# FAMU-FSU College of Engineering

# Department of Electrical and Computer Engineering

# System-Level Design Review

# EEL4911C – ECE Senior Design Project 12

Project Title: Energy Management

Team #12

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EEL4911C – ECE Senior Design Project 12

# Project Executive Summary

Florida State University is one of the largest universities in the country, and with any institution, there are many costs associated with operations and maintenance. One of the largest costs that most students or alumni do not associate with a University is the cost of energy to run a campus of this scale. FSU spends close to $30 million a year purely on energy and they even control their own 15kV distribution system. For senior design, our team was asked to help reduce this cost by implementing a Demand Side Management (DSM) system in two buildings on campus: Dirac and Shores.

As technology progresses at a high rate, one sector that has been behind the curve is the power utility. In the past few years, pressure has been put on utility users to cut down energy costs and reduce environmental impact through new technology. One of the new concepts that have been introduced is DSM, which incentivizes customers to reduce energy at peak times. The traditional utility plan used peaking power plants to adjust for energy consumption throughout peak times. Through DSM, customers try to better control their load through the use of energy efficient technologies and Demand Response (DR).

Through DR, customers curtail their energy use during peak hours to mitigate increased rates. While not all customers understand that there are different energy costs associated with periods of the day, large utilities are trying to even their load through highly inflated rates during peak hours. Another tactic to lower energy cost, is to install more energy efficient technologies. Customers can avoid paying higher energy rates purely by choosing more energy efficient devices and lighting. New technology being developed, both inside and outside the power sector, has a large contingency built around energy efficiency. It can be seen in the home, with energy star appliances, as well as in commercial practices, through the development of more energy efficient mechanical equipment.

The design team will employ various methods of DSM to lower and even out the energy use of the targeted buildings. The goal for the team is to design a system, that when installed, will see finical return within a span of 7-8 years. Through economic analysis, one should be able to forecast the financial benefits of the system depending on local rate tariffs and different incentives that are provided through Tallahassee Utilities. The system will be able to store data points, which are captured through a Siemens control system, to analyze efficiency and environmental impact.

The end product will be a DSM system that saves the University money, lowers their environmental footprint, and provides a model for other buildings across the campus.

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# 1 Introduction

## Acknowledgements

The design team would like to thank Dr. Omar Faruque and Mr. Jim Stephens for their contributions so far to the project. These individuals have given the team much needed guidance and instruction on various aspects of the project. Mr. Stephens is supplying the team with the funds. The team would also like to thank the University for allowing the use of two buildings for our project implementation.

## Problem Statement

This project is to design, implement, and evaluate a demand side management program for two large buildings on the Florida State main campus. This project will collaborate directly with the FSU Utility department in order to implement a solution that will be able mitigate the demand of power for the buildings mostly during the peak energy usage times. The main goal of this project will be to create a design specifically tailored to each building that will be able to substantially lower energy use not only during peak demand, but possibly have an energy use average that is lower than the current average.

The number one priority of this project is to reduce the energy costs associated with running the University. The University as a multi-million dollar annual budget for the utility bill associated with electricity. The University is looking into ways to shave this bill down. The utility tariff that FSU is currently on must be taken into account when designing the Demand Side Management system. The design team has been tasked to implement a DSM scheme in two buildings on campus: Dirac and Shores. There are a few items that must be considered: critical loads in each building, the current systems implemented in the buildings along with the systems’ capabilities, and a way to capture and store relevant data.

There are a few different techniques that can be employed to decrease the overall energy use throughout the two buildings. Using the existing Siemens system in place, there are many different ways to approach a solution. The system can be used to control various loads that are in the building such as water pumps and large ventilation fans. Other loads that can be included in the system could be classroom components, computers, and vending machines. Other non-central solutions can also be employed such as motion activated lighting. The Siemens system uses Power Process Control Language (PPCL) for programming the different functions of the DSM design.

## 1.3 Operating Environment

Some of the existing components of the Siemens system are housed in the same rooms as the water pumps and the air handlers. This is a dry room that is weather protected and stays a steady temperature throughout the year. Any equipment placed throughout the building will be in a climate controlled environment. Equipment should still be fairly sturdy/reliable, as equipment control rooms are often only checked on average once every three months. The team will ensure that all products implemented are stored in their recommended operating environment.

## Intended Uses and Users

The DSM design will contribute to cost savings in the utility cost aspect of running the university. It is intended to reduce the costs attributed to energy usage. It will ensure that the total peak demand charge is lower each month by implementing a DSM design in the two buildings chosen. The system will have the capability of monitoring and recording data such as energy usage throughout the day, temperature in the different rooms and spaces, and possibly CO2 levels throughout the building.

This system will be maintained by people with the proper experience and the end user/implementer will be a knowledgeable engineer with experience with the FSU Siemens system. There will be no one working on the system without the proper authority or know-how.

## Assumptions and Limitations

Assumptions: The first assumption the design team has had to make is that the tariff rate FSU is currently on will not change its basic structure. The rates may go up; however, this should not affect the design at all. Any major electricity tax breaks or breakthroughs in the efficiency of natural gas could lower price, however utility companies are often monopolies within their respective area with little incentive to do so. When writing a program, the writer usually assumes that the data received is correct. This is not always the case. For example, a temperature sensor could constantly read 75 deg F or could read 100 deg F. The program will make assumptions based off of the readings at the given time even if they are incorrect. Any issues similar to this must be fixed as quickly as possible.

