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A Capstone Project: Assessment of Energy Savings from Retuning of Air Handlers

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Abstract

One of the best ways to reduce operating costs for buildings is to reduce energy consumption. Energy is used to run equipment in classrooms and laboratories, provide area lighting and hot water, but heating and cooling typically account for the largest energy use in a building.

Facilities Management at Western Carolina University (WCU) maintains over 300 air handling units (AHUs) covering almost 3.1 million square feet. These AHUs provide heating and cooling and operate continuously while their respective building is occupied. Some newer AHUs have variable frequency drives (VFDs) to reduce the current to an AHU's fan motor in order to throttle energy use when the demand for heating or cooling is low. However, some of these VFDs were only configured during installation, and run at a constant setting, regardless of the demand. WCU's Facilities Management has enlisted the help of School of Engineering and Technology in researching and determining a more energy efficient setting. During the 2015-16 academic year, a School of Engineering and Technology capstone team conducted a case study to determine potential settings for a VFD, in order to reduce energy use and electricity expenditures while maintaining a comfortable environment for students, faculty and staff.

A specific AHU in the new Health and Human Science building was selected for testing by the capstone team. It was determined that the driving force behind the actions of the VFD was feedback from the programmable logic controller (PLC). The PLC monitors air flow requirements at the zone or room level in order to control the static pressure set-point. After conducting an on-site analysis, the team collected data from the AHU through the building's automation system. The energy use of the selected AHU was recorded during November 2015 while the static pressure was set to its normal constant setting. This provided the team with control data. Then the static pressure set-point was lowered on December 1, 2015. The energy use of our experimental unit was compared to our control data. After determining that further adjustment would not affect the AHU's ability to maintain a comfortable environment, the set-point was again lowered in early April 2016. This change resulted a reduction in energy use by the AHU's supply fan, while still meeting airflow requests. The AHU is now much more responsive to demands, and can fill them quickly and efficiently. This has led to lower energy use, and thus reduced the operating costs for the entire building. This showed the potential for WCU's Facilities Management to apply a similar change to most, if not all of the other AHUs in the Health and Human Science building, and in other buildings across the campus.

This paper provides an overview of the project-based learning courses within the School of Engineering and Technology, a summary of the needs, requirements, research, analysis, and findings of this capstone team project, as well as an assessment of several student outcomes.

I. Introduction

In the U.S., electric motors consume over half of the electricity produced[1]. If heating, ventilation and air-conditioning (HVAC) applications of electric motors included, then this consumption approaches two-thirds of the electricity produced. Therefore, any effort that would help conserve energy through electric motor driven systems will have a great impact on overall economy as well as the environment. For example, according to a U.S. Department of Energy report market assessment, if all industrial motor systems run more efficiently in the U.S. by utilizing mature, proven technologies such as VFDs, energy saved annually is approximately equal to the annual energy used by the entire state of New York[2].

HVAC systems and air handlers were topic of interest and investigation in engineering education for the past two decades[3-7]. In an NSF funded project, Marcks et al. [6] presented teaching methods of control loop tuning in HVAC systems in order to improve control system dynamics and save energy. In this project, control trainers were used to expose the student to the behavior of typical HVAC control systems. It has been observed that student understanding and retention of loop tuning methods through the proposed teaching methods appears to have improved greatly. Inexpensive equipment made available for data collection in this project and basic loop tuning methods were relatively easy to learn.

In another comprehensive student team project, a university campus energy audit involving HVAC systems and air handlers was specifically discussed by Jansson et al.[8]. The student team of four majoring in electrical, civil/environmental and mechanical engineering learned the basics of building energy analysis, how to perform lighting surveys and energy audits and developed recommendations to the University's Energy Review Panel. Since all the energy being used on campus is originally unknown for each specific building, the team also completed a sub-metering analysis to prioritize which buildings on campus should be investigated first based upon their energy consumption.

The unique nature of the capstone project presented in this paper is that it details the steps for retuning a fully commercial building automation system and evaluates several student learning outcomes. Understanding the communication protocol for appropriate data logging, understanding and analyzing the functions of VFD, understanding and evaluating overall interactions within the building automation control system for AHU tuning, experimenting and evaluating new operational set-points comprise the major milestones in this study.

The following sections describe the capstone project model at Western Carolina University (Section 2), project design steps (Section 3), lessons learned, results and findings (Section 4), and Conclusions (Section 5).

II. Engineering Capstone Projects at WCU

At Western Carolina University, engineering and technology students are required to participate in a two-semester senior capstone project. Students work on a challenge proposed by a project sponsor who has been invited by the Center for Rapid Product Realization, an EDA-designated university center, to submit "real-world" problems that are open-ended, complex, require innovation and self-directed learning and are of sufficient scope to require a team approach.

Each capstone team is made up of two to four students in a multidisciplinary setting selected from four majors: electrical engineering, electrical and computer engineering technology, BS in engineering (mechanical concentration), and engineering technology. Each capstone student team works with the course instructor, a faculty mentor, and a mentor selected by the project sponsor. Student teams use a stage/gate process, progressing from a project proposal to a minimum of three conceptual designs; continuing to a preliminary design review, a critical design review, and fabrication and testing of a prototype or proof of concept; and finishing with a wrap-up of documentation, test results and modifications, if needed, to resolve any issues revealed through testing.

