Industrial Collaboration for an Interdisciplinary Elective in Applied System Design and Remote Diagnostics

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Abstract

Electrical and mechanical engineering technology students at Penn State Erie, The Behrend College are being provided the opportunity to make a connection between theory and real life practice. In this class, the students analyze a large system (a locomotive) and systematically break the large system down into its respective subsystems. The integration of these subsystems is discussed in terms of reliability from both a theoretical and practical viewpoint, as guest lecturers from industry supplement the class theory with their own real-world experiences. Students get hands-on experience with the locomotive, including taking the locomotive on test runs, while also studying system design analytically using Matlab. Specific locomotive systems will be addressed, such as engines, control, communications and remote monitoring. Other issues to be discussed include sensors, Global Positioning Satellites (GPS), risk assessment, the system design process and the importance of quality and reliability issues in the design of real-world systems. At the conclusion of the class, the students will be capable of looking at engineering through the eyes of those in the field. Both successful as well as unsuccessful systems engineering practices are absorbed before the students enter the engineering workplace.

Introduction

Most electrical engineering and electrical engineering technology curricula focus on specific aspects of electrical engineering, such as circuits, motors, communication systems, etc. However, it is rare to find an undergraduate class whose purpose is to not only look at electrical engineering and technology from a systems level, but also to look at how the electrical system integrates with mechanical systems. Furthermore, very few classes ever discuss real-world aspects of the reliability and design limitations associated with putting a real-world design into practice. At Penn State Erie, both electrical engineering technology and mechanical engineering technology students were offered the opportunity to take a real-world system (a locomotive) and break it down into its subsystems. The students then looked at how the subsystems were integrated together, as well as the difficulties encountered in achieving system integration. In this paper, the authors will discuss the major components of the class, along with the unique industrial interactions provided to the students.

Course Content

The course is entitled "Applied Systems Design and Remote Diagnostics". The class material was broken up into five major sections:

- Systems Engineering
- Communications and Navigation
- Engines
- Propulsion Systems
- Remote Diagnostics

These sections are individually discussed below.

Systems Engineering

In the systems engineering portion, students learned about the actual process associated with systems engineering. This overlooked portion in most engineering and technology curricula focuses on the interdisciplinary process that ensures that the customer's needs are satisfied throughout a system's entire life cycle [1]. This process is comprised of the following seven tasks found at [1]:

1. **State the problem**. Stating the problem is the most important systems engineering task. It entails identifying customers, understanding customer needs, establishing the need for change, discovering requirements and defining system functions.
2. **Investigate alternatives**. Alternatives are investigated and evaluated based on performance, cost and risk.
3. **Model the system**. Running models clarifies requirements, reveals bottlenecks and fragmented activities, reduces cost and exposes duplication of efforts.
4. **Integrate**. Integration means designing interfaces and bringing system elements together so they work as a whole. This requires extensive communication and coordination.
5. **Launch the system**. Launching the system means running the system and producing outputs -- making the system do what it was intended to do.
6. **Assess performance**. Performance is assessed using figures of merit, technical performance measures and metrics -- measurement is the key. If you cannot measure it, you cannot control it. If you cannot control it, you cannot improve it.
7. **Re-evaluation**. Re-evaluation should be a continual and iterative process with many parallel loops.

The students followed this process closely, and were given homework and laboratory assignments which reinforced these concepts. For example, student teams (consisting of both electrical and mechanical engineering technology students) were tasked to system engineer a common product, from a doorknob to a wide body aircraft. The teams needed to address real-world issues, such as:

- Reliability of the doorknob
- Ease of use
- Cost
- Ease to manufacture
- Brainstorm new ideas + Comparison with existing products
- Project Schedule

Communications and Navigation

In a locomotive system, the location of the locomotive is critical in determining:

- Geographic Information Systems (GIS) mapping depictions
- Whether the locomotive is on the same track as another locomotive
- Whether the locomotive (and its cargo) is going to reach its destination on time
- Where to send service crews if needed

In this class, the discussion of communication systems focused on wireless communications, since this is the method most commonly used on locomotives. Although mechanical engineering technology (MET) students did not have any prior knowledge of communication systems, unlike the electrical engineering technology (EET) students, the material was taught on a systems level, allowing for ease of comprehension. The material focused on different wireless navigation and communication technologies, such as:

- Satellite communications
- Cellular communications
- Digital radio
- Spread spectrum concepts, such as CDMA (code division multiple access)
- Global position satellite (GPS) systems

The students were able to demonstrate the use of GPS for locomotive tracking by actually using GPS receivers on a moving locomotive and tracking the locomotive's position in real time. The students also performed experiments using GPS handheld receivers whereby the distance between points in space were measured. The results were compared with a mapping computer aided design (CAD) program. The students were able to show that both methods yielded similar results (within a few feet), when determining the true distance from one end of campus to the other (approximately 0.50 mile). Besides discussions involving cellular devices, students also demonstrated satellite communication by connecting to a satellite via a personal computer (pc) based modem connection, and transmitting data from the pc through the satellite to a host receiver located elsewhere on campus.