Limitations: There are quite a few limitations that must be considered. For starters, the buildings environment must be maintained. The users of the building want a nice, comfortable environment to work and learn in. The university gets a 7.5% discount on the energy bill for not generating power itself, which eliminates the viability of using renewable energy sources, namely wind and solar with regards to FSU. Another limitation is the supercomputer in the Dirac building. This computer is often making computations for various scholars at the university and is considered a critical load. Not only does the supercomputer have to remain properly powered, but the room it is housed in must have the proper temperature and ventilation.

## Expected End Product and Other Deliverables

The end product will be a system that adapts to a given set of inputs and mitigates the peak demand on a daily bases to reduce the costs attributed to energy use by the university. This design will ensure that no critical loads are affected and that the Quality of Life in the buildings will be maintained. It will be up to the University to determine whether our system gets implemented. We will also deliver our report and lab notebooks for the project.

# System Design

## 2.1 Overview

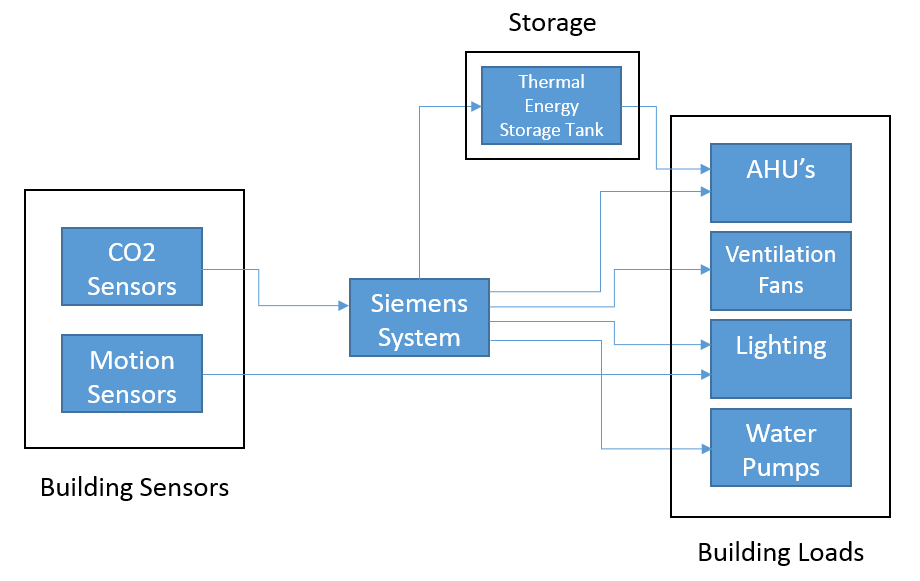


Figure - Top Level Block Diagram of Design

The diagram above shows the top level design of the proposed system. We will utilize the existing Siemens system to integrate and control the different components of the system. The CO2 sensors will be connected to the system to determine the current atmosphere in the building. The ventilation fans and water pumps will be connected to variable speed drives whose speed will be controlled by the Siemens system. The thermal energy storage tank will be connected to the central water supply.

## 2.2 Major Components of System

### 2.2.1 Sensors

There are a few different sensors that will be utilized in the design. Each sensor will be responsible for collecting the necessary motion or air quality data to determine the building occupancy. This data will be sent to the Siemens system and analyzed to react to changing building environments.

There will be two main types of sensors utilized in the buildings: CO2 and motion sensors. The CO2 sensors will be duct mounted and will measure the concentration levels of the return air to the air handler units in ppm. The range of most CO2 sensors will be from 0 to 2000 part per million.

Motion sensors will be installed in the hallways and other sparsely populated areas throughout the buildings. Rather than relaying information back to the Siemens system, the motion sensors can be tied in directly to the lighting to reduce power consumption when there is no occupancy in the areas of observation.

### 2.2.2 Storage Tank

The Thermal Storage Tank is another major component of our design. The tank will act as an “energy storage” device by storing water during non-peak times. Once the peak time of the day approaches, the HVAC system will then pull water from the storage tank to maintain the QOL in the building.

### 2.2.3 Motors and Motor Control

The ventilation motors and water pumps will be upgraded to allow for more precise control of the motors. This will provide a few different benefits for the system. The system will be able to curtail the power usage of the motors by adjusting for the needed ventilation requirements based on the data received from the sensors throughout the building. To do this, variable speed drives will be implemented in the design.

### 2.2.4 Lighting

The lighting system in the buildings utilizes fluorescent fixtures. While fluorescent fixtures are fairly energy efficient, there can be an energy savings if the lighting used LED technology instead of fluorescent. LED lighting has the benefit of less power consumption while having a similar light output.

The needed lighting in the different areas of the buildings can also differ. This is where the motion sensors tie into the lighting system. If there are no occupants in a room or area, then the lights in that room or area have no reason to be on.

## 2.3 Subsystem Requirements

### 2.3.1 Subsystem: Variable Frequency Drives

The purpose of adding variable frequency drives is to reduce power being consumed by the drives by adjusting to the demand in real time. This is accomplished by reducing the speed of the motor. This will greatly reduce the total energy consumed by the electric motors.

