Project Proposal

Proposal for Investigation of Alternative Systems

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Defense Media Activity Building

Fort George G. Meade

Pavel Likhonin

Penn State University

Architectural Engineering

Mechanical Option

Faculty Advisor: Dr. Treado

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Executive Summary

Defense Media Activity is as the new media center for the Army Corps of Engineers. This building has a large load contributed by the data center as well as high internal loads from specialty equipment in the editing suites, television studios, and media centers. This facility operates 24 hours a day and requires a redundant design in order accommodate the needs of the owner.

To condition the spaces within the DMA Building, a Variable Air Volume system has been selected by the engineer. This type of system is conventional in design and is fairly easy to install and maintain.

The object of this proposal is to minimize energy consumption of the building and make it less expensive to operate. Doing this will in effect reduce the carbon footprint of the building. In order to optimize the building's energy use, several systems have been proposed as an alternative. These systems are; Combined Heat and Power, Thermal Energy Storage, and System Optimization.

Implementing any one of the three alternatives will require high integration within the building systems. Each of the systems will have to be evaluated to check for feasibility and operability within the DMA Building. The best option will be selected and presented based on the goals of the project which are reducing energy consumption as well as minimizing operational costs.

In order to analyze these systems, several programs will have to be used. These programs will include Energy Modeling Software, Engineering Equation Solver, and Microsoft Excel. These tools are essential in doing the analysis required for selecting alternative systems.

System Description

Introduction

Defense Media Activity is a 3 story, 186,000 square foot facility designed for the Army Corps of Engineers. This building has a data center, television studios, media centers, offices, and editing suites. The DMA Building will operate 24 hours a day which separates it from a typical office building. It is designed to operate with redundancy in mind, as well as efficiency for LEED Certification.

Design Objectives

The main design objectives for the DMA Building are as follows; meeting the ASHRAE Standards and earning LEED certification as a government requirement. Based on these standards, the building must meet energy, ventilation, temperature, and humidity requirements. With these requirements in mind, the design produced an energy efficient building using a conventional Variable Air Volume (VAV) system to condition the building. The mechanical system consists of high efficiency chillers, cooling towers, and boilers to condition the building as well as high density APC cooling racks to take care of the data center loads.

Site and Budget

The site for the DMA building is located in Fort George G. Meade, Maryland. Fort Meade is one of the largest Army installations in the US. It is currently expanding to accommodate the Base Realignment and Closure (BRAC) plan. The current site of the DMA Building is on a golf course that is being prepared for construction. Special storm water permits and wetland waterway permits had to be obtained for site work in order to prevent erosion and provide sediment control. The building was bid and awarded for $56,195,000 which was within the budget. The building was designed to be energy efficient while keeping budget in mind. The current economic situation certainly helped in keeping the building within the original budget.

System Design and Equipment Summaries

The majority of the DMA Building is conditioned by a Variable Air Volume (VAV) system. There are a total of 168 terminal units in the building. These terminal units are connected to 6 Air Handling Units (AHU's) with 2 units per floor. The rest of the ventilation is done with 9 Roof Top Units. The sizes of AHU's range from about 12,000 CFM to almost 18,000 CFM. RTU's range from 3,200 CFM to almost 23,000 CFM.

The DMA Building uses three 500 ton centrifugal chillers that have a COP of 6.1. The condenser water is then pumped to the three cooling towers. These cooling towers are double cell induced draft and have a maximum flow rate of 1500 GPM with 25Hp fans. The building is heated by three 3000 MBH natural gas condensing boilers which are 98% efficient are used to heat the building. One chiller, one boiler and one cooling tower are on standby in case of failure.

The chilled water side of the mechanical system uses a primary/secondary flow system with two sets of pumps. One set is dedicated to pumping refrigerant through the chiller, and the second set distributes the refrigerant throughout the building. Pumps are a major component of the mechanical system. Most of the pumps used in the DMA Building are variable frequency drive except for the primary side of the chilled water system. Each set of pumps for the chilled water and hot water systems consists of 3 variable frequency drive pumps. Two pumps are dedicated for the heat exchangers. Chilled water pumps are 1000 GPM each for the primary loop and 2000 GPM for the secondary. The condenser water pumps are 1500 GPM and the hot water pumps are 150 GPM for the primary and 300 GPM for secondary.

