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Senior Elective Communications Systems Courses as Pathway to Capstone Projects in Electrical Engineering Technology Program

Abstract

In any engineering program the capstone project is the most comprehensive work completed by the students, and is regarded as the pinnacle of their engineering studies, with all their course work culminating with this major design, implementation and reporting product. Coming up with the actual topic of the project is sometimes the most difficult part of the project, especially in programs where the project topics are not solely proposed by the faculty, and they are for the student and advisor to develop together. This is especially the case of engineering technology programs, where a large percentage of students have work background (either from military training or industry, as interns or full-time employees) to which they can relate their senior projects, and the programs allow and encourage them to apply their coursework studies to application areas where they have strong hands-on skills. While core courses of any curriculum provide the foundation of the engineering education, the elective courses give the students the chance to refine their education path and focus on the area of their interest. Senior elective courses are defining the areas of specialization within a major, and they may also serve as grounds for the students to explore potential options for the capstone project, and to have the opportunity to get a good starting point for it, ahead of the capstone semester. In this paper, the senior level courses specific to communication systems area of concentration within an electrical engineering technology program are discussed, their course content and the term projects included, and how they offer venues to capstone project choices. The paper presents specific examples of how these course projects gave students successful pathways for capstone projects. The course content that can be covered by the curriculum of an undergraduate technology program is somehow limited, especially for a broad field such as communication systems, and beyond the fundamental theories, the courses can go in more details only on very few narrow areas. Therefore, with a term project in an elective course, students have the opportunity of a semester of deeper study of a topic of their choice, and the learnings and new skills developed can be later applied for the completion of a capstone project. The paper also discusses students' opinions on the option of developing initial results or skills as part of a course project and continuing such project into a senior project, as well as how their topic selection is related to their background, previous experience and future goals.

Introduction

The capstone/senior project in any engineering program is the most comprehensive product that students work on, and is a culmination of their engineering degree studies. Extensive surveys of the current practices related to senior projects, as well as of engineering teaching through senior projects are available in the literature [1, 2]. For their senior projects, students apply the background and skills accumulated through coursework in researching a problem, for which then a solution is investigated, designed and implemented. A significant part of the knowledge and skills needed for the projects are straightforward learning from the actual courses taken in the program, but often new skills are needed, specific to the project topic selected, and students need to apply their learning skills in researching a new subject, or getting familiar with a new

piece of hardware or software platform. Developing these independent study skills is also very important for graduates ready to enter the work industry. Project Based Learning is an important concept related to senior projects, especially in engineering technology programs, it represents active learning techniques used in courses throughout the curriculum, from freshman years up to senior design projects, and it is a concept extensively studied in the literature [3, 4]. Other concepts related to student projects and ultimately to senior design projects, are Design Based Learning [5] and Experiential Learning [6]. Yet another concept covered in the literature is Service-Learning Projects, which is related to community based projects that are integrated in undergraduate courses as instruments to develop student engineering skills [7].

One of the most important aspects of any capstone project is the actual topic that the students select to pursue. While the way the senior projects are coordinated and delivered in most of the programs across the nation are similar, the way the project topics are selected vary largely. The variability lays mostly in who exactly decides on those topics [8], and the way the project topics are selected and what better practices can be used for high quality projects were investigated by various groups [9, 10]. One approach is for the individual faculty to come with project proposals every semester, and students to sign up on a project based on their strengths and interest, leading this way to team projects for each of the proposals. Another approach is for large project proposals formulated by faculty groups, usually in pretty general terms, which may lead to different implementations from different groups of students, as well as to subdivision of the projects in smaller portions for groups of students to sign up for. One of the most desired option for capstone projects is for industry involvement, or industry led projects [11, 12, 13]. In such case the topics for the projects are proposed from industry, and the industry partners may offer additional support either in terms of funding, of access to equipment and facilities, or of mentoring. And yet another option is to have student led project selection, when the main idea of the project comes from the student, and the faculty advisor mostly helps in refining this idea and make it fit for a senior project, and then supervises the student in completing the project. This last alternative is the model followed in the Electrical Engineering Technology program at Old Dominion University, and is a model followed by other programs as well [10, 14]. While the project options still include projects proposed by faculty, aligned with their specialization, as well as some general project topics from which students may get a starting point for their selection, in most of the cases students in this program initiate their projects, based on their background and interests, since most of them have some industrial experience accumulated either prior enrolling in the program or due to their full or part time employment while students.