Students gain valuable experience by working on a "real-world" project; analyzing and solving engineering problems; learning teamwork and presentation skills; setting goals, specifying deliverables and meeting deadlines; testing and modifying their work; and achieving measurable results.

The capstone experience is implemented with two three credit hour courses: ENGR 400 Engineering Capstone I and ENGR 450 Engineering Capstone II. In ENGR 400, students from capstone teams, formulate project specifications, develop a work plan and individual roles, and potential design solutions.

The project presented in this paper was sponsored by WCU's Facilities and Management division. The team members included one Electrical and Computer Engineering Technology (ECET) major and another Electrical Engineering (EE) major.

III. Capstone Project Objectives and Design Steps

WCU's Facilities Management department sought an opportunity to reduce operational costs and to reduce the energy use of its heating and cooling systems. The workhorse of these systems are building's air handling units, which provide heating and cooling and operate continuously while their respective building is occupied. Some newer air handlers have variable frequency drives (VFDs) to reduce the current to the handler's fan motor in order to throttle energy use when the demand for heating or cooling is low. However, some of these VFDs' settings were only configured during installation, and run at a constant setting, regardless of the demand. The capstone team was tasked with designing and performing an energy study to:

- Determine baseline usage of a typical air handler
- Gather baseline energy usage data
- Analyze data and propose possible changes to the air handlers for reducing operation costs
- Gather energy usage data using proposed changes
- Analyze data to quantify energy savings
- Generalize steps to possibly incorporate changes in other buildings on campus
- Continue to provide a comfortable environment for occupants
- Demonstrate reduction of costs by generating energy use statistics

The facilities management department selected the newly constructed and isolated Health and Human Sciences building to begin its test. This building has the most advanced building automation system on campus. The building is also equipped with eleven air handling units; each designated for a specific zone. Facilities Management was wary of performing testing on a handler that covered large hallways, foyers, atriums, or other wide open spaces that are difficult to maintain a constant temperature and pressure. Another consideration is that some air handlers cover spaces that require special settings. For example, there is a large locker containing certain biological specimens which require that they be stored at a constant temperature, even at night. The second air handler on the third floor (AHU-32) was selected as the test unit due to its area of coverage being only classrooms and offices. Figure 1 illustrates the overall HVAC system that is actuated by AHU-32, located in the upper portion of this figure. The unit was operating at 52% of its nominal speed at this specific instance of time.

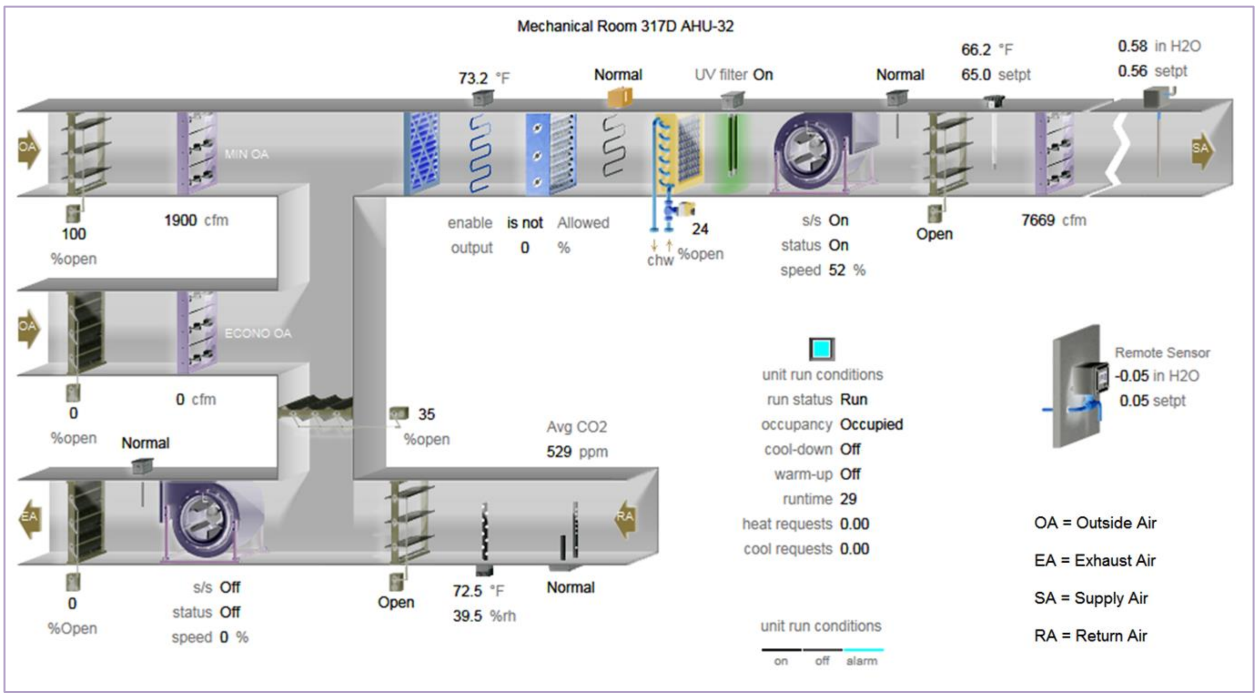

Fig 1. Graphical Representation of the Overall HVAC System Associated with AHU-32

The testing began by recording a baseline usage example during the month of November, using the building's automation system. This system controls the logic that determines the output of the air handlers, and other components of the heating and cooling system. Figure 2 shows a layout of the control system that determines the static pressure output setting, which would later be used for energy savings measures.