A 2000 KW 480/277V emergency generator is used as a backup to provide 48-hour stand-by power to all life safety power loads as well as a backup for the Data Center. The system is also backed up by 20-minute UPS at a technical and critical level.

Mechanical System Evaluation

Overall, the mechanical system of the DMA Building is well planned out and implemented. Very efficient equipment is used to keep the energy usage of the building to a minimum. VAV systems combined with high efficiency chillers and boilers can be very effective if implemented correctly. VAV systems have been used in many office buildings and it is the most typical mechanical system used today.

The building envelope for the design of the DMA Building was one of the first considerations made in building efficiency. The envelope plays one of the biggest roles on mechanical system performance. The envelope for the DMA Building was done to exceed the ASHRAE Standard 90.1. This can be seen Technical Report 1 which discussed the building envelope of the DMA Building. The envelope was well designed and the only major changes that could be made are on implementing different mechanical systems.

The estimated construction cost for the mechanical system about 18% of the total cost. This is a typical cost of mechanical systems in office buildings. VAV systems are conventional and not too complicated to install and operate. The biggest costs and added value for this VAV system are the high efficiency chillers and boilers controlled by a DDC control system.

Operating cost of the building is quite high because of the type of loads in the building. The calculated operating cost is \$5.03/ft^2 a year. 67% of this cost is contributed by the data center. Cost of maintenance for this system should be relatively low. The system consists of only boilers, chillers, pumps AHU's and VAV boxes. It is a conventional system installed in many of today's buildings. Typical building engineers will knows how to work on this type of system because there is no special maintenance or training that needs to be done.

Implementing a simple design with a DDC control system and high efficiency boilers and chillers was a good solution for this building. However there are a few improvements that could be made to minimize operational cost and further reduce energy consumption. Looking into more sophisticated designs and doing an in-depth analysis of new energy efficient systems can provide a more environmentally friendly building with fewer emissions.

Proposed Alternative Systems

The current mechanical system is sufficient to meet LEED certification and save energy over the ASHRAE Standard 90.1. However, there are several alternatives that can further reduce energy consumption and reduce the costs of operation. The objective for alternative solutions is to increase efficiency as well as reducing operating cost and carbon footprint. These alternatives can be easily implemented into the design and their potential for the DMA building will be discussed below. The following alternatives will be included in this report: Combined Heat and Power, Thermal Storage, and System Optimization.

Combined Heat and Power (Cogeneration)

DMA has a high electrical demand as well as a high cooling load year round. The current utilities available to the DMA building include a natural gas line and two electrical feeds from Baltimore Gas & Electric. An onsite emergency generator is also implemented in the original design. The DMA building may be a good candidate for CHP, because the building will operate around the clock with a fairly constant electrical load.

Combined Heat and Power uses several types of prime movers to provide onsite generation of electricity. It also uses waste heat recovery for heating and cooling the building. Two prime movers will be discussed for CHP in the DMA building. The two prime movers that will be evaluated are: reciprocating internal combustion engines and natural gas turbines. An advantage of internal combustion engine is the higher efficiency at making electricity. An advantage of a turbine is the higher output of thermal energy for use in heating or cooling. The building will be evaluated for the optimum prime mover in terms of initial cost, payback, and efficiency.

The biggest advantage of CHP is the utilization of fuel, and the impact it has on carbon footprint of the building. Fuel utilization is much higher with a CHP system than a typical setup where the building uses grid power. CHP has this advantage because it utilizes waste heat, which is a byproduct of electrical generation, and uses it to run a process such as an absorption chiller. A typical power plant doesn't utilize waste heat, which is simply rejected to the environment, and just concentrates on producing electricity.

