Multidisciplinary Design of a Reporting System Utilizing Pager Technology

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Abstract

This is an industrial capstone design project involving the design of an electromechanical transfer system capable of winding and unwinding a material from one spool to another. The distance between the spools is provided. It is also specified that the material be under constant tension during the operation; the linear speed of the material be user-controlled during run time; and the system be able to operable in the either clockwise or counterclockwise direction. It is also required to design a monitoring system using microprocessor technology to periodically report the operating status, operating speed, operating time, and operating direction to an alphanumeric pager. Due to the multidisciplinary nature of the problem, the electrical engineering and mechanical engineering departments formed an interdisciplinary student design team to participate in the project. The students designed, produced and tested the system to fulfill the major requirements. The paper presents the design and more importantly the lessons learned and the benefits derived this experience.

I. Introduction

Each department in the College of Engineering at North Carolina A&T State University has a capstone design project course requirement. This project seeks to engage mechanical and electrical engineering seniors to work in a multidisciplinary team. The electrical engineering department offers a two-sequence capstone design projects course for its students. Design teams are formed. However teams are formed within the discipline and there is no cross interaction with students from other disciplines. Each design team is assigned a project selected from a list of topics suggested by industry and faculty. They design, develop specifications, implement the design, build a working prototype, estimate costs and develop a formal report all within the confines of each discipline. Unfortunately, most of these projects involve mechanical components, which the typical electrical engineering student is not capable of analyzing

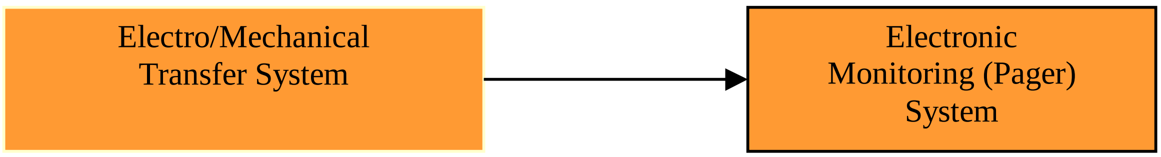
The mechanical engineering department has had a different senior design philosophy for sometime. It considered the two major stems of the program, namely, the thermal and mechanical system. Students take a 3-hour thermal systems design course with the emphasis on fluids and energy system design to meet system performance and economic constraints. Then there is a 3-hour mechanical system capstone design course. Comprehensive group projects are assigned involving the design of engineering systems aimed to apply the student's knowledge of solid mechanics, theirs of failure and manufacturability. Faced with the new ABET EC 2000 requirements, the mechanical engineering department has revised its philosophy and has combined the two design courses into two a two-sequence capstone project courses. Although this move has resulted in more comprehensive and meaningful capstone design projects, most of the projects involve knowledge of electrical/electronic components, which the typical mechanical engineering student is not capable of analyzing.

This project, suggested by Kimberly-Clarke(KCC), provides an opportunity for the formation of electrical and mechanical engineering interdisciplinary team. The basic requirement is to design a system that will unwind XYZ material from a spool onto another spool. The distance between the two spools should be 12 inches. The material should maintain a constant tension throughout the whole process. Additionally, the user should be able to set the linear speed at run-time and operate the system in either clockwise or counter-clockwise direction. The team is also to design an independent system that will monitor and report the status of the transfer system using microprocessor technology. This reporting system should be able to periodically (every 5 to 10 minutes) provide Motor Operating Status, Operating Speed, Operating Time, and Operating Direction to an alphanumeric pager.

A representative of KCC met with the members of the team to discuss the project and joined in the brainstorming to gather ideas. Kimberly-Clarke Corporation uses industrial automation techniques to manage machine operation, and alarm technicians of error codes that may occur. Kimberly Clark Corporation is currently using the devices needed to perform the particular tasks for this project. However, Kimberly Clark Corporation would like to monitor the operation of these machines through pager technology so that the technician will still be able to obtain error information while he/she is away.

2. The Design Process

Eight electrical engineering and three mechanical engineering students were selected to participate in the project. The team was subdivided into two functional groups; namely, electromechanical group and electronics group. The electromechanical group consisted of four electrical and three mechanical engineering students. The electronics group consisted of four electrical engineering students. The entire team came up with the general design concept and each group was given the subtask of working out the details. The requirements and tasks for each subgroup are outlined in Figure 1.