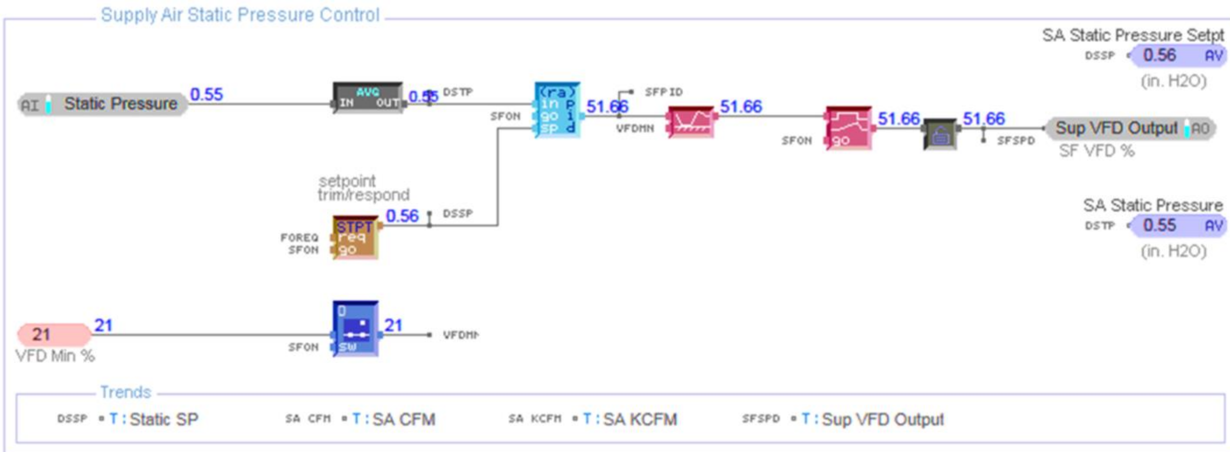

Fig 2. Supply Air Static Pressure Control Logic

The block labeled "set-point trim/respond" outputs the handler's desired pressure setting based on the minimum and maximum values set by Facilities Management. The unit of set-point is inches of water (in H2O or "), a conventional industrial measure for pressure difference between two points. Its input is Full Open Requests (FOREQ), which are requests for 100% airflow until desired pressurization is reached. These FOREQs are generated by the air handler's different zones. The air handler is set to respond only when there are at least two FOREQs. Trends in temperature, pressurization changes, and energy usage were recorded for the air handler in our study, as well as the two others on the same floor. On December 1st, the pressure set-point (the point at which the air handler will have registered that it has fully pressurized the room and slowed down its fan) was lowered from 0.75" to 0.70". Due to school holidays during winter break, when the building was mostly shut down and the needs of the air handling system were minimal, our team was able to make adjustments without having an adverse effect on occupants. We monitored the usage through the window of December through April. We came to the conclusion that the minimum setting should be lowered as much as possible in order for the system to have free rein to determine its most efficient operating mode. On April 13th, the set-point was lowered to 0.40", the lowest setting that Facilities Management was comfortable with. The changes from April were recorded into mid-May and compiled as this is when the capstone projects were due to be complete.

IV. Capstone Project Results and Lessons Learned

The pressurization trends from the April change were compared to those from the change in December and to the control month of November. Included below are some sample days that are representative of the different minimum set-point settings discussed. It is worth noting here that the air handler is only operational on weekdays from 7 AM to 10:30 PM.

The upper portions of Figures 3 through 5 display the set-point and actual static pressure of the air handler, for three different set points, respectively. The lower portions of Figures 3 through 5 display the occurrences of Full Open Requests (FOREQ). The system is set up to only respond when there are two active requests. One would want those requests fulfilled as rapidly as possible. A Static Pressure greater than zero represents the air handler actively blowing air into an area in an attempt to meet the static pressure set-point. For example, when an outside door is opened, there will be a drop in the hallway pressure, which may trigger a FOREQ.

In Figure 3, it is clear that the static pressure set-point never drops below 0.75”. This is the minimum that was programmed during installation (likely based on a blanket study performed by the manufacturer). Also note that the static pressure itself is only loosely following the set-point. The number of FOREQs show that there is almost constantly at least one request that is not satisfied, even though the handler is blowing all day. The air handler won’t react until it receives two FOREQs, so one request goes ignored while the handler blows all day. When the handler did get a second request at 11 am, it wasn’t fulfilled for two hours.

In Figure 4, the same air handler nine days after a 0.05” reduction in the pressure minimum, the set-point stays at the minimum almost the whole day. Our team took this as an indication that the air handler is capable of being satisfied at a lower pressurization level. The static pressure during this time is also constantly wavering around the minimum. There is not a single FOREQ this entire day, indicating that the handler’s zone is satisfied. While the goal of the handler may be to satisfy the needs of its area, there is an opportunity to reduce energy use by slowing down the fan when there are not two active FOREQs. In this case, the Variable Frequency Drive spins up the fan and never has it back down.

In Figure 5, a day after the additional 0.30” reduction, the set-point is actually adjusting over time. The number of FOREQs jumps up to two occasionally, but the second request is usually quickly satisfied. Since the air handler is actually changing to suit its needs instead of sticking to the minimum, our team was comfortable declaring that the air handler is now doing what its automation system was intended to do: adjust to the needs of the user *and* save energy.