Several factors have to be considered while implementing CHP into the design. One of the biggest factors that would have to be considered when evaluating CHP is the Spark Gap. Spark Gap is the difference in cost between electricity and natural gas. The larger the difference, the more feasible it is to implement CHP into the design. Another factor that would have to be considered is the base load and peak loads. It would be much easier to use CHP in a building when the load profiles are relatively flat, since that would allow the fuel-fired generator to operate at its most efficient load condition.

Thermal Energy Storage

Thermal storage can be a great asset in reducing equipment size as well as reducing peak loads. It allows the building to level its load profile. Areas where on-peak electricity charges are much larger than off-peak can greatly benefit from cost savings. Running equipment during off-peak at full load and then using the stored energy during the on-peak hours is the basis of thermal storage. There are also energy savings because there are very little part load inefficiencies due to chillers running at full load to store chilled water or ice. Operating equipment at a fairly constant load and during the night when conditions are moderate, allows for better COP of equipment.

Adding thermal storage to the DMA building would reduce the on-peak cooling hours and as a counter effect, lower the operating cost by reducing the on-peak electricity use. It will also reduce the peak loads during the day and level the load profiles. CHP can greatly benefit from thermal storage because of load leveling.

Two types of available thermal storage are: ice storage and chilled water storage. Both of these options will be evaluated for the DMA building as both of these systems have advantages and disadvantages.

Several requirements would have to be evaluated for thermal storage such as space requirements for chilled water storage as well as ice storage, and the efficiency of producing ice vs. chilled water. Efficiency of storing chilled water and ice would also have to be considered when sizing and estimating total operation costs and benefits.

There are also several options for operating thermal storage. Full storage has the highest initial cost because the entire on-peak cooling load is shifted to off-peak hours. Using this option requires large tanks and large equipment. This option would work well in areas where the rates are a big driving force. Partial storage is shifting the peak load to off-peak hours and operating at base capacity at all times. This special case is called load leveling, and will have the best results when coupled with CHP. This option will be evaluated for the DMA building.

System Optimization

There are several ways that system optimization can benefit the DMA building. Modifications to the current system can further reduce the energy use of the building as well as operational costs. Several options can be looked at such as Dedicated Outdoor Air Systems (DOAS) and dedicating a chiller to the data center to reduce energy consumption.

DOAS

Dedicated Outdoor Air Systems use 100% outside air to ventilate the space. In a DOAS system, latent and sensible loads must be decoupled and treated separately. Several advantages are associated with using DOAS. Because only ventilation air is delivered to the spaces, your duct sizes are reduced dramatically over a conventional VAV system. The rest of the load is met with a parallel system such as fan-coil units, radiant panels (chilled ceiling), chilled beams, etc. The latent load must be met at the AHU while the sensible load can be picked up in the space.

A typical DOAS system consists of an enthalpy wheel, AHU's, and parallel terminal units. Total heat recovery is also a must in DOAS because 100% of the supplied air is outside air. In a typical VAV system, mixing is done between the outside air and the return air to precondition the air before the coils. In a DOAS system, there is no mixing and therefore preconditioning the air with a total energy recovery unit is required by ASHRAE 90.1. The energy from inside of the building is exchanged in this process with the fresh outside air based on the effectiveness of the heat recovery unit.

Incorporating this type of system into the DMA building may have significant energy savings according to an article in ASHRAE Transactions. [1] AHU fan energy is reduced, the cooling coil load is reduced, and the chiller energy consumption is reduced as well. There are a few areas where the DOAS system consumes more energy such as pumping. These will have to be taken into account when calculating the total energy usage of the system and then compared to the VAV system that is currently installed in the DMA building.

Dedicated Chiller for the Data Center

The data center in the DMA building uses a considerable amount of electricity to run. The connected load of the data center for the first five to ten years will be 1089 kW. This

[1] Jeong et al. "Energy Conservation Benefits of a Dedicated Outdoor Air System with Parallel Sensible Cooling by Ceiling Radiant Panels." *ASHRAE Transactions*. 109. KC-03-7-1 (2003): 627-636. Print.

load is connected 24 hours a day, seven days a week. Reducing this large load will result in considerable savings.