Curriculum Considerations for the Communication Systems Specialization

The Electrical Engineering Technology (EET) program at Old Dominion University has offered ever since was introduced two areas of concentrations, Computer Engineering Technology (ComET) and Electrical Systems Technology (SysET), which was consistent with the usual partition of an electrical engineering program into computer and electrical sides. All the students in the program, regardless of the concentration, take courses in DC and AC circuits, electronic devices and circuits, digital electronics, linear electronics, microprocessors and programming, instrumentation and programmable logic control systems. The computer engineering technology

track has embedded in the curriculum a minor in computer science, and students are completing several courses in basic and advanced programming, operating systems and data structures, and they have the option of few computer science electives. On the electrical systems technology track students were taking upper division courses in microprocessor based design, digital electronics, power systems and machinery, communication systems and programmable logic design systems, with core courses at 300 level and senior elective courses at 400 level. However, the electrical systems option of the program was covering a broad range of areas and, as they were starting the program, students were not always clear what the electrical system specialization meant for them. After discussions with the industrial advisory board and based on feedback from students and industry partners, the faculty team decided in 2018 to split the electrical systems concentration in few more specific ones, aligned with industry trends and job market demands [15]. As a result, the communication systems, embedded systems, mechatronics systems and power systems concentrations were introduced, to replace the former electrical systems concentration. The differences among these concentrations are minimal, mostly two or three courses, and the students have the option to change among concentrations if such they decide at any time during their studies, but the major gain with the new partitions is that the students get a much clear idea of the focus of their studies from the very beginning of their program, and they also have a way to clearly signal the area they focused on to a potential employer. Among these four new concentrations, only the mechatronics track follows the model of the computer engineering track and comes with an embedded minor in mechanical engineering technology, the other three concentrations allowing the students to select their own engineering or science minor. The completion of the minor is required for the bachelor's degree, as a way to satisfy the upper division general education requirements, and the most popular choices are engineering management, mechanical engineering technology, energy engineering, and cybersecurity.

With the introduction of the new areas of specialization, several courses were updated and few new courses were also added to the curriculum in support of the specific areas. On each of the concentrations, students are required to take some upper division courses that are specific to their chosen field, while they still have the flexibility of two senior elective courses. With the senior elective courses students have the choice to select courses in the same area as their concentration, and this way to deepen the knowledge in their field, or they can choose courses that are specific to the other concentration fields, for a broader background. Specific to the communication systems track the EET curriculum offers a 300-level core course that introduces the students to the principles of communication systems, frequency analysis, filtering, frequency conversion, analog modulation methods, analog to digital conversion and an intro to digital communication systems. This course is required for all concentrations expect for the power systems concentration, students on this concentration being still able to take the 300 communication course as an elective. The program offers also three courses at the 400 level that are specific or related to communication systems. One of these courses focuses on wireless communication systems, and is the 400 level course that is required for the students pursuing the communications track. A second course specific to the communications field, which is offered as senior elective for all students, is a course on computer networks. And the last course in this group is a course on smart power grids, which is at the cross roads between communications and

power systems, a course also offered as senior elective for all students. While the wireless and networking courses were not new in the curriculum, they were completely revised in the new program format, and the smart grids course is a completely new addition to the curriculum. Students on the communication track may also select for their minor the area of cybersecurity, and this way they can take additional courses in programming, networking or cybersecurity that complement nicely their communications background in the major.