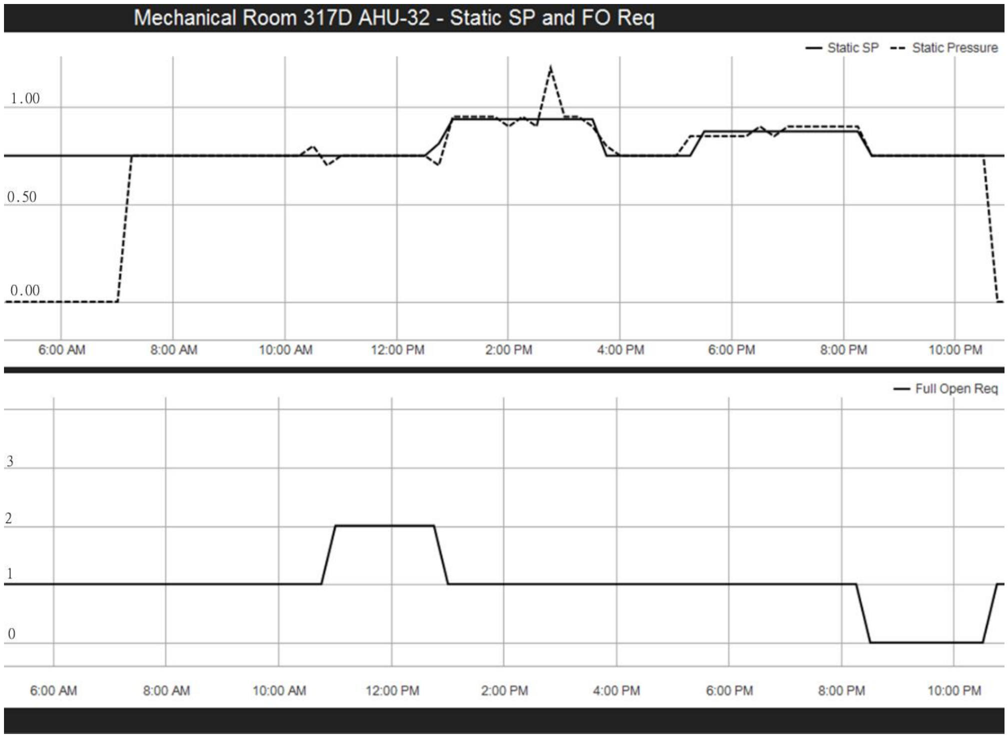

Figure 3: Actual Static Pressure, Static Pressure Set-Point (Static SP) and Full Open Requests for November 11 with a set-point of 0.75”

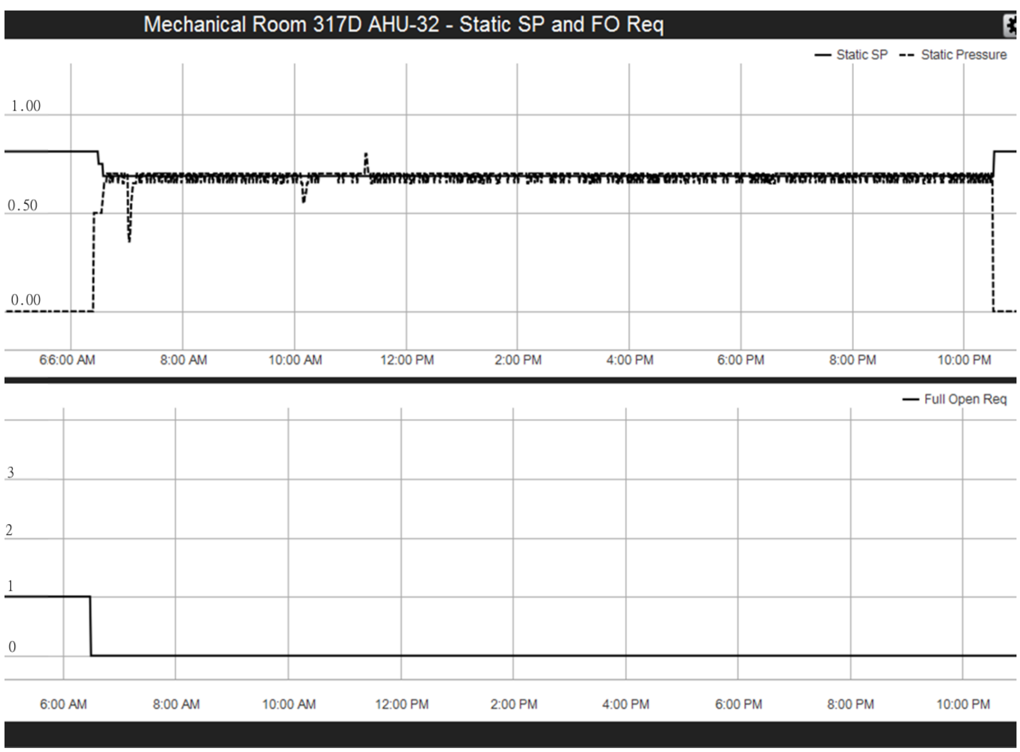

Figure 4: Static Pressure and Full Open Requests for December 9 with a set-point of 0.70”