#### 2.3.1.1 Interface Variable Frequency Drives with Siemens System

The system must be able to interface with the current Siemens system in order to control the variable speed drive and to write software to correspond with demand on the system.

#### 2.3.1.2 Monitoring Software for Variable Frequency Drives

Monitoring software will be used to determine the speed and energy usage of the drive throughout the day. This will allow accurate readings in order to analyze the cost savings and monitor the hardware to ensure proper functionality.

### 2.3.2 Subsystem: Load Scheduling

Load scheduling can be used to mitigate peak demand costs as well as serve as a tool to create a more even load. One will need to observe which non- essential tasks that are performed throughout peak demand can be scheduled for times when the load is less. The various loads that can be on a specific schedule such as some lighting or computers will be shed at appropriate times. Another design aspect is to shift the large loads in the building to non-peak hours. When the peak energy usage of the day approaches, the system should also react in a way to ensure the peak is mitigated effectively. This would include starting to pull cold water from the thermal storage tanks and reducing ventilation fan speeds if possible.

#### 2.3.2.1 Software for Load Scheduling

Software must be implemented to track and communicate with the different loads throughout the buildings. This software will be on the Siemens system. The loads include all motors (ventilation fans, water pumps, any power hungry motors). This will allow a flexibility as to when the loads will be shed or brought online.

### 2.3.3 Subsystem: Thermal Storage

Thermal storage tanks are a financially responsible and efficient storage option for energy. This will allow for storage of energy in the form of cold water during off peak times and use of the stored energy during peak times. This could dramatically improve energy costs since energy use during peak times can be attributed to a multitude of buildings needing to maintain their indoor environment.

#### 2.3.3.1 Scheduling of Storage

The times at which the water in the tanks can be stored and then released to maximize the reduction of energy usage must be analyzed and set. The times will change based on the projected valley and peak for the day.

#### 2.3.3.2 Software and Interfacing with Thermal Storage

Software must be implemented to monitor the condition of the storage tank. Some relevant information from the thermal storage tank would be: water temperature, water level, and flow rate. Sensors for each of these data points must be implemented to work with the Siemens system. The Siemens system must also be able to communicate to the thermal storage system when to engage.

### 2.3.4 Subsystem: Lighting Renovation

Lighting renovation could make a significant impact to both off peak and peak loading of the building. The lighting renovation will provide a reduction in overall energy usage as well as provide a demand charge reduction due to a lower peak.

#### 2.3.4.1 Adding Lighting/Motion Sensors

Motion sensors will be added or optimized to decrease lighting needs throughout the building. This should be done in areas that are primarily vacant. The motion sensors would be implemented in a decentralized solution i.e. not connected to the Siemens system.

#### 2.3.4.2 Control of Lighting

The lighting will be controlled through dimming switches or through turning off the lighting when areas of a building have sparse occupancy or is not in use. The motion sensors will be utilized in order to determine occupancy in certain areas of these buildings. When a person is detected, the lights should automatically come on. After there is no movement for a certain amount of time i.e. 2 minutes, the lights should dim or shut off automatically.

### 2.3.5 Subsystem: Ventilation Control

Ventilation control can create a large impact on the load for the buildings. One must consider many different components for comfort level in the building, but if the approach is sound, then it can provide a large economic impact.

#### 2.3.5.1 CO2 Sensors for Ventilation Control

Installation of CO2 sensors can be an addition to the Variable Frequency motors installed in the previous sections. These CO2 sensors will provide data to determine the amount of airflow required. The speed of the fans can be varied to maintain the minimum airflow requirements.

#### 2.3.5.3 Monitoring Software for Ventilation Control

Software must be implemented to track and monitor the data that will be produced from the Siemens system pertaining to ventilation and atmospheric conditions in the building. This will allow for efficiency improvements by adjusting to the pertinent data produced by the Siemens system. This will also allow real time updates to the Siemens system for immediate action to reduce the demand of the building.

## 2.4 Performance Assessment

The main way to test if our system meets the needs is to perform an economic analysis. Since the scope of our project is limited to the design phase, a true analysis of performance will depend on speed of implementation of the system, even then only a couple of months will be able to be tracked for a system designed to pay itself off over a time-frame of 7 years.

To determine whether a part should be implemented, you can:

1. Analyze the amount of power that a specific component will save over the course of each average month (taken from average data from last few years), the peak power difference on average should also be analyzed.
2. Calculate new costs based off of new peak and total power estimate
3. Subtract new costs from old costs to determine power saved over an average month.
4. Estimate how long system will take to pay off itself – if time is <7 years, then the technique is viable.

To analyses the savings from an already implemented system, simply compare the total power usage before a system was implemented to power usage after a system was implemented, then calculate the savings from the standard FSU rate plan.