The Senior Project Approach

In the Engineering Technology program at Old Dominion University the senior project is a two semester course, which is the case in most of the undergraduate programs. The *Introduction to Senior Project* is a first semester 1 credit course, which covers a series of career related topics related to engineering technology such as engineering codes and standards, engineering ethics, technical report writing, job search and resume writing techniques, patents and property rights, and professional engineering licensure. By the end of this course the students are expected to decide on a project topic, establish partnership with a faculty advisor for the project and submit a project proposal. In the second semester, the actual *Senior Project* is a 3 credits course in which students work under advisor supervision to complete their research, design and implementation of their project, as well as their written report. This second semester course culminates with students submitting their final report, a presentation poster and a live presentation with demo of their project. Maybe the most difficult part of this whole process is the selection of the project topic. The student body in the engineering technology program is very diverse, with the majority of students being employed either part or full time. A large percentage of the students have military background, and they are either active or retired military. This group of students has extensive hands-on experience and they have excellent practical skills. Pretty often these students prefer to select a project in which they can put these skills to work, and take advantage of their practical experience developed prior to the college courses. There is also a good portion of the student body that are already employed and working in major related jobs when they embark in the college studies. These students also have very good practical skills and they also often select senior projects topics related to their work area, or to their personal interests and hobbies. And there is a smaller group of students that even if they are not full or part time employed, they work shorter time periods for industry internships, which is also a good way for students to learn about practical applications that may be investigated for senior projects. While students initiate their project ideas and preferences, there is still for the faculty advisor to discuss the details of the projects and help the students to formalize the proposal and then the actual project, making sure that the final goal of the project is achievable and it is up to the degree's standards. It is mostly the case for traditional students, with no industry experience during their time in school, to have more challenges in selecting a project topic. These students rely on their interaction with faculty to learn of faculty's research interests or strengths, or to discuss student own interests, and select something of common interest for student and faculty. In those cases when students fail to establish a partnership with a faculty advisor on a specific topic, the faculty in charge with the senior project course has to discuss with the student a list of potential topics proposed by faculty and to help the student formulate an idea that fits his/her own background and strengths.

With the development of a total of five concentrations within the electrical engineering technology program, one other goal is that once students set up on one of the specializations, for them to get a better understanding of their selected field, and the knowledge accumulated in the courses they take specific to this field to converge towards the topic they choose for the senior project. In other words, with core and elective courses better aligned with the specialization it is expected for the students to have a better and more informed way of deciding on their senior project topic. All of the 400 level courses are very specialized, or are taking previous subjects to a higher level which involves design, and most of them include as a main part of the course a term project. These course projects are narrower in scope than a senior project, but they give the students the opportunity to experience on that specific area, develop background and skills, learn new software packages or new hardware equipment, and most importantly get curios to experience further and apply these new skills to a more complex project. Thus, these term projects, completed by students for their senior elective level courses, are expected to become the main mechanism for students to develop new skills and get ideas to further investigate in the senior projects. The idea of using course projects in preparation for senior project readiness was also previously investigated in the literature [16, 17]. Students in the junior and senior stage of their studies, get to take one or two senior elective courses ahead or in parallel with the Introduction to Senior Project Course. Thus, by working on some term projects they have the potential to develop in parallel their senior project proposal as well. In such case, the term project gives a boost for the next semester senior project, with a good portion of the research and design already completed. If a course project continues or not into the senior project is also a matter of timing, of how the course aligns with the senior project stage for each student. If students take a specific elective course in parallel or ahead of the Introduction to Senior Project course, then they have good chances to use this course project towards their senior project proposal. If the students are in their final semester, and they already have a senior project proposed, which means that the specific course is taken in parallel with the actual Senior Project Course, then the course project cannot be further continued due to students graduating by the end of the semester. In this case, students still have the option to use the course project for a portion of their senior project and get this way additional support and a deeper understanding for that part.
This paper presents next the senior elective courses on the communication systems track and the corresponding term projects, and how these projects contributed to students' selection of senior projects.