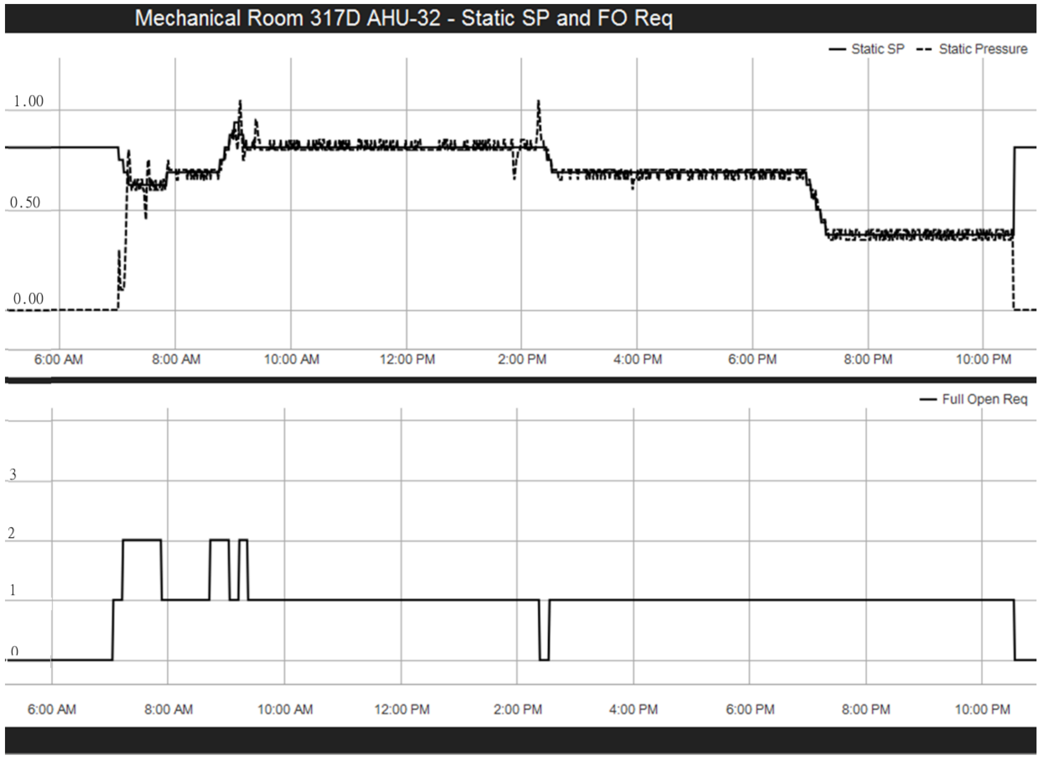

Figure 5: Static Pressure and Full Open Requests for 14 April with a set-point of 40%

Below in Table 1 are the results of our setting reductions. 0.40" set-point assessment was only done for a duration of 2 weeks.

Table 1: Energy Usage and Savings based on Static Pressure Set-point

Static Pressure Set-point	Average Energy Use (kWh)	Demonstrated Reduction
0.75	38.644	--
0.70	35.173	8.98%
0.40	34.333	11.16%

Figure 6 shows daily energy usage before and after the set-point change. The set-point was 0.75" before December 1 and 0.70" after that. Note that, in addition to the overall group of days using less power after the change, the curve trend is flat against what appears to be a minimum. One key point to note is that before the change, there were no days in which the energy usage was less than 30 kWh. After the change, there were over a dozen days in which the energy usage was below 30 kWh. There are still opportunities for energy reduction, but this study has shown to be a success.