Engines

The engine is the source of all power to the locomotive. For this part of the class, the MET students had prior course work in the material, while the EET students were in general seeing this material for the first time. To understand how the engine works, guest lecturers were brought in from industry who were experts in engine design. The guest lectures discussed the differences between engine types, such as diesel and gas engines. The main topics covered in this part of the class included:

- Combustion engine theory
- Gasoline engines versus diesel engines
- Four stroke diesel engines (intake, compression, combustion, exhaust)
- Discussion of a specific locomotive engine design (the 7FDL diesel engine)
- Detailed discussion of the 7FDL diesel engine components (crankshaft, pistons, etc.)

Students visited the manufacturing facility for the diesel engine, and saw how all of the different engine components were manufactured, assembled and tested. The students were also able to see how diesel engines are reliant upon electrical engineering technology to be efficient. For example, electronic fuel injection optimizes the fuel efficiency of the engine and minimizes wasteful emissions.

Propulsion Systems

The locomotive requires the power generated by the (diesel) engine to be supplied to motors which propel the locomotive. To achieve this, the engine shaft is connected to a synchronous generator (see Figure 1) which converts the mechanical power of the engine to alternating current (ac) electrical power. A three-phase full-wave bridge controlled rectifier then converts the ac power from the generator to direct current (dc). The dc is used either to directly drive dc traction motors, or is converted back to a variable frequency ac to drive ac traction (induction) motors. The dc traction motors are easier to control but requires more maintenance due to the brushes on the motor. The ac traction motors do not have the brushes and are therefore more reliable, but the control of the motors is more complex.
The students toured the factory where the motors are manufactured from the ground up. The copper windings are shaped and wrapped with insulation, and then inserted into the stator core. The students also saw where the rotor was machined and integrated with the commutator (for the dc motor). The students saw how the motors were both balanced for vibration and performance tested.