Electro/Mechanical Transfer System

<u>Requirements</u>
Spool-to-Spool Transfer
Spools - 12 inches apart
Constant Tension
Specified Operating Speed
Bi-directional operation

<u>Mechanical Tasks</u>
Evaluation and maintenance of constant tension
Force/Stress analysis
Design/Analysis of machine members
Selection of shaft, keys/pins, clutches, bearings and couplings
Machining of spools, shaft, and supporting frame

Electronic Monitoring (Pager) System

<u>Requirements</u>
Motor Status (ON/OFF)
Operating Speed
Operating Time
Operating Direction

<u>Electrical/Electronic Tasks</u>
Controller Design/Selection
Motor Analysis/Selection
Sensor Selection
Comparator Selection
Potentiometer Selection/Analysis
Shaft Encoder Analysis/Selection
Circuit Design
Logic/Monitoring/Control System
Programming of Microprocessor
Design of Display Unit

Figure 1: Mechanical and Electrical Requirements and Tasks

2.1 The Electromechanical Transfer System

Several design concepts were developed as a team. Each concept was rated on fuctionality, simplicity, and safety of operation. The mechanical engineers were given the task of rating each concept and recording the information in the decision matrix. The first concept would use a motor to turn a driver gear, which would turn two other driving gears in the train. The driving gears would be connected to shafts which were rigidly attached to the spools. However, the electrical engineers favored the use two motors for easier montoring. Thus this idea was modified to include two motors. The schematic of the system is shown in Figure 2.

The initial speed of the system is set by means of a potentiometer connected to the two driving motors. A follower arm with a rotary potentiometer is placed on the periphery of each spool. As the spool diameter changes, the output current of the potentiometer is adjusted. A magnetic clutch, which is rigidly connected to the spool, senses the change in the current and changes the speed of the spool. Thus the linear speeds are maintained in a closed-loop. A comparator is used to determine the linear speed differential between the spools. The tangential speed of the spools must be the same to maintain the tension in the material. As the material unwinds from a spool its linear speed decreases, thus the rotational speed of the controlling motor must be increased to maintain the linear speed. Likewise as the material winds onto a spool, the diameter increases and thus linear speed increases and the rotational speed must be decreased. Thus the potentiometer ensures that the linear speed is maintained and the controller ensures that the speed is the same for both spools.

The system was designed based on the tension the material could withstand or the horsepower being supplied by the motor(s). The mechanical engineers decided to begin by designing the system with a 0.4 HP motor, (the smallest motor the electrical engineers could find) and selecting polyester as the material. The electrical engineers found that the maximum tension for this material was to be 0.75lbs. The electromechanical engineering team determined the tension in the material at different radii. Using 0.4HP and 1,000 rpm from the motor, and a radius of 2in. the highest tension achieved was 0.792lb. Thus the sytem specifications were determined. Figure 3 provides a picture of the completed system.