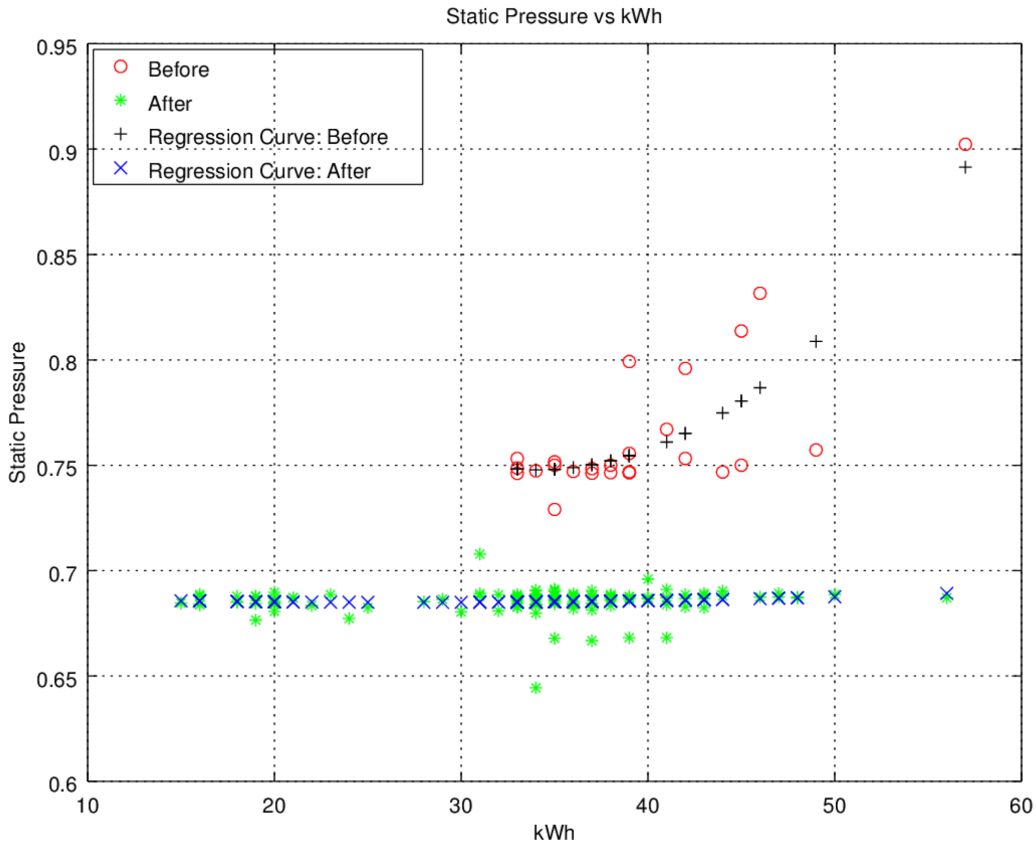

Figure 6. Static Pressure Settings vs. Energy Use, Before and After

Compared to the initial usage value of 34.33 kWh/day in Table 1 for 0.40" set-point, another post-analysis done over the duration of approximately 5 months right after project completed in May 2016 showed an average daily usage of 32.212 kWh or 16.64% reduction from original levels.

V. Assessment of Student Learning Outcomes

ABET-EAC student outcomes c, d, g and k were assessed for the one EE major on the capstone team, and ABET-ETAC criteria a, f, g, and k were assessed for the one ECET major on the capstone team. To assess these student outcomes, several performance indicators were developed as shown in Tables 2 and 3. Rubrics were developed for each performance indicator (PI). Sample rubrics are shown in Tables 4 and 5. The activities included in the assessment are student reports, oral presentations, and poster presentations. For each student, possible scores of 4-Excellent, 3-Satisfactory, 2-Marginal, 1-Unsatisfactory were assigned to each performance indicator. The scores for each performance indicator were averaged to compute the score for each student outcome. For example, PI scores for k1 through k4 were averaged to compute the score for ABET-EAC outcome k. All average scores were 3.0 or above for each outcome. The aggregate score for all student outcomes combined was 3.55 out of 4. Outcome g is common to both students. The average score for outcome g was 3.53 out of 4.

Table 2. Assessed EAC Student Outcomes and the Associated Performance Indicators

ABET Student Outcome	Performance Indicator
EAC (c) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	(c.1) An ability to design a system, component, or process to meet desired needs.
	(c.2) An ability to apply realistic constraints within a system, component, or process design.
EAC (d) An ability to function on multidisciplinary teams	(d) An ability to function on multidisciplinary teams
EAC (g) An ability to communicate effectively	(g.1) An ability to produce written technical reports
	(g.2.) An ability to present oral reports
	(g.3.) An ability to apply graphical communications techniques
EAC (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	(k.1) An ability to select and apply the knowledge of the discipline to broadly-defined engineering activities
	(k.2) An ability to select and apply the techniques of the discipline to broadly-defined engineering activities
	(k.3) An ability to select and apply the skills of the discipline to broadly-defined engineering activities
	(k.4) An ability to select and apply the modern engineering tools of the discipline to broadly-defined engineering activities

Table 3. Assessed ETAC Student Outcomes and the Associated Performance Indicators

ABET Student Outcome	Performance Indicator
ETAC (a) an ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities	(a.1.) - An ability to select and apply the knowledge of the discipline to broadly-defined engineering technology activities
	(a.2.) - An ability to select and apply the techniques of the discipline to broadly-defined engineering technology activities
	(a.3.) - An ability to select and apply the skills of the discipline to broadly-defined engineering technology activities
	(a.4.) - An ability to select and apply the modern tools of the discipline to broadly-defined engineering technology activities
ETAC (f) an ability to identify, analyze, and solve broadly-defined engineering technology problems	(f.1.) - An ability to identify broadly-defined engineering technology problems
	(f.2.) - An ability to analyze broadly-defined engineering technology problems
	(f.3.) - An ability to solve broadly-defined engineering technology problems
ETAC (g) an ability to communicate effectively	(g.1.) - An ability to produce written technical reports
	(g.2.) - An ability to present oral reports
	(g.3.) - An ability to apply graphical communications techniques
	(g.4.) - An ability to identify and use appropriate technical literature
ETAC (k) a commitment to quality, timeliness, and continuous improvement.	(k.2) - A commitment to timeliness