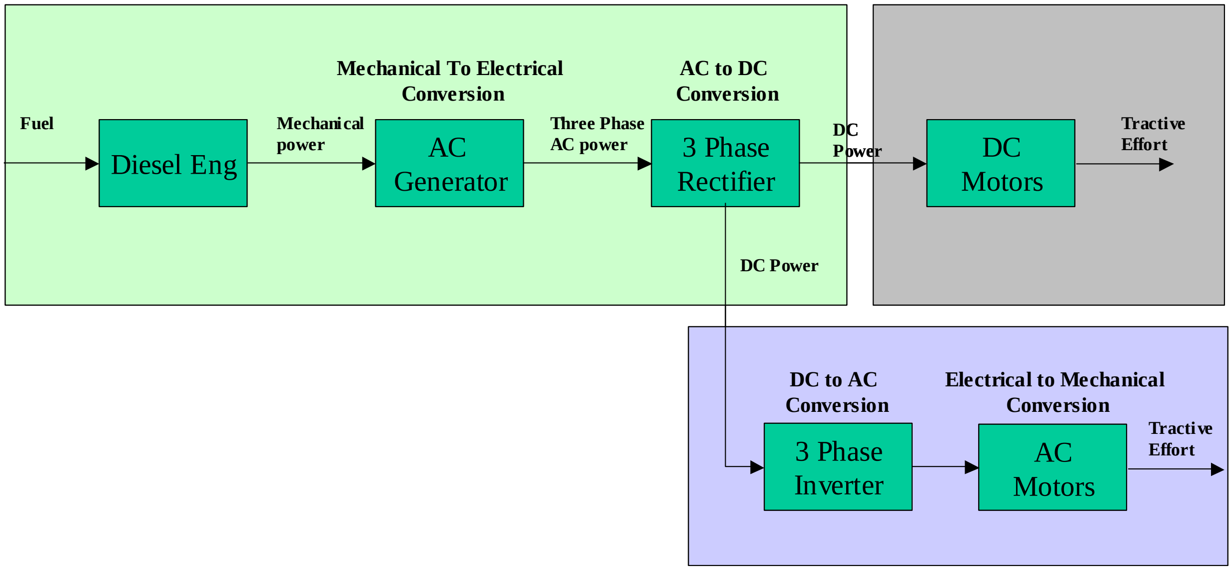

Figure 1. Power conversion on a typical locomotive

<u>Remote Monitoring and Diagnostics</u>

When the locomotive is in the field, a means of determining and improving the reliability of the system needs to be implemented. Using remote monitoring and diagnostics, specific locomotive parameters, such as oil pressure, oil temperature, fuel quantity, engine rpms and locomotive location can be continuously monitored from the home office. The information from the locomotive is digitized and then sent from a computer on the locomotive to a computer at the home office via wireless communications (see Figure 2). Errors introduced in the communication process, such as errors in the communication channel (bit errors), quantization errors, and sensor errors were discussed. The students were able to plot and analyze captured raw data using Matlab. The students realize that after proper analysis of the downloaded monitoring data, a preventive maintenance corrective action would result. The students were able to tour a remote monitoring and diagnostics center, to witness how the retrieved information from the locomotive was able to accurately track the locomotive in the field, as well as specific locomotive parameters.

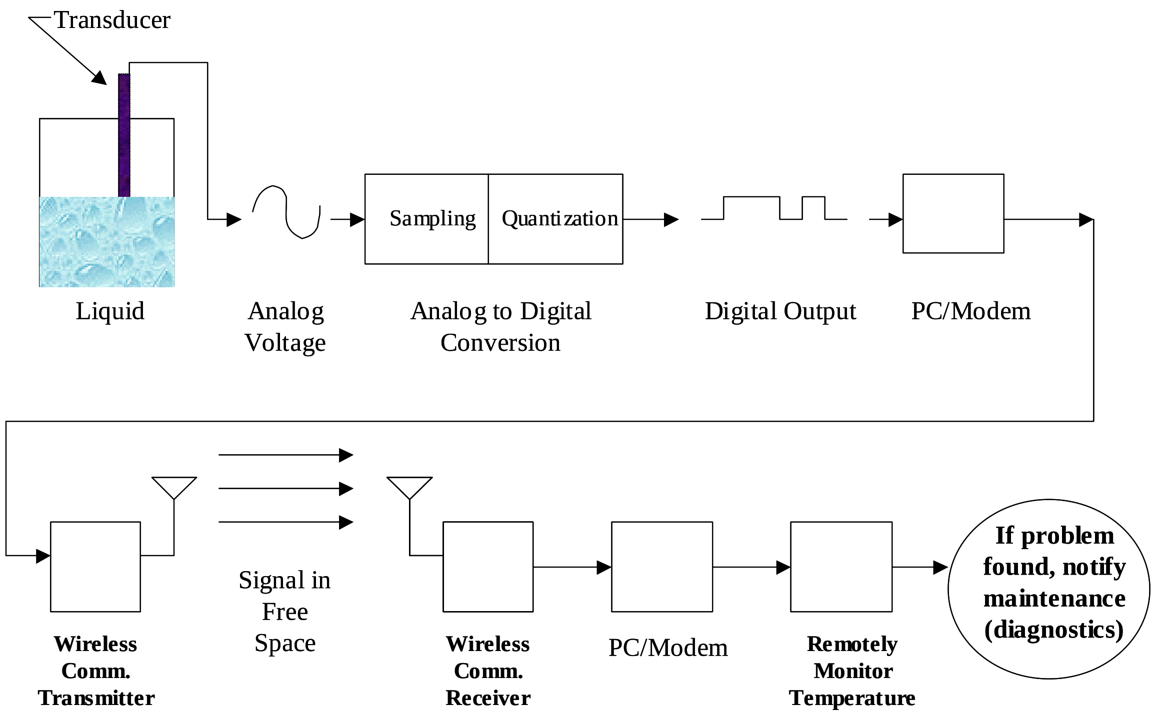

Figure 2. Remote Monitoring of a Liquid's Temperature

Summary

MET and EET students at Penn State Erie were able to take a complex system and break it down into its subsystems. The students were then able to look at the inter-relationships between the subsystems, and how the overall reliability of the system is affected by the integration of these subsystems. The use of guest lecturers from industry, with their real-world experience, provided essential insight on the non-ideal nature of technology. Students were able to see how reliability becomes an integral part of the whole system design process, since in the real world, the whole system may not behave as expected when its parts are integrated together. Students were able to both see the equipment in the manufacturing facility and perform experiments showing the uses of some of the systems (such as GPS) on the locomotive. This class also allowed the students to take knowledge and tools used in previous classes and apply them to a real world system. Software such as AutoCAD, Excel and Matlab were used consistently throughout the class as part of the system design process. Students were reminded that many of the design concepts and remote diagnostics ideas learned in this class can be applied to other systems such as aircraft, automobiles or miniature devices, such as embedded internet system applications.

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