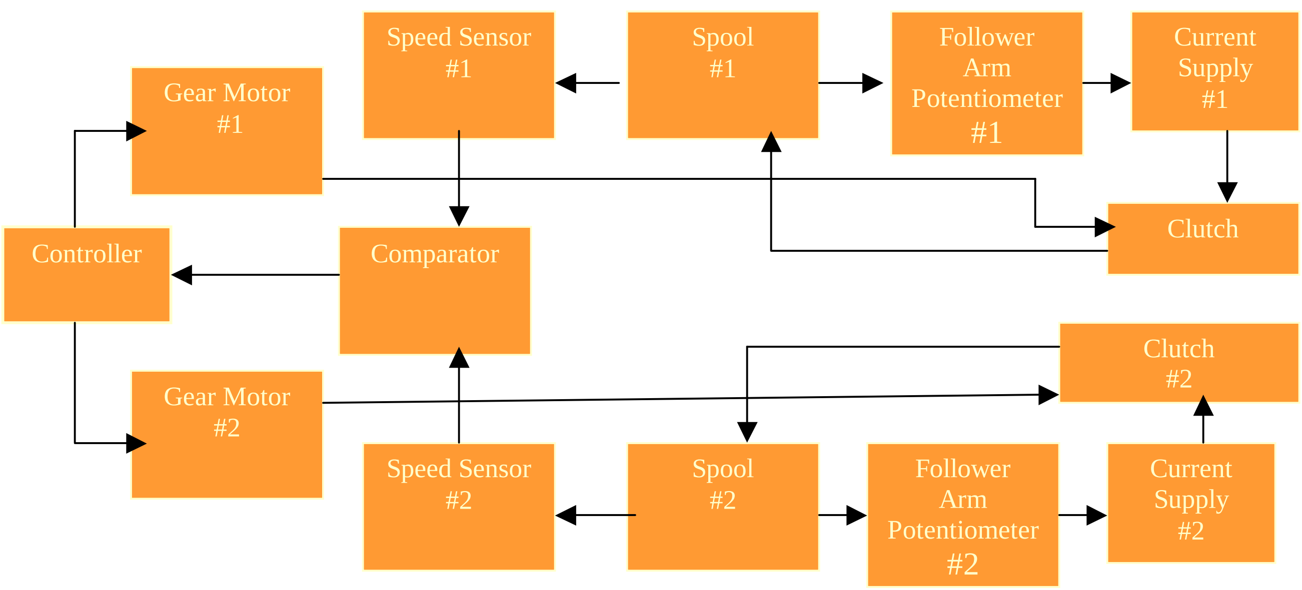


Figure 2: Schematic of Spool-to-Spool Transfer Unit

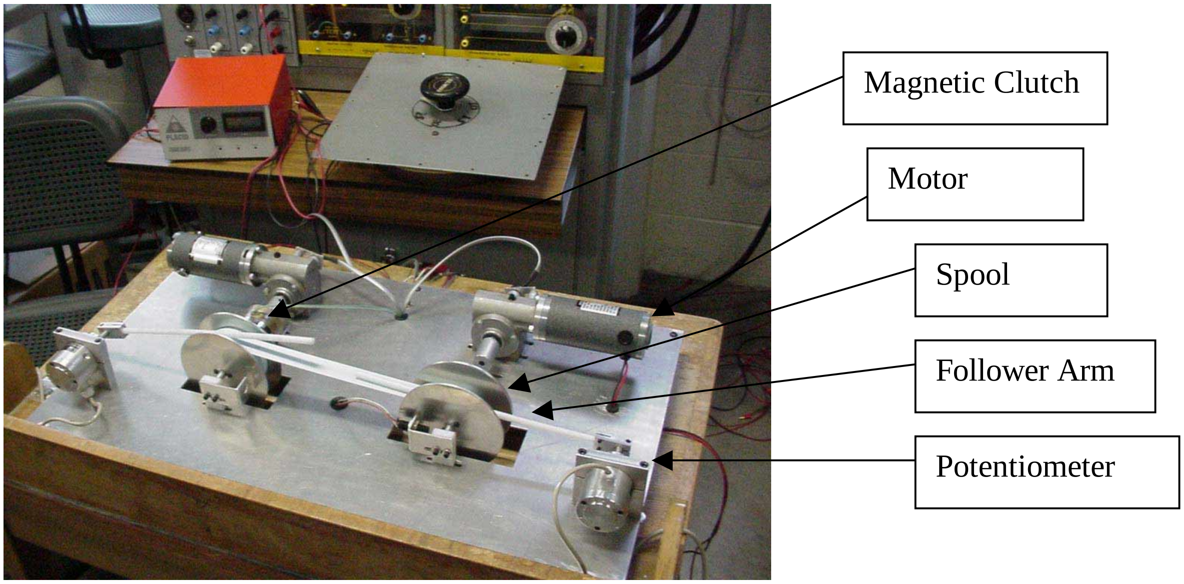


Figure 3: Picture of the Spool-to-Spool Transfer System

2.2 The Monitoring System

The input is the output data from the electromechanical transfer system that winds/unwinds material from one spool to another as described above. The user sets the operating speed, at run time. The spools run in a clockwise or a counterclockwise direction.

A shaft encoder converts shaft rotations to pulses for accurate and precise measurements. This is used to quantify the incoming data coming. The output of the shaft encoder is used to extract operating speed, operating time, motor operating status and operating direction information. This status can be classified as either ON or OFF. These two conditions are represented as machine codes. The pulse rate is used to evaluate the operating angular velocity. An operating time block reports the operation time, in real time. The time starts from the instant power is applied to the transfer system and information is transferred to the monitoring system. An operating direction module reports the direction of the rotating component. This is specified as either being in the clockwise direction or the counter-clockwise direction. Four logic devices are used to receive information about the operating status, the operating speed, operating time, and the direction. A microprocessor unit interprets the information from the logic devices and translates it into quantitative data via a software program. The interface is the AD5 Quadrature Encoder with Software Engineering Institute (SEI) Bus Adapter which interfaces up to four encoders to US Digital's SEI Bus which is interfaced with a microcomputer. The AD5 takes the place of Logic Devices 1-4. The pulses from the shaft encoder are fed into the AD5 and converted into direction, angular velocity, operating status, and operating time. The AD2-B, which accompanies the AD5, is a connector that converts the pulse information received from the AD5 to a PC readable format. The unit then outputs the results by interfacing with a display unit.

The SEI Explorer (see figure 4), a software package allows the user to interface with each of the above-mentioned devices. Information such as position or switch status is automatically updated several times per second and displayed graphically. Moreover, the software may be altered to meet various design specifications. This software takes the place of the microprocessor mentioned in the system description. The display unit displays the information in a form that a user can interpret in a form similar to an alphanumeric pager unit. The information is displayed in terms of operating speed, operating status, operating time and operating direction.