## 2.5 Design Process

Some decisions have been made regarding the project:

* Decided on what modifications in the buildings are the most viable and cost-effective:
  + Thermal Storage Tank
  + LED Lighting
  + Motion Sensors in sparsely populated areas
  + Duct-mounted CO2 sensors
  + Variable Speed Drives for any water pumps or ventilation fans that are fixed speed

Some decisions still need to be made:

* Need to come up with a Load Scheduling plan. There are many aspects involved in this:
  + Must find a way to accurately predict when the daily peak will occur
    - This can be done by analyzing old data or even detecting when a peak is approaching on a daily basis using some kind of method
  + All lighting, Quality of Life, and critical loads must be maintained
    - Need to find the minimum standards for the lighting and quality of life

# 3 Design of Major Components/Subsystems

### 3.1 Sensor

#### 3.1.1 Sensor Interface

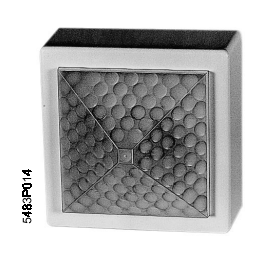
Some sensors will need to interact with the current Siemens system that is implemented throughout the FSU distribution network. There are already over 800,000 data points on the system, and with the addition of these sensors, the team will add on more pivotal data in order to have an accurate DSM program. These sensors will provide feedback on the Siemens system, which will then be sorted, and sent to a controller that will be able to implement it on the algorithms that will be designed to shed and shift loads.

It is necessary to purchase hardware that will easily and accurately interact with the Siemens system. These data points will be used to keep building and living conditions in a specified range, that are crucial to both the occupants and the building administration. Therefore, the sensors most also be tested and reviewed once implemented to ensure accuracy and correct installation.

The group will need to work with the Controls Engineer at FSU Utilities to create code on the Siemens system, in the Siemens proprietary code, to sort the data into useful components. This means accurately laying out system level design blocks to be implemented, by their Controls Engineer, once the sensors are installed. The code must then be tested and reviewed with the design requirements to ensure accuracy.

#### Sensor Hardware

##### Motion Sensors - Siemens Presence Detector QPA82.2

Installing a motion detector such as the one depicted can be beneficial for monitoring the activity in a certain room or corridor, and can be used to control either the lighting or HVAC systems serving those areas. This motion detector uses microprocessor based passive infrared to detect very subtle changes in movement. This high level of sensitivity can be used even in classroom or study area environments where students would be seated for extended periods of time. The time delay for turning off lighting or equipment can also be varied from 5 minutes in areas where there is a heavy flow of traffic like hallways, up to 15 minutes for more idle areas such as lecture halls to prevent the lights from turning off while the space is still occupied. Implementing these sensors allows for a demand-dependent control of lighting and HVAC as opposed to the fixed time schedules already in place. Due to the detection area however, it would be necessary to have multiple sensors installed in the various hallways and lecture halls for these buildings in order to fully cover the spaces that were being monitored. Most readily available motion sensors will have the option to be either ceiling or wall mounted so installation space does not pose much of a concern. It was determined by the design team that motion detectors can be implemented in the sparsely populated areas of the buildings such as the bottom floor of Dirac where there is mainly storage for book stacks. Using the motion sensors in this area would tie directly into the lighting and work independently of the central Siemens system. While they will not be the main element in determining building occupancy, they can be used to alter the lighting schedule and reduce the power consumption in the vacant areas of the buildings.

##### Wall Mounted CO2 Sensors - Siemens QPA2000

Another option for detecting whether certain rooms are occupied is to use wall mounted CO2 sensors. These sensors can provide a room by room analysis of the carbon dioxide concentration. One of the main advantages to this implementation is that measuring the demand for the rooms using CO2 also provides an air quality analysis along with determining if the room is occupied or not. This lets the user know whether or not the air quality standards are being maintained when supply fans are running at reduced capacities and can measure levels ranging from 0 to over 2000 parts per million. These sensors can also measure environmental variables such as the temperature and humidity in the building, and come with the option for a display on the sensor for real-time analysis from within the area it is serving. These sensors tend to be slightly cheaper than using a duct mounted sensor, but it would be necessary to install a larger quantity throughout the building in order to cover all of the necessary spaces. While this option would most likely be the more expensive route when considering using CO2 sensors, it would give a more accurate representation of the individual rooms or areas of detection than using a duct mounted sensor due to having multiple detectors covering smaller areas.

##### Duct Mounted CO2 Sensors - Siemens QPM2100

The alternative option for using CO2 sensors would be to install duct mounted sensors. While these would not provide the level of detail obtained from having a wall mounted sensor in each individual room, the cost to purchase and install them would be quite a bit lower. The cost per sensor is higher than using the wall mounted style, but implementing this option would require fewer overall sensors. Rather than having multiple sensors for each area of detection, one sensor could be placed in the return air duct for each floor to provide an overall picture of the air quality for the building. In cases such as the library study areas where it is likely that the occupants will be dispersed among the area fairly evenly, these sensors would still provide an accurate reading of the CO2 levels, duct air temperature, and duct air humidity. This allows for a reduction in the cost for implementation in areas where there are not extreme highs and lows in terms of level of occupancy. Duct mounted sensors were chosen as the primary option for the collection of atmospheric data for this project. Since most of the areas of observation are expected to be fairly uniform in their occupancy, it was determined that using these sensors can provide an accurate estimate of the occupancy levels while reducing the total cost for sensors.

### 3.2 Storage Tank

#### 3.2.1 Storage Tank Interface

The storage tank that will be implemented on the DSM system will be done to shift load from peak hours to off-peak hours. The Siemens system will be used to monitor levels of the storage tank and the necessary output for the AC chillers. The Siemens system will also have to implement the scheduling of load that will be output from a controller.