Wireless Communications Course Project as a Step towards Capstone Project

The curriculum of the electrical engineering technology program is limited in the number of specialized courses that can be offered on each of the area of specializations. These limitations are due to the overall number of credits of the program, the limited number of required elective courses, the availably of faculty to develop and offer new courses, and mostly because of the limited number of students that may register for senior elective courses within each term. Due to these considerations, on the communication systems track only two communications courses are required: a 300 level course that is a core course on principle of communication systems, and which is in fact a required course for most of the students out of the communication track also, and a 400 level course on topics of wireless communications, which may be taken as elective by students on concentrations other than communication systems. The goal of the wireless

communications course is to expose the students to the wide range of communication systems topics faced by the current industries and technologies. The topics covered in this course include: M-ary systems and information rate; networks basics and protocols, with data link layer and MAC layer covered in more details; antennas; wireless systems, including channel propagation models, spread spectrum methods, and cellular systems; satellite communication systems; vehicular networks and routing algorithms (as part of network layer); and an introduction to software defined radios. Not all these topics are evenly presented, since this would not be possible within the time frame of a semester. Few topics, such as digital systems, data communications –MAC layer protocols, wireless channel, and cellular systems, are presented in more details because they are indeed core topics of wireless communication systems. Other topics, such as antennas, satellite or vehicular communication systems are more briefly presented, mostly to introduce the students to the field, get them the basic knowledge and terminology, and present them the current state of the art and the future trends of the field. The term project assigned in this course is intended to supplement the class material. Selecting a topic of their choice, students are expected to go deeper into the study of that topic, review literature materials, standards, as well as hardware and related software packages if is the case. Another goal of the project is for the students to get the chance in this course to explore a topic of their choice and use the background gained in this class to continue on a senior project. The course project has a total of three due dates, one for topic selection, one for a draft and one for the final submission. The instructor offers feedback to the students after their topic and draft submission, helps the students to refine their topic selection and what content the final project will cover, and also offers assistance along the way based on students requests. Students are asked to submit a final report, but depending on their project they may as well include hardware development or software code with their submission. They are also required to prepare a PowerPoint presentation, and present live their project during the last lecture time. Especially for Fall 2020 semester, due to all online course delivery due to the health pandemic, the final live projects' presentation was a great virtual event, students getting the chance to see each other, talk to each other, present their results and learn from each other, and was highly appreciated by everybody.

The course project may end up in one of the two main categories. Some students decide on reference based studies rather than design projects, which is a fine choice for this course project because in such case students are expected to research in details their topic, and by doing so they build up background for an eventual senior project, or they complement the material studied in the course. Another group of students decide on actual design projects, which still require a study portion for any background part not covered by the course, but these projects go further into designing and developing an original project with the use of the new material learned. Among these projects there are good chances for several of them to be further extended into senior projects. Students that are taking this course in parallel with the actual senior project course, and who have already selected a capstone project topic, may still choose to identify the communication aspects of their senior project and make that portion of their senior project the focus of the course project. This is also a very good option, for the two projects to complement each other, because the student can use the learning and feedback from this course to enhance the ongoing senior project.