Table 4. Rubric for EAC Outcome K

k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. Performance Criteria (k.1.) - An ability to select and apply the knowledge of the discipline to broadly-defined engineering activities Performance Criteria (k.2.) - An ability to select and apply the techniques of the discipline to broadly-defined engineering activities Performance Criteria (k.3.) - An ability to select and apply the skills of the discipline to broadly-defined engineering activities Performance Criteria (k.4.) - An ability to select and apply the modernengineering tools of the discipline to broadly-defined engineering activities					
REF	**Performance Indicator**	**Excellent (4)**	**Satisfactory (3)**	**Marginal (2)**	**Unsatisfactory (1)**
k.1.	*CPI #1: The student shall be able to apply fundamental technology principles in solving advanced engineering problem(s)*	Able to articulate and apply fundamental principles of the engineering discipline; demonstrates application of engineering principles in advanced problem solutions; able to relate theoretical concepts to practical problem solutions; demonstrates ability to apply prior knowledge to new problems.	With minor assistance, able to articulate and apply fundamental principles of the engineering discipline; acceptable ability to apply engineering principles to advanced problem solutions; with minor assistance, able to relate theoretical concepts to practical problem solutions and apply prior knowledge to new problems.	Exhibits difficultly in articulating and applying fundamental principles of the engineering discipline; difficulty in applying engineering principles to advanced problem solutions; difficulty in relating theoretical concepts to practical problem solutions and applying prior knowledge to new problems.	Exhibits much difficultly in articulating and applying fundamental principles of the engineering discipline; difficulty in applying engineering principles to advanced problem solutions; difficulty in relating theoretical concepts to practical problem solutions and applying prior knowledge to new problems.
k.2.	*CPI #1 : The student shall be able to apply fundamental technology techniques in solving advanced engineering problem(s)*	Able to select appropriate equipment and instrumentation required to perform experimentation; able to use laboratory equipment manuals to discern capabilities and limitations of laboratory equipment; demonstrates safe laboratory practices; maintains currency with regard to computer usage; able to learn and implement process simulation software.	Generally, able to select appropriate equipment and instrumentation to perform experimentation; may need minor assistance in determining capabilities and limitations of laboratory equipment; demonstrates safe laboratory practices; maintains currency with regard to computer usage; may need minor assistance with learning and implementing simulation software.	Has difficulty in interpreting equipment specifications and how they apply to applications; needs supervision from instructor in use of laboratory equipment; adheres to basic safety procedures; lacks thoroughness in experimentation procedures and documentation.	Unable to interpret equipment specifications and how they apply to applications; needs supervision from instructor in use of laboratory equipment; lack of attention to basic safety procedures; lacks thoroughness in experimentation procedures and documentation.
k.3.	*CPI #1 : The student shall be able to apply fundamental technology skills in solving advanced engineering problem(s)*	Able to select appropriate equipment and instrumentation required to perform experimentation; able to use laboratory equipment manuals to discern capabilities and limitations of laboratory equipment; demonstrates safe laboratory practices; maintains currency with regard to computer usage; able to learn and implement process simulation software.	Generally, able to select appropriate equipment and instrumentation to perform experimentation; may need minor assistance in determining laboratory equipment; demonstrates safe laboratory practices; maintains currency with regard to computer usage; may need minor assistance with learning and implementing simulation software.	Has difficulty in interpreting equipment specifications and how they apply to applications; needs supervision from instructor in use of laboratory equipment; adheres to basic safety procedures; lacks thoroughness in experimentation procedures and documentation.	Unable to interpret equipment specifications and how they apply to applications; needs supervision from instructor in use of laboratory equipment; lack of attention to basic safety procedures; lacks thoroughness in experimentation procedures and documentation.
k.4.	*CPI #1 : The student shall be able to apply tools such as unique laboratory equipment, software packages, Gantt charts, in solving advanced engineering problem(s)*	Uses computer applications effectively in assignments and/or projects; demonstrated ability to learn and implement process simulation software; demonstrated ability to apply advanced test equipment in experimentation; highly effective in resourcing and/or researching particular information.	Uses computer applications effectively in assignments and/or projects; with minor assistance, has ability to learn and implement process simulation software; with minor assistance, has ability to apply advanced test equipment in experimentation; acceptable ability in resourcing and/or researching particular information.	Difficulty applying computer applications in assignments and/or projects; difficulty in learning and implementing process simulation software; need assistance with applications of advanced test equipment in experimentation; resourcing and/or researching particular information is time consuming.	Difficulty applying computer applications in assignments and/or projects; difficulty in learning and implementing process simulation software; unable to comprehend the application of advanced test equipment in experimentation; resourcing and/or researching particular information is time consuming.

Table 5. Rubric for ETAC Outcome G

g. an ability to communicate effectively

Performance Criteria (**g.1.**) - An ability to produce written technical reports

Performance Criteria (**g.2.**) - An ability to present oral reports

Performance Criteria (**g.3.**) - An ability to apply graphical communications techniques

Performance Criteria (**g.4.**) - An ability to identify and use appropriate technical literature