The storage tank will have to accurately send data to the current Siemens system such as temperature, level of water, and water output. This may require more sensors in order to accurately receive the necessary to schedule loads around peak times.

The Siemens system will also capture data that will be pertinent to energy and economic analysis in order to make the system as efficient as possible. The output of the storage tank will be integral for the economic analysis of the system, as it will show the benefit of shifting load from peak to off-peak hours and leveling off the load throughout the day.

#### 3.2.2 Storage Tank Hardware

Using some form of thermal storage would help with peak shifting by using slightly more load during the off-peak hours in order to curb the usage when demand and prices are high. One example of this that has already been implemented at the AME building near the College of Engineering is the use of chilled water storage tanks. Installing these tanks provides the ability to store chilled water during off-peak hours when the energy cost is low. Once this water is stored, it can then be used to supplement the air handlers during peak hours to reduce the amount of supply cold water being used. In a scenario where one of these tanks would be installed, it would be necessary to calculate the flow rate during the peak hours for the building in order to determine the capacity needed depending on how long it is desired to supplement the water usage. For example, the Dirac building averages a water usage of approximately 200 gallons per minute under normal conditions. Assuming that during peak times this increases by roughly 15%, this creates a 30 gpm peak in usage. Since the peak occurs for roughly two hours on a daily basis, the required capacity to offset this peak would be 3600 gallons. This value could be altered to increase or decrease the amount of water supplemented, or to alter the length of time the tank would be used. The main limiting factor for this option would be the space concern. If the buildings were separated from main campus this would not be an issue, but since space is limited the available areas would need to be analyzed to determine if a tank could fit without a major disruption to the flow of foot or vehicle traffic in the area. The option to use thermal storage tanks was decided to be the best option for peak shifting. This was compared with using energy storage through photovoltaic production and it was decided that thermal storage would be the option. The rationale for this decision hinged on the facts that the efficiency of photovoltaic arrays do not make them a cost effective option, and the savings that FSU receives through an agreement to not generate any of its own power. The main factor that still remains for whether or not this can be implemented is the space necessary to install the tanks. If it is determined that one or both of the buildings has adequate room to house the tanks then they can be implemented as an efficient way to shift the daily peak.

### 3.3 Motors

#### 3.3.1 Motor Interface

The variable speed drives will need to interface accurately with the current Siemens system. The motor output will be controlled by the Siemens system and will be driven by control algorithms. These algorithms will be planned based upon energy consumption of the building.

It is essential to have extremely accurate data points on this system in order to be able to meet the needs of the building. This means that the data the is being received by the CO2 sensors mentioned in the previous system will also be providing information for the controller to output different controls of the variable speed drive based upon building usage.

The variable speed drive data will also be used for analysis. The Siemens system will be able to capture the data necessary for economic and energy usage analysis. This analysis will also allow for corrections and efficiency changes in the future based on changes in the building or changes in the energy rate tariffs.

#### 3.3.2 Motor Hardware

Variable frequency drives can be used in a wide array of applications when it comes to demand side management. A synchronous motor’s speed is determined by the frequency of the alternating current supplied to it, given by:

Where is the speed in revolutions per minute of the motor, f is the supply frequency (60 Hz for most American applications), and n is the number of poles on the motor. Additionally, there are Affinity laws for pumps that relate the variables for pump performance such as shaft speed, head, and flow rate to the power consumption and capacity for the pump. These laws state that running a motor at 50% of its full speed can reduce the power consumption by 12.5% of the full power. Since the motors used in the air handlers, water pumps, and supply fans are some of the main consumers of energy for the two buildings, installing variable frequency drives and regulating the speeds of these motors based on the demand is one of the most effective ways to respond to the peaks in consumption. Virtually all of the motors in the Dirac library have variable control, so this building would only require the system to control the speeds for these motors throughout the course of the day. However, the Shores building contains mostly fixed speed motors, so there would need to be an upgrade to the existing system in order for this option to be implemented. However, for a 40 horsepower motor, of which there are two in the Shores building, the power consumption running at full load would be approximately 30 kW. This means that a 30% reduction for one of these motors would result in a 9 kW usage reduction. Assuming that the reduction would occur for two hours during the peak times each day, this would result in a reduction of over 6,500 kWh per year.

##### 3.3.2.1 Taco-HVAC Advantage 61



Features:

* Under load and overload detection and alarm.
* Low flow detection.
* 1 to 900 HP 3-phase 380-480V
* Graphic screen with customizable display
* Optional application card for multiple pump system control
* Continuous, real-time display of operating parameters of the motor.

Using a variable speed AC drive such as the Taco-HVAC Advantage 61 would allow for the motors in either building to be controlled both in the mechanical rooms and from the central utilities plant. The graphic display simplifies the user interface and can be programmed for different modes of operation. This device could also be interfaced with the existing Siemens system to allow for remote control of motor speeds from the central utilities plant. Using a variable speed drive also provides a one size fits all approach to regulating pump speeds in that it can be used with motors ranging from 1-900 HP, which covers all of the pumps that would need to be modified. This drive is also a good choice for this application due to the application card allowing for control of multiple pumps, allowing for fewer numbers of drives requiring purchase.