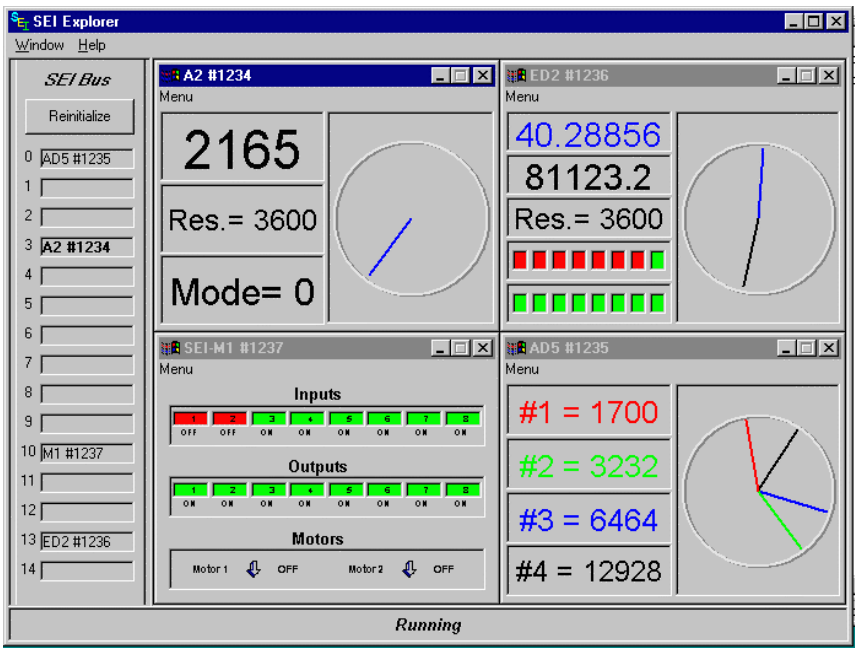


Figure 4: SEI Explorer Software Demo

3. Discussion

The project was first assigned to the electrical engineering department. However, due to it the interdisciplinary nature of the problem, mechanical engineering students were sought to join the team. Thus there was the initial problem of ownership of the project. The mechanical engineering students thought that they were just assisting the electrical engineering students and were not very enthusiastic and stayed behind the scenes. However, as time progressed, they found they role to be significant as they were relied upon to make important decision regarding the development of the project schedule, design matrix for selection of alternative designs and mechanical analysis. The electrical engineers who were members of the electromechanical group did not seem very comfortable with the project at the initial stages. The members of the electrical/electronic group were all electrical engineers and they seemed to be more comfortable than the electromechanical group. This could be due to the fact students are used working within their own disciplines.

Problems that were witnessed include inability to schedule meetings due to different class schedules, and difficulty in understanding the discipline-specific terminology. For example the electrical engineers had to learn about mechanical components such as keys, clutches, and machine shop terminology and the mechanical engineers did not have experience with electronic shop procedures.

An assessment of the course objectives was done by means of a questionnaires. The assessment of the course objectives involves the effect the course has on the students abilities in the ABET "a" through "k" items. The entire class is divided into groups of two or three. There were 13 control groups and the members of the multidisciplinary team were split into five groups for this study. Group members discussed each item and indicated the extent to which they agreed on the abilities gained as a result of the course. They are four levels of agreement. These are Strong, Moderate, Weak, and Not Applicable. Table 1 shows the response to the question "To what extend did the course contribute to your abilities in the areas listed below? Students who were members of this project team are indicated as "Members" and those who worked on other projects are noted as "Control". Column 1 shows the pertinent ABET criteria which at least one group indicated as "Strong". Columns 2 and 3 show the ratio and percentage of the number of groups which indicated a strong agreement.

Table 1: Percentage of groups which indicated strong agreement with criteria

Criteria	**Control**	**Members**
Ability to apply knowledge of engineering	2/13 (15.4%)	3/5 (60%)
Ability to design a system to meet needs	2/13 (15.4%)	4/5 (80%)
Ability to function on multidisciplinary team	0/13 (0.0%)	5/5 (100%)
Ability to identify engineering problems	3/13 (23.1%)	3/5 (60%)
Ability to communicate effectively	4/13 (30.8%)	3/5 (60%)
Ability to use engineering skills for practice	4/13 (30.8%)	4/5 (80%)

The responses indicate that the students who worked on this multidisciplinary project were more satisfied with the course than those who worked on projects within their restive disciplines. It also shows that the program objectives are met by the project. Those who were involved in this project indicated their ability in working on multidisciplinary teams while those who did not had a weak response to this question.

4. Concluding Remarks

The project provided students with interdisciplinary design team experience. Students gained the experience in converting an unstructured problem into a well-defined design problem, specification of design objectives, generation of alternate solutions and the selection of the most appropriate solution. Through a series of progress reports, students improved their ability to develop written and oral reports in a team environment. Students were made aware of safety in design, legal responsibilities and project management tools. The project provided a unique opportunity for students of both disciplines for system integration and prototype development.

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