REF	Performance Indicator	Excellent (4)	Satisfactory (3)	Marginal (2)	Unsatisfactory (1)
g.1.	*CPI #1: The student shall be able to compose a well structured and organized written technical report.*				
	Organization	Structure is clear, appropriate and effective; logical presentation of information; main points and conclusions well organized; information in report is complete.	Structure is clear and appropriate to purpose of document; most major points are cited; logical presentation of information; all necessary information is included in report.	Basic structure is evident, but needs improvement; needs improved flow of information from main points to conclusions; some topic areas need more information regarding topic being discussed.	Report lacks good structure from beginning to end; difficult to make sense of conclusions based on data presented.
	Data Displays	Data displays are excellent; makes use of computer-generated displays; interpretation of data is well explained; appropriate mathematics, as necessary, is well applied.	Data displays are generally good; makes use of computer-generated displays; interpretation of data, in most cases, is correct; mathematics, as necessary is applied.	Display of data can be improved; difficult to draw conclusions based on data display; limited application of mathematics.	Poor display of data; interpretation of data is extremely difficult; mathematics is applied incorrectly.
	Report Format	Report format according to requirements; all aspects from cover page to any appendices are included.	Primary elements of the report are included; information in report is adequate.	Significant elements of report are not included; information in report is minimal.	Significant elements of report are not included; information in report is minimal.
	Summary or Conclusions	Conclusions are well thought out, stated very well, and understandable based on data presented.	Generally, conclusions are consistent with data in report.	Conclusions are inconsistent with data in report and reflect limited knowledge of report content.	Conclusions are inconsistent with data in report and reflect limited knowledge of report content.
g.2.	*CPI #1: The student shall be able to present technical information in a logical manner and demonstrate a satisfactory level of knowledge of the pertinent subject matter*				
	Organization	Excellent organization; clear introduction; main points well stated; logical process of presenting information; clear summary and conclusions.	Satisfactory organization; clear introduction; generally, main points are clear; information flow is acceptable but could be improved; clear conclusions.	Organization somewhat haphazard; more clarification of main points; more order to flow of information; conclusions could be stated more precisely.	Introduction not clear and concise; some main points and conclusions are not clear; difficulty in following logic of presentation.
	Delivery	Natural, confident delivery; emphasizes main points of presentation; excellent use of volume and pace of presenting information; speaks directly to audience.	Matter of fact delivery; covered main points of presentation; pace of information is acceptable; can improve delivery mechanics.	Lacks confidence as a presenter; delivery mechanics need improvement; covered all necessary information; needs more awareness of audience.	Low voice, occasionally inaudible; some distracting gestures; pronunciation not always clear; difficult to follow presentation; not aware of audience.
	Information/ Data Displays	Computer-based presentation; excellent display of information and data displays; displayed materials easy to read and interpret. conclusions related very well to data.	Computer-based presentation; display of information and data were acceptable; generally, displayed materials were readable; conclusions were based on data displayed.	Computer-based presentation; data displays need improvement, difficult to comprehend at times; conclusions need to be more specifically related to data.	Poor computer-based presentation; conclusions drawn from data displays were incorrect; at times, confused about the information being presented.
	Audience Questions	Able to answer questions from the audience; very comfortable with material presented.	Able to answer questions from audience; comfortable with material presented.	Able to answer most questions from audience; difficulty with certain topics.	Inability to satisfactorily answer questions from audience.
g.3.	*CPI #1: The student shall be able to convey technical data in an appropriate graphical format, making use of engineering graphical standards, if appropriate, ([e.g. ANSI, ASTM, ASME, IEEE)*	Demonstrates excellent knowledge of computer-based technology applications in written and oral communications; maintains an excellent knowledge of computer applications; demonstrates ability to learn and apply computer graphics software as necessary; effectively used charts, tables, graphs, etc., to explain complex ideas, data, processes, or solutions.	Demonstrates a solid level of knowledge of computer-based technology applications in written and oral communications; maintains an acceptable level of knowledge of computer applications; with minor assistance, is able to learn and apply computer graphics software as necessary; incorporates charts, tables, graphs, etc., to explain complex ideas, data, processes, or solutions.	Exhibits some difficulty with applications of computer-based technology applications in written and oral communications; difficulty in learning and applying new or different software applications; limited incorporation of charts, tables, graphs, etc., to explain complex ideas, data, processes, or solutions.	Very limited understanding of computer-based technology applications in written and oral communications; extreme difficulty in learning and applying new or different software applications; limited incorporation of charts, tables, graphs, etc., to explain complex ideas, data, processes, or solutions.
g.4.	*CPI #1 : The student shall be able to demonstrate the use of creditable technical literature in an effective technical communication report or presentation*	Demonstrates ability, independently, to research and resource topic under consideration; demonstrates familiarity with journals and online resources in the technical field; includes appropriate citations where necessary; uses proper format for citations in report; appendices included in report where necessary; demonstrates ability to link content of literature to present a coherent and logical report.	With some instructor assistance, demonstrates ability to research and resource topic under consideration; demonstrates some familiarity with journals and online resources in the technical field; includes appropriate citations where necessary; uses proper format for citations in report; appendices included in report where necessary; demonstrates acceptable ability to link content of literature to present a coherent and logical report.	Exhibits difficulty in researching and resourcing topic under consideration; limited familiarity with journals and online resources in the technical field; limited knowledge regarding the use of citations in a technical report; limited knowledge regarding the structure of appendices in a technical report; difficulty in linking content of literature to present a technical report.	Extreme difficulty in researching and resourcing topic under consideration; Not familiar with journals and online resources in the technical field; limited knowledge regarding the use of citations in a technical report; limited knowledge regarding the structure of appendices in a technical report; extreme difficulty in linking content of literature to present a technical report.

VI. Conclusion

This study has documented the efforts of a student engineering capstone team to assess energy savings from retuning of the building automation system for an air handler. The results demonstrated the amount of energy savings and reduction in the campus carbon footprint as well as potential educational opportunities. As a result of the team's effort, the air handler usage is reduced by approximately 6.43 kWh/day or 2348 kWh/year. This was an excellent demonstration of a capstone project involving students solving a "real-world" engineering problem, requiring project management skills, team work, life-long learning, analytical ability, and presentation skills. Assessment results revealed that the students on the capstone team were able to demonstrate proficiency in key student outcomes related to these skills. Both students met or exceeded expectations in the assessed ABET outcomes.

Future work will involve the monitoring and analysis of multiple similar zones of which one is used for control purposes and the others are configured with different set points. This would show the impact of weather conditions on the air handlers and provide a clear view of the energy savings. Further research will include analysis of the building automation system to explore the energy saving opportunities for the air handlers across the campus.

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