### 3.4 Lighting Design

#### 3.4.1 Lighting Interface

The lighting system must be able to accurately interact with the current Siemens system. It is pivotal that one be able to monitor and use the data points already on the system to schedule lighting loads and track efficiency.

The lighting loads will be monitored on the Siemens system in order to provide economic analysis of replacing the current bulbs with LED bulbs. As the old bulbs brake and are replaced by LED bulbs, one should be able to see the change in load accordingly. This will allow for simple economic analysis of load scheduling.

The data points on the current system will also allow for scheduling of lighting per the buildings usage. The Siemens system already has data points implemented that will help schedule but one will also use the motion sensors outlined in the previous section to turn on and off lighting based upon occupancy of rooms. The system will also capture the data points to track this information for economic analysis.

The scheduling of loads will be done from algorithms that will be engineered based on hours of the specific building/rooms, motion sensors, and occupancy. A controller will be responsible for implementing the designed algorithm with the data captured form the Siemens system.

#### 3.4.2 Lighting Hardware

Another option available for overall power reduction in the two proposed buildings would be updating the lighting throughout the inside and outside of the buildings. This is a way to reduce not only the peak, but also the energy usage during off-peak hours. Most of the current fixtures are using fluorescent bulbs, which use approximately 25 W per bulb. In a three bulb lamp this translates to a 75 W usage if the lamp is fully on. There are currently available LED replacement tubes that can produce a comparable light output while using approximately 18 W per bulb. This means that for every three bulb lamp there would 21 W reduction per lamp. Assuming roughly 1000 lamps per building, this would result in a 21 kW reduction assuming mainly three bulb lamps or 14 kW reduction assuming mainly two bulb lamps. This reduction would affect both the peak and off-peak hours and generally lower the load on the building. It is safe to assume that not all of the fixtures in the buildings will have three bulbs, so the actual reduction would fall in the mid-teens kW range. However, due to the current costs of LED bulbs, this option may not be suited to immediately take effect. Rather than going through the buildings and demolishing the existing lights to replace with newer ones, it may be a better strategy to implement this as the current fixtures reach the end of their life cycle. Delaying the implementation of this option also allows for technological advancements to either lower the price of the LED bulbs and fixtures or to increase their efficiency. Historically, the price for LED bulbs has been decreasing steadily, so when it comes time to replace the currently installed fixtures with their LED counterparts, the overall length of time required for the savings to recoup the installation cost will be even shorter.

# 4 Schedule

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Gant Chart Task List Description

Team Member Key

|  |  |
| --- | --- |
| Member | Key |
| Patrick Dawson | A |
| Dallas Perkins | B |
| Matthew Streich | C |
| David Gonsoulin | D |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Task | Subsystem | Title | Team Member(s) | Expected Completion Date | Skills and Knowledge |
| 1 |  | Project Management | A | 4/15/2015 | Leadership, Planning, Communication |
| 2 |  | Research | Mainly D  A,B,C to a lesser extent | 11/29/2014 | Reading Comprehension,  EE background, search engine use |
| 3 |  | Design | A,B,C,D | 1/19/2015 | Simulation Software, Critical Thinking, Power Systems, Programming |
|  | 1 | Variable Frequency Drives(VFD) | B,C | 11/27/2014 | Power Systems,  Software |
|  | 1.1 | Interface VFD with Siemens system | C | 11/5/2014 | Software |
|  | 1.2 | Monitoring Software | C | 11/9/2014 | Software |
|  | 2 | Load Scheduling | B | 11/15/2014 | Power Systems |
|  | 2.1 | Identifying Loads to be shifted | B | 10/31/2014 | Observation |
|  | 2.2 | Shift Loads | B | 11/15/2014 | Power Systems |
|  | 3 | Thermal Storage | D | 12/4/2014 | Power Systems, Thermodynamics,  Spatial Analysis |
|  | 3.1 | Analysis of possible locations of tanks | D | 11/11/2014 | Spatial Analysis |
|  | 3.2 | Scheduling of Storage | D | 12/4/2014 | Thermodynamics, Power Systems |
|  | 4 | Lighting Renovation | A,B,C | 1/1/2014 | Spatial Analysis, Budgeting, Wiring, Software |
|  | 4.1 | Updating Lighting | A | 12/20/2014 | Budgeting, Wiring |
|  | 4.2 | Adding Lighting Motion Sensors | B | 12/1/2014 | Spatial Analysis, Wiring |
|  | 4.3 | Lighting Control | C | 1/11/2014 | Software, Wiring |
|  | 5 | Ventilation Control | A,C | 12/31/2014 | Software, Power Systems, Wiring |
|  | 5.1 | Installing CO2 sensors | A | 12/2/2014 | Power Systems, Wiring |
|  | 5.2 | Cooling of Buildings during Off-Peak Hours | A,C | 12/25/2014 | Software |
|  | 5.2.1 | Monitoring Software | A,C | 12/31/2014 | Software |
| 4 |  | Implementation | A,B,C,D | 4/1/2015 | Programming, Wiring, Simulation Software(SIMULINK), Power Systems |
|  | 1 | Simulation | D | 1/31/2015 | SIMULINK |
|  | 2 | Review of Simulation | B,C,D | 2/5/2015 | Power Systems |
|  | 3 | Physical Implementation | A | 4/1/2015 | Wiring, Power Systems |
| 5 |  | Integration into Siemens System | B,C,D | 3/17/2015 | Electrician skills, Software Interfaces |
|  | 1 | Hardware Connections | School-contracted electrician | 3/1/2015 | Electrician skills |
|  | 2 | Interface Hardware into Siemens System | B,C | 3/5/2015 | Software Interfaces |
|  | 3 | Add extra controls software | C,D | 3/17/2015 | Software |
| 6 |  | Analysis | A,B,D | 4/1/2015 | Data mining, Budgeting,  Environmental Science |
|  | 1 | Economic Impact to University | A | 1/15/2015 | Budgeting |
|  | 2 | Future Savings | B | 1/17/2015 | Budgeting |
|  | 3 | Analyzing Environmental Impact | D | 1/1/2015 | Environmental Science |
|  | 4 | Measure Efficiency of Installed System | A,B,D | 4/1/2015 | Data Mining |
| 7 |  | Documentation | A,B,C,D | 4/5/2015 | EE background,  Programming(for psuedocode), Technical Writing |
|  | 1 | Course Reports |  | 4/5/2015 | Technical Writing, EE Background, Programming |