The wireless communications course was offered in the new format in fall 2019 and fall 2020. First offering was more of a pilot course and a small group of students took the course, only 7 students. From this group four students chose to study in details specific wireless protocols, such as Bluetooth, LTE and WiMax. The presentations of these protocols to the class were excellent additions to the material presented in the class, since the course had not enough time to cover them in the lectures. Two of the students chose to learn more about software defined radios and another student decided to investigate antenna design. For the software defined radios (SDR) projects the instructor provided the students with hardware equipment and they learned to operate the equipment and to experiment using the Matlab software. Students made demo to the class with radio received signals and spectrum analysis. For the antenna design, the student decided on building an actual multi-element collinear array antenna and he made a live demo using it to receive a TV station. From the group of seven students two of them continued their class projects into senior projects. One was software defined radio related, and the student continued with a senior project to design an SDR based signal detector, with focus on drone detection. The other project continued into a senior project was the antenna one, and the student pursued a broad study on antenna design, built 5 antennas, from folded dipole, multi-element array, Yagi Uda to quadrifilar helix antenna. Standing wave radio testing was conducted for tuning for all five antennas built, and Feko and Matlab software packages were used for modeling and analysis.

The second semester the course was offered the enrollment was much larger, with 22 students in the class. Again, there were either study type term projects, as well as design projects. Among the studies, the following topics were researched by the students: SONET protocol, 5G technologies, Lidar and applications to self-driven cars, investigation of optical communications and data modulation, Bluetooth protocol, software defined radio studies based on RTL-SDR with Matlab software, FEKO software for antenna design. Some students decided to go into studying the details of communication devices such as digital walkie –talkie or a Garmin hound tracking device. There were several design projects in the class and they were on the following topics:

- The building of *a complete crystal radio*, which included an antenna, a resonant circuit built from scratch including the building of a variable inductor, and with the use of galena crystals for the point contact crystal rectifier, a high impedance earpiece used as a listening device, and the design of a common emitter amplifier to be used for radio signal amplification. While redoing the steps of the very first radio technology, this project gave the student the opportunity to research several theoretical areas, and to use his hands-on skills in building and tuning all the components. This project will be further continued by the student as undergraduate research and eventually may lead to a senior project.
- *Hardware design to illustrate frequency shift keying (FSK)*. This project used a microprocessor design with a keypad to facilitate user input. The selected signal is modulated by hardware, and the signal is presented at a test point for display via oscilloscope. A simple 555 timer and cascading filter network were chosen for the frequency generation module. The design process, circuit schematic, program code, and theory of operation were included in the project. The project demonstrates that a student interested in wireless communication can construct a simple circuit to measure and test the fundamental

elements of RF generation and modulation. Student plans to develop additional modules to demonstrate amplitude shift keying (ASK) and binary phase shift keying (BPSK, and to add a power amplifier and antenna to create a model transmitter, all as part of his senior project.

- Using an RTL-SDR and Matlab software platform *a communication lab manual* was prepared. The student went into the details of preparing documentation on hardware requirements and how to install the software needed and get everything ready for experimentation, and a set of laboratory documentations for: displaying the RF spectrum, frequency tuning, amplitude modulation, frequency modulation, digital modulation methods such as BPSK, QPSK and 16-QAM. The student expressed interest in using the background he developed in using the SDR for a future senior project.
- *Serial display voltage monitor*. The project presented the use of a USB to UART converter, microcontroller, and an ADC to transmit a voltage reading from a voltage divider to a serial monitor. The purpose of this project was to demonstrate how a serial-based communication method can be used to transmit data from one device to another. The project used a custom-built PC-Board with a TI-based microcontroller, a microchip USB to UART converter, and a microchip 10 bit-ADC. The Serial data was displayed using TI's CCS IDE, and the code for the microcontroller was developed also using the CCS IDE. The student working on this project has the intention to use the work developed in this term project, along with the background from another course term project, into a future senior project.
- *Decoding ADS-B signals for aircraft tracking*. In this term paper the student mostly went into the details of the communication protocol Mode Select Beacon System for transmitting/receiving ADS-B (Automatic Dependent Surveillance-Broadcast) signals. As hardware component a NESDR SmarTee XTR SDR was chosen. The student considers to further use a RTL_SDR along with a quadcopter drone to test the receiving of signals at various altitudes for his senior project.
- *Handheld radio range extension*. Students working on this project used a BaoFeng UV-5R two-way handheld amateur radio. They designed a counterpoise to transform the monopole antenna into a dipole antenna for the device. Other than their hardware design the students did extensive testing of their devices for the operation range.
- *Bluetooth environmental control system*. This project was in fact a subpart of a senior project completed in parallel in the same semester, which focused on flood detection and damage mitigation system. For this course project the student developed a system for data transmission from a remote sensor using Bluetooth communication, as a part of an environmental monitoring station. The Arduino based design with data sensors, layer protocols, coding, advantages and disadvantages of the design, were all discussed in the project.
- *UHF Antenna design with FEKO software for portable handheld devices*. For this term project the student mostly familiarized himself with FEKO software and researched the problem. He is considering using the background developed into a future senior project focused on the design of multi-band antennas.