The current data center uses state of the art APC liquid cooled cooling racks. These cooling racks are much more efficient than conventional CRAC units. However, because the data center uses a big part of the building's energy, possible reduction of the cooling load for the data center in the system optimization analysis will be considered.

Breadth Topics

Electrical

Implementing a CHP system will reduce the loads for chillers. CHP will utilize absorption chillers to cool the building which run off the waste heat and not electrical power. Implementing a CHP system will also have electrical implications because the building would be generating its own electricity. Enough power must be supplied to the equipment as well as the data center in the DMA Building. Emergency power must also be accounted for to ensure non-stop operation of the building. An electrical analysis will be done and compared to the current design to make sure that all the necessary loads are met.

Acoustical

Acoustics can play a big part in building design when CHP is being considered. CHP prime movers such as turbines are very noisy. Acoustical considerations must be accounted for when designing this type of system. Spaces adjacent to the plant as well as above and below must be designed to reasonable operating levels. Noise levels from equipment must be isolated from the conference rooms and television studios. An acoustical study on the mechanical rooms with CHP equipment will be done on the DMA Building to make sure acceptable noise levels are achieved.

MAE Course Related Study

As part of the MAE requirement, graduate level classes must be incorporated into the proposed changes in design. AE 557 is Central Cooling, where thermal storage was a topic that evaluated for peak shaving. This course related material will be used in the depth analysis of thermal storage for the DMA Building. AE 551 is Combined Heat and Power. This course will be taken during the spring semester during the evaluation of the proposed systems. CHP directly relates to the proposed cogeneration system for the building.

Tools for Analysis

Energy Modeling

To determine monthly and annual energy use as well as associated costs, energy modeling software will be used. Energy modeling will be done either in Trane TRACE, Energy Plus, eQuest, or IES VE depending on the modeling capabilities of each one of the software packages. All of these packages have some limitations on modeling the alternative systems. All of these packages will be compared and analyzed to see which software would be capable of modeling the proposed options accurately. ASHRAE base building as well as the current design will be compared to the different options that are mentioned in this proposal.

Engineering Equation Solver (EES)

Engineering Equation Solver will be used to do a component evaluation of the different proposed systems. It has the capability to accurately model and provide results for analysis of thermal storage, DOAS systems, and CHP. It will be most likely used in combination with Microsoft Excel in order to evaluate different prime movers for CHP. Some difficulties may exist in understanding the programming of this software to do a comparative analysis of ice storage vs. chilled water. Some programming will have to be learned in order to implement this tool.

Standards

ASHRAE Standards as well as ANSI-ASA Standards will be used in the evaluation of the proposed alternatives. It is important to meet the thermal and ventilation requirements when redesigning a mechanical system. These standards will be referenced when evaluating DOAS. The ANSI-ASA Standard will be used as a guideline to evaluate the acoustics of the mechanical room for the proposed design of a CHP plant.

Appendix A: Preliminary Research

Thermal Storage

Bahnfleth, William. "Cool Thermal Storage: Is It Still Cool." *HPAC Engineering*. April (2002): 49-53. Print.

- This article discusses the application of thermal storage where it talks about load factors, peak shaving and different types of load leveling. The biggest factor in Thermal Energy Storage (TES) that this article talks about is the integration of TES with the building systems to see the full benefits. One type of integration considered in this proposal is integrating TES with a DOAS system.

Bahnfleth, William, and William Joyce. "Energy Use In District Cooling Using Chilled Water Storage." *ASHRAE Transactions*. 94-32-4 (1994): 1767-1778. Print.

- *Energy Use In District Cooling Using Chilled Water Storage* article talks about the advantages of chilled water storage in large district cooling systems. This concept can be applied to a single building as well. In the case of CHP, load management is essential which the main topic that this article talks about is. Different performances such as storage efficiency, pumping energy, and chiller efficiency are discussed in detail. These factors will be evaluated when designing TES for the DMA Building.

CHP

"Combined Heat and Power Partnership." *U.S. Environmental Protection Agency*. 21 07 2009. U.S. Environmental Protection Agency, Web. 12 Dec 2009. < www.epa.gov/chp/basic/index.html>.