# 5 Budget Estimate

## 5.1 Rough Budget ROI

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## 5.2 Overall Cost Estimate

|  |  |  |  |
| --- | --- | --- | --- |
| **Personnel** | Cost/unit | Total Units | Total Cost |
| Matthew Streich | $30/hr | 360 | $10,800 |
| Patrick Dawson | $30/hr | 360 | $10,800 |
| David Gonsoulin | $30/hr | 360 | $10,800 |
| Dallas Perkins | $30/hr | 360 | $10,800 |
| Electrician | $60/hr | 50 | $3,000 |
| **Subtotal A.** |  |  | $46,200 |

|  |  |  |  |
| --- | --- | --- | --- |
| **Fringe Benefits** |  |  |  |
|  | $46,200 | .29 | $13,398 |
| **Subtotal B.** |  |  | $59,598 |

|  |  |  |  |
| --- | --- | --- | --- |
| **Minor Expenses** |  |  |  |
| **Subtotal C.** |  |  | $59,598 |

|  |  |  |  |
| --- | --- | --- | --- |
| **Overhead costs** |  |  |  |
|  | $59,598 | .45 | $26,819.10 |
| **Subtotal D.** |  |  | $86,417 |

|  |  |  |  |
| --- | --- | --- | --- |
| **Equipment** |  |  |  |
| 40 Hp Variable Speed Drive | $15,000 | 2 | $30,000 |
| 7.5 Hp Variable Speed Drive | $10,000 | 2 | $20,000 |
| 5000 Gallon Water Electricity Storage Tank | $1,600 | 1 | $60,000 |
| LED Lights | $20.00 | 7,202 | $144,040 |
| Siemens Duct-Mounted Sensor | $711 | 11 | $8,019 |
| Motion Sensor | $50 | 200 | $10,000 |
| **Total Project Cost** |  |  | **$358,476** |

# 6 Overall Risk Assessment

If implemented by the FSU utilities department, our demand-side management system will involve the modification of existing power systems in buildings, as well as the installation of new sensors/equipment in buildings. This creates the potential for risk to both the people installing the equipment, and the actual equipment itself. This section will examine some possible risks, and mitigation strategies the team is taking to limit/eliminate this risk. Potential risks include:

## 6.1 Technical Risks:

### 6.1.1 Installation Risk

Risk: Modifying/replacing the existing electrical system will involve handling building main lines, as well as disconnecting/connecting new wires for equipment. These lines are deadly, so only someone who has been trained and licensed as an electrician should handle the building power system. Installation of new sensors could involve the use of power tools, which if improperly trained can prove dangerous to the user or bystanders. Modifying systems can involve the use of a ladder, which could lead to falling injuries if improperly used. Equipment that has not been properly installed could also pose a fire hazard.

Solution: Contract out an electrician to perform building installation with the FSU utilities department. Familiarize ourselves with the National Electric Code (NEC) when planning our design. Get design signed off by the FSU utility department in-house professional engineer. Read safety manuals before using ladders/power tools.

### 6.1.2 Equipment damage

Risk: Modifying/replacing existing power system components in buildings could cause power outages/surges in power that could damage critical loads. Many of these loads are expensive to replace, additionally there is a supercomputer in the Dirac building, which if damaged would disrupt experiments and destroy potentially useful data. There is also the possibility that equipment could become damaged and fail over time, costing the school more money. This is a serious risk because equipment rooms are checked at an average of once every three months.

Solution: Model solutions extensively before implementation, including surges/high loads being introduced in order to test how the system will react. Get the professional engineer at FSU to review and sign off on our system design. Study which loads can absolutely not be affected by demand side management, and which we can modify. We will make sure to get sturdy components which have good ratings, as well as create a monitoring system that can let engineers know if something is faulty. The FSU Utilities department also as a last resort has controls engineers with years of experience who should be able to tell if equipment is behaving incorrectly, monitoring the entire system for possible defects and spikes in power usage.

### 6.1.3 Software Failure

Risk: Although not technically “physical”, software malfunctions could cause equipment damage, as well as increase utility cost.