The wide range of term project topics shows that students have a strong interest in communication related applications and that they are seriously considering to further investigate such topics in their senior projects. They often combine their other interests, such as electronics

or microprocessor based design, into communication applications. Personal interests also play a very important role in selecting the topics. One interesting example is of a student that enjoys hound hunting and he wanted to build his own tracking device for his dogs, and eventually come up with a cheaper version to the commercial available options. For various reasons this project ended up mostly as a study of existing devices, but the student was very excited about the project and along the way he learned a good deal on the communication systems side.

Based on student feedback from an end of the semester survey, it can be concluded that students appreciated very much the broad coverage of communications topics of this course, the flexibility of the term project which allowed them to build on their background in areas of their own interest, or to develop a step stone towards a future senior project. Very few of the students in the course were in fact pursuing the communication systems track, but they all recognized that communication systems are often design components of larger purpose systems and learning how to work with these systems will help them later to integrate such components in more complex projects. The survey conducted had open end questions about the course in general, about project topic selection and the plans for the senior project. Students appreciated the comprehensive presentation of the course and some of them made comments that even if they are not considering pursuing communications area in their career, they understand the importance and ubiquity of these systems in the current technology, and that having a strong background in this area will help them overall in the future. The answers were split regarding the selection of the topic for the project, about half of the class making a selection based on previous background and experience, and the other half of the class making their choice based on their curiosity and interests for the future. About a third of the class considered to continue the course project into a senior project or they were working in parallel on their senior projects and the wireless communications project fit as a part of their senior project. Given that this is only one senior elective course option, and that communication track is one out of five possible concentrations, this is in fact a very high response with respect to term projects contributing to senior projects, and it is mostly the result of the communication systems being currently integrating components of so many types of applications.

Computer Networking Course Project as a Step towards Capstone Project

The computer networks course was completely redesigned in the new curriculum structure and was aligned with the new communication systems concentration. The course is offered as an elective course, and with the pre-requisites reduced to basic junior standing in the program, it is open to all EET students as well as to students in other programs as part of an EET minor. This course focuses primarily on the local and wide area networks (LANs and WANs) along with the OSI layered structure network model and a set of hands-on activities. The course content consists of three main modules: fundamental concepts of data communication and OSI-layered structure, network technologies, and network design and management. In addition, trending topics in data communication and networking, such as the Internet of Things (IoT), cloud computing, and 5G were integrated into the course curriculum. For a major part of course assessment and grading, a term-project is assigned, with the main objective to extend student knowledge and research skills in addition to the hands-on classroom activities. To complete the term project, students are