- This website provides basic information on the CHP systems as well as special considerations when integrating energy systems into a building. It describes different benefits and applications of CHP.

Ghahremani, Farhad. "Cogeneration Feasiblity Study." *Hydrocarbon Engineering*. September (2002): 39-42. Print.

- The study reported in this article included an economic as well as an energy analysis on gas turbines being applied to projects with more than 500kW demand. This article demonstrates how to determine feasibility of a CHP system and does an economical evaluation of a cogeneration plant.

Sanaye, Sepehr, and Mehdi Meybodi. "Selecting the prime movers and nominal powers in combined heat and power systems." *Applied Thermal Engineering*. August (2007): 1177-1188. Print.

- Selecting different types of prime movers based on the type of building is an important part of doing a CHP analysis. This article discusses gas turbines, reciprocating IC engines, and fuel cells. Information from this article will be used when evaluating the DMA Building.

DOAS

Jeong, Jae-Weon, Stanley Mumma, and William Bahnfleth. "Energy Conservation Benefits of a Dedicated Outdoor Air System with Parallel Sensible Cooling by Ceiling Radiant Panels." *ASHRAE Transactions*. 109.KC-03-7-1 (2003): 627-636. Print.

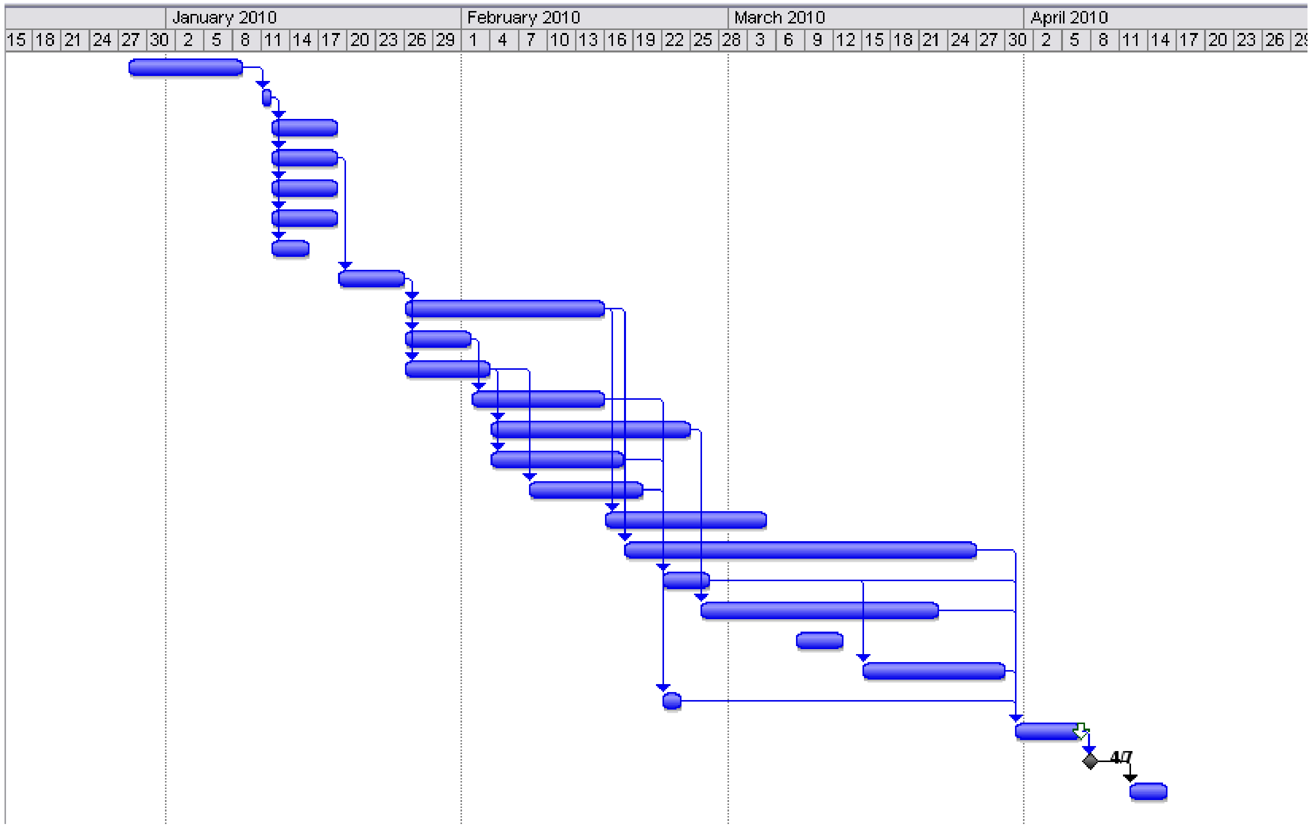
Mumma, Stanley. "Overview of Integrating Dedicated Outdoor Air Systems with Parallel Terminal Systems." *ASHRAE Transactions*. 107.AT-01-7-1 (2001): 545-552. Print.

