product (only if it is a can), which it should be, and places it onto an exiting conveyor, which will ultimately send this product to the "next" process. (Packaging) If this happens, a counter will increment keeping track of the number of cans exiting the process. If there is no product there, this pick and place will not activate and the "can" counter will not be incremented.

11. This process repeats until the system is halted.

12. Prior to starting the system, all positional data must be cleared from systems memory.

I/O Definitions

Function		I/O	Description
Clock System		I0.0	Load Product onto Table
Select Product		I0.1	Bottle Product Selector
Select Product		I0.2	Can Product Selector
Fill Product (Position -3)		Q0.0	Bottle Fill (0.5 sec)
Cap Product (Position -3)		Q0.1	Bottle Cap (0.1 sec)
Fill Product (Position -4)		Q0.2	Can Fill (0.5 sec)
Cap Product (Position -4)		Q0.3	Can Cap (0.1 sec)
Exit P & P (Position -5)		Q0.4	Bottle Exit & Count
Exit P & P (Position -6)		Q0.5	Can Exit & Count
Table Turn		Q0.6	(Pilot Light indicates table turn) (VFD Shaft rotates 360 degrees in 1 Second)
Exit Product Counter		Cxxx	Bottle
Exit Product Counter		Cyyy	Can

Hardware/Software Requirements:

Using the Siemens' Simatic Software along with the Siemens Model 224 Programmable Logic Controller (PLC) trainers in conjunction with the I/O Load Centers and Variable Frequency Drive trainers, design a process that accomplishes the "constraints and requirements" listed previously. The simulation **must** be working and a demonstration **must** be provided.

Report Requirements:

Your group **must** provide **two copies** of a **professional report** that outlines your design and explains completely ALL of the functions you have provided in your design. You must also provide any and all diagrams necessary to support the documentation to the user of this system. These diagrams, among others, must include a "ladder" diagram fully documented and a Symbol Table for reference and any other necessary materials to sustain your design and (grade).