required to prepare a proposal, a mid-term report, and a final report. The semester ends with live presentations and demos of the term projects. There are several project options available to the students, and these are: hardware and software development with Arduino or Raspberry PI for IoT applications, network design with network simulator, e.g., GNS3 or NetSim, or a research paper related to data communication technologies. Most students preferred the first option, to work on specific applications with Arduino or Raspberry Pi processors. Their choice is mostly motivated by a stronger/previous background in data communication and networking, and most of the time they express their intention to extend and continue the course project into a senior project. Another group of students decided to work on term papers related to trending and emerging communication technologies, such as network security, the future of network protections, and electronic passport. For spring 2020, when the course was last offered, no student chose the network design with a network simulator for the term project. It was mainly because students were not confident in their ability to incorporate such simulators in future senior projects and they prefered to work on projects that were more familiar to them and they had higher confidence that will further assist them in senior projects. An end of the semester student survey showed that students had a positive attitude towards the course project administrated, appreciated its flexibility, and stated that the project assignment significantly contributed to improve their knowledge in data communication and networking. Also, some students chose to continue their course projects into senior projects and appreciated the choice to apply the background and initial setting developped in this course as a step ahead towards their senior projects. Some examples of the projects that students worked on for this course are briefly presented as follows:

- *Smart Home Automation Server.* For monitoring and control, all smart devices require a server to connect the user to the smart device. Usually, this is provided by an Internet connection between the user's home network and the manufacturer's host server. If the smart device is controlled and monitored by a protocol other than Transmission Control Protocol (TCP), a manufacturer specific hub connected to the user's home network is required to convert the smart device communication protocol to TCP, for which an Internet connection is needed. This is a significant drawback in the case of limited access to the Internet. This project investigated the possibility and cost-effectiveness of building a smart home automation server that can monitor and control smart devices without the need to communicate through a third-party server via the Internet.
- *Smart Home Hot Water Heater Monitoring System.* The goal of this project is to monitor and control a home water heater system locally and remotely. Water detector and temperature sensors are installed at the base of the water heater. The project focused on the development of software program to interfaces the Raspberry Pi processor with the sensors and with a smartphone using an app.
- *Home Security System.* The goal of this project is to cover most aspects of a home security system. This includes but is not limited to fire, smoke, electrical short-circuiting, and intruder detection. The system developed would alert the homeowners in cases of fire, smoke, and burglar detection, and notify them via text message. It would also incorporate preventive mechanisms such as turning off the power supply in case of a fire caused by short-circuiting. The system includes a smoke sensor, flame sensor, Hall-Effect current

sensor, PIR motion sensor, sonar proximity sensor, relay module for controlling power switching, GSM module for SMS-based communication, and a notification buzzer for local alerts from the Arduino Uno control unit.

- *Serial Communication between Arduino and MATLAB to Graph Real-Time Sensor Data.* This project utilizes a DHT11 Humidity and Temperature Sensor connected to an Arduino Uno processor programmed to receive the sensor data and send the information to a Windows PC. MATLAB software is installed on the PC computer and is used to program the receiving of data from the Arduino Uno and to display the real-time data graphically on the PC monitor. The Arduino Uno and the Windows PC are connected by an USB cable for serial communication. The system also includes an alarm with visual and audio alerts controlled by the Arduino Uno.
- *Surf Report: ESP8266MOD Wi-Fi Data Capture Implementation and Applications.* The main goal of the project was to use the ESP8266MOD connected to Surfline.com to capture the surf height and wave conditions and display them using RGB LED. The ESP8266MOD was used as a soft access point to establish its own Wi-Fi network. When the ESP8266MOD is booted it operates in this mode, but once it establishes the connection with the credentials provided it switches to station mode. To send, receive, and process data, the client class was used.