Solution: Create a number of test cases for software in simulation stage. Prove that all algorithms/programs written are invariant.

### 6.1.4 Quality of Life (QOL) risks

Risk: Modifying the HVAC system could pose the risk of lowering the quality of life in the buildings. Modifying the system to do more cooling in the morning could lead building users to be uncomfortably cool or hot. Modifying the speed of the fan could lead to the build-up of excess CO2, which could lead to building users getting headaches or feeling tired, in extreme situations even leading to unconsciousness and death. Even in minor cases this is unacceptable, as university buildings need to be conducive to learning and studying.

Solution: Monitor building temps, provide safeguards in software to keep temperatures from going out of an acceptable range, provide manual override in the case of faulty sensors. Use CO2 sensors to monitor levels of the gas, adjusting fan speeds accordingly to provide proper building ventilation.

## 6.2 Scheduling Risks

### 6.2.1 Completion Risks

Risk: Not allowing enough time for testing/implementation of design. There is a significant amount of time that must be allotted to complete this project, if not properly planned than the project could fail. There is also the risk of a team member being unwilling or unable to complete all tasks that are assigned to them.

Solution: Schedule extensively for upcoming deadlines. Communicate plan with customer, advisor, and Dr. Frank, in order to stay on top of what needs to get done. Schedule regular meetings with team, discuss who is doing what and timeframe for each item, assist struggling team members in order to achieve goal. Make sure skill-set is diversified, there shouldn’t only be one person who knows how to do a critical task.

### 6.2.2 Installation Time Risk

Risk: Since the majority of the installation work will need to be contracted out, the possibility arises that the installation timeframe could exceed the scheduled amount. This could be caused by delays in the bidding or hiring process, or slower than expected installation.

Solution: In order to accommodate the necessary time required for the full installation, it is required to allocate a substantial timeframe for this period of the design. Additionally, having the design fully developed before the assigned due date would be preferable. This would allow for a scheduling margin in case of any delays in the installation process.

### 6.2.3 Equipment Malfunction/Failure

Risk: There is a low probability that the equipment purchased or provided to implement the system could at some point during the installation have a malfunction or failure. A malfunction will take time to troubleshoot, and it will have to be determined if the device can be repaired or will need to be replaced. For a failure there will be downtime waiting for new parts or pieces of equipment to arrive.

Solution: In the case of equipment malfunction or failure, it will be necessary to adjust the schedule as necessary to keep the project progressing at a steady pace. If one of the non-critical devices needs to be replaced it can be pushed off until the new part arrives and then integrated into the system. Otherwise, the installation can continue in different sections of the building or can continue to build around the necessary part until it arrives and can be installed.

## 6.3 Budget Risks

### 6.3.1 Equipment Costs

Risk: Improperly gauge cost savings of equipment we install. This could lead to the project costing money rather than saving money, and will discourage future collaboration between the FSU utility department and the COE senior design program.

Solution: Study rate plan, always anticipate real-world savings to be less than simulation, research items to make sure they perform as well as they are specified to, and price-shop to get the best deals possible.

### 6.3.2 Installation Costs

Risk: There is a moderate chance of variation with the cost to install the equipment specified. The cost could be driven up due to lack of competitive bids, or could possibly be reduced through the use of in-house electricians. This leaves the possibility of variation in installation cost in either direction.

Solution: In order to accommodate the possible fluctuation in the installation cost it is preferred to send out multiple invitations to bid to provide multiple competitive bids to be chosen from. Additionally any tasks that can be completed by in-house electricians or other employees would help to reduce the costs from external contractors. Taking these steps will allow for more of a budget margin so that any unexpected costs that might arise.

# 7 Conclusion

The full design of project is well underway and beginning to near completion. As the university will be implementing the actual installation of components if they choose, the scope of our project only consists of design of hardware and software, meaning that we are on the path success. While we have not begun an in depth development of software components, these interfaces with components are already in place and will only require a simple modification to operate correctly within our desired conditions, and we will begin work shortly. We have performed research on possible demand side management techniques we wish to use, and have narrowed down techniques that we will implement to the most feasible of these.

Even though this project exists as a whole design, it can easily be broken down into a bunch of subcomponents that will all be independently operational. One of the main components that we are working on is load shifting. This can be done through the design of a system that will store power from off hours to power the system during peak hours. For this we chose a thermal storage tank. We have analyzed the economic impact, but still need to work out both software and location for where we will put the tank. Both of these should be simple tasks that should not take much time. Another key component is the lighting system. We have calculated the estimated cost of the lighting, based off of pricing plan data from the University as well as lighting fixture counts, as well as an estimated time it should take to pay off the lighting. We also analyzed the effectiveness of using motion sensors to disable/dim lights. We decided that this would be an effective tool in reducing power in large wide-open spaces. We still need to create the software to run the motion sensors, but this should not take much time. The last system that we are working on is installing a variable speed drive into shores. We have analyzed the economic viability of both the drive and the CO2 sensors needed to properly implement using a variable speed drive. We would have to write code to interface the drive with the CO2 sensor, but again this should not be difficult.

The design is well underway, and because the project is all design we are well within schedule for completion. The demand side management system we are creating will save the university money as well as power.