Good Luck

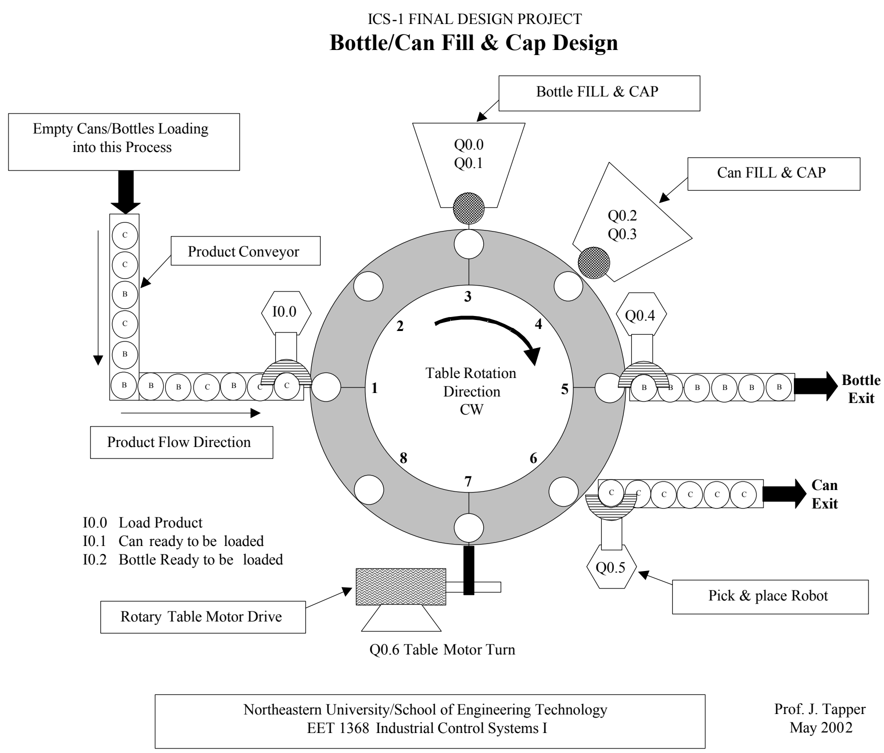

Figure 2 Process Filling/Capping Operation Diagram

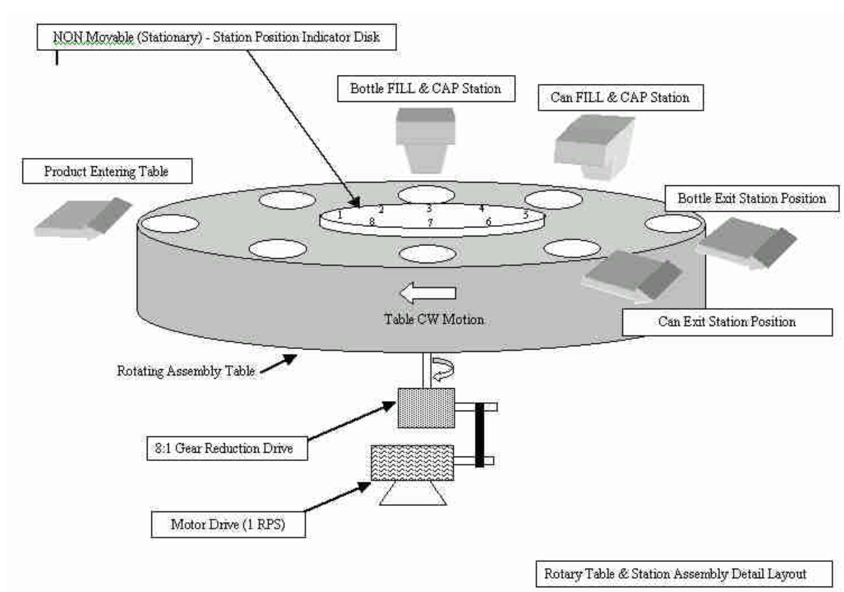

Figure 3 Filling/Capping Equipment Prospective View Diagram

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Students' Response

There were seven groups of two students per group. The time allotted for this project was nine hours. This took place in the last three weeks of the term and included three contiguous laboratory hours per week. Some design work such as planning, structure, etc., was performed outside of the laboratory, but the bulk of it took place in the industrial control systems laboratory itself.

Of the seven groups, one group took a record two hours to design, build, simulate, and demonstrate the system, while others took the majority of allotted time. Students can be seen in Figure 4 below working on their final projects in the laboratory.

Figure 4 Student technology-engineering groups working on their "Final Projects"

Project Results

Hardware/Software

All of the groups completed their projects to varying degrees. Some were unable to utilize the "Variable Frequency Drive" equipment to simulate the "Rotary Index Table" as they became bogged down in programming. The majority, however, did complete the design assignment successfully utilizing all of the hardware available.

Project Report

Participants were required to complete a "professional" report detailing their design that would be good enough to be used as an operations manual for the customer. The author was very pleased at the professional results of these reports. Some reports were more thorough than others, but on the whole exhibited a great deal of professionalism.

Industry Feedback [5]

Industry advisors commented favorably. The following was typical of Industry Advisor feedback. One advisor stated that:

> "…My own engineers do not produce reports
> that are this organized and thorough…"
>
> Ken Cavanagh, Vice President
> Parkinson Technologies, Inc.

Grading

Students were graded on their ability to demonstrate to the author their understanding and grasp of what was required and how to successfully complete their assignments. In addition, "limited pay" in the form of grades was given for projects that did not work. As in industry, customers do not pay for equipment that does not function properly. As part of the project requirement, projects must work (operational) to get a grade above a "C." Groups with non-properly functioning projects may only realize a maximum of a "C." In addition, students not utilizing all of the required hardware can only have a grade of "C" as their ceiling grade.

The following items were elements of the final project grade:

- Class preparedness
- Class participation
- Laboratory participation
- Group team work
- Oral descriptions and presentation
- Project report
- Ability to respond to questions related to their design by the instructor and other students

Summary

Students responded quite well to the rigors of being treated as engineers. Most were quite happy, while a small minority wanted to be spoon-fed. It appears that all of these students had put a great deal of effort into completing their assignments. Although some were more successful than others, all were gratified with their results. In an informal independent class/instructor evaluation, students gave the class high marks for treating them as professionals. In addition, the majority of students polled in this informal evaluation said that they had wished that other courses were organized in this manner. Most agreed that forcing them to design and build a system on their own gave them a great sense of self-accomplishment. Many even personally thanked the instructor for creating an academic environment that simulated so closely the "real-world."

Industry advisors were pleased with the results as was displayed in their interest in retaining students for coop employment or permanent employment after graduation. Their comments on the students' final reports were nothing less than amazing. All agreed that this is what it takes to be successful in a real world industrial environment.

It is obvious that "mature" students enjoy being treated as engineers. They are even more self-fulfilled, just as graduate engineers are, when their designs "actually" work.

Industrial Control Systems is a fascinating field with a great deal of potential. Through industry partnerships and intervention, today's engineering technology students can garner a great deal of self-fulfillment though Senior or Capstone projects such as this. Giving students the opportunity to work on "real-life" projects goes a long way toward creating a "real" engineer. Realism in the classroom is a must if we as engineering educators are to help 'bring good things to life."

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