Smart Grids Course Project as a Step towards Capstone Project

The *Introduction to Smart Grids* is a completely new course introduced in the new curriculum structure. The course is offered as an elective course and is designed mostly to serve the students pursuing the power systems concentration. However, since the smart grids are in large part dedicated computer networks, this course is also a very nice elective choice for communication systems students. The smart grids and the networking courses are offered in alternate semesters, such that students at different stages of their studies have the option of one of such electives. The course content was designed with the focus on smart grid key areas: integrated communications, advanced components, advanced control methods, sensing and measurements, improved interfaces, and decision support. Traditional power systems courses are concentrated on the fundamental power systems components and may not cover emerging technologies, such as distributed energy resources, advanced data communication, big data, transactive control, electric vehicle, smart buildings, blockchain-based energy trading, or cybersecurity issues, which are components of the smart grid environment. The course content is structured in three parts: power grid components, communication technologies and cybersecurity, and smart grid applications. In addition to the lectures, a term project is assigned with the goal of students to design and analyze smart grid technology or related applications, such as smart home/building, smart meter, smart distribution system, microgrid, communication infrastructure, distributed energy resources (e.g., the status of rooftop PV, solar/wind penetration), electric vehicle (EV), customer engagement, smart cities, energy generation forecasting, load forecasting, and other similar topics. As part of this assignment, the students are required to complete two reports, a two-page project proposal early in the semester, and an end of the semester research paper. The semester ends with live presentations of the term projects. The course was already offered two times and most of the term projects were related to renewable energy generation and smart systems. An end of the

semester survey was conducted, and students expressed their appreciation for the course content and the introduction to the emerging smart grid technologies. Current interest in renewable energies and electrical vehicles also motivated the increased interest of students in this course. The project assignment was positively received, and students appreciated the challenge of experimenting in a new field. They considered that the knowledge and skills developed in this course will be important in their future industry careers. They also appreciated the opportunity to use this course project as a step stone for a future senior design project. Some course project examples, for which students expressed interest to consider for their senior projects are briefly presented below:

- *Modeling a Photovoltaic Generation System Using Simulink.* Until recently coal-fired plants were first choice for electrical energy generation, as the environment was not considered a relevant factor, and pollution was not a concern yet. Today, these considerations have changed, and climate changes and pollution control are driving factors for new energy developments. This has led to a surge in electrical generation research for cleaner ways to produce electricity, including technologies for solar energy generation. The goal of this project was to use Simulink software to create a model for a solar panel and to monitor the energy production and distribution of solar systems.
- *International Space Station (ISS) Smart Energy Storage.* The goal of this project was to develop a Simulink model of a smart grid to provide redundancy to the ISS power supply. The battery characteristics were taken into consideration as well as the details of the electrical system of the ISS. The simulations were generating graphs to display the performance of the smart microgrid. The Simulink implementation followed the smart microgrid structure.
- *Geothermal Energy (Geyser).* Geysers are sources of thermal energy. For this project the student studied the details of how the geysers function, how pressure is formed and how the hydrothermal explosion is generated. While harnessing geothermal energy seems a cheap energy alternative, electricity is needed for heat pumps as well as for the circulation of large amounts of water. The goal of this project was to develop an energy model for the geysers, model that can be used to estimate the energy produced and the costs, and to identify ways to minimize these costs in order to make geothermal energy efficient and safe for the environment.
- *Thermoelectric Generators Applied to the Solar Arrays of the International Space Station.* The power production aboard the International Space Station is essential for its ability to operate for multiple years. Currently, the ISS utilizes eight solar arrays to provide for its power. Alternative methods for generating energy can utilize the heat wasted by the arrays. The application of thermoelectric generators (TEG) to the backside of the solar arrays can be used to create additional source of power through simple heat transfer. This project focused on studying two different size TEG devices that could potentially serve as additional power sources for the ISS, and analyzed the output power and voltage of these devices.
- *Smart Home.* The main objective of this project was to design a smart home system to minimize operating costs, improve comfort, and simplify the use of technologies. The system developed enabled the control of various devices such as smart lighting, smart music, security system, and daily alerts and notifications.

Conclusions

Capstone projects are the most extensive products of any undergraduate engineering studies. The topic selection is probably the most difficult part of the project and it shows the most variety in the approach across programs. This paper discussed the senior project approach in an electrical engineering technology program, and how the senior elective courses on the communication systems specialization area, through their course projects, offer a pathway for senior project selection for students pursuing this are of specialization and not only.

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