- Both of the DOAS Articles discuss the benefits of using 100% outside air as opposed to a conventional VAV system. These articles explain the different applications of DOAS in buildings. These articles also describe the types of terminal units to be used in DOAS applications.

Appendix B: Work Plan

Completing the analysis for the proposed alternatives requires a significant amount of time. A schedule of work below will be used to complete the analysis in the time allotted. It includes the task deadlines and a clear indication of what type of work should be done at any given time to complete the tasks in time.

	Task Name	Duration	Start	Finish	Predecessors
5	Learn Energy Plus	10 days	Mon 12/28/09	Fri 1/8/10	
1	Classes Begin	1 day	Mon 1/11/10	Mon 1/11/10	5
2	Research capabilities of each energy modeling software	5 days	Tue 1/12/10	Mon 1/18/10	1
3	Research Different types of Storage	5 days	Tue 1/12/10	Mon 1/18/10	1
4	Learn eQuest	5 days	Tue 1/12/10	Mon 1/18/10	1
9	Research on DOAS systems	5 days	Tue 1/12/10	Mon 1/18/10	1
13	CHP Research on feasibility	4 days	Tue 1/12/10	Fri 1/15/10	1
6	Build Energy Model to analyze peak consumption	5 days	Tue 1/19/10	Mon 1/25/10	3
7	Evaluate chilled water storage vs. ice storage	15 days	Tue 1/26/10	Mon 2/15/10	6
10	Selection of DOAS equipment	5 days	Tue 1/26/10	Mon 2/1/10	6
14	CHP Prime mover study	7 days	Tue 1/26/10	Wed 2/3/10	6
11	Analysis of Standards for DOAS	10 days	Tue 2/2/10	Mon 2/15/10	10
15	CHP sizing and consumption	15 days	Thu 2/4/10	Wed 2/24/10	14
20	Acoustical Breadth analysis	10 days	Thu 2/4/10	Wed 2/17/10	14
19	Electrical Breadth analysis	10 days	Mon 2/8/10	Fri 2/19/10	14
8	Compare costs and energy requirements of Thermal Storage Systems	13 days	Tue 2/16/10	Thu 3/4/10	7
18	Thermal Storage Summary Due	27 days	Thu 2/18/10	Fri 3/26/10	7
12	DOAS Energy Summary	5 days	Mon 2/22/10	Fri 2/26/10	11
17	CHP Summary Due	17 days	Fri 2/26/10	Mon 3/22/10	15
16	Spring Break	5 days	Mon 3/8/10	Fri 3/12/10	
21	Compare Options	11 days	Mon 3/15/10	Mon 3/29/10	12
22	Breadth summaries due	2 days	Mon 2/22/10	Tue 2/23/10	19,20
23	Review Summaries	5 days	Wed 3/31/10	Tue 4/6/10	18,17,12,22,21
24	Final Summary Report	0 days	Wed 4/7/10	Wed 4/7/10	23
25	Final Presentation	4 days	Mon 4/12/10	Thu 4/15/10	24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