Energy Performance Contract — Technical Evaluation of Air Conditioning Operation and Control at Ipswich Hospital

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Summary

As a proactive proponent for positive change, the West Moreton Health Service District was among the first to participate in the Queensland Health Energy Performance Contracting program.

This paper presents the results from one major energy using area - air conditioning - from that program.

The scope of works evaluated in this report involves heating ventilation & air conditioning (HVAC) systems installed at Ipswich Hospital, Queensland. The works are:-

- Upgrade existing constant volume by-pass system to variable air volume (VAV) system
- Install variable speed drives (VSD) on supply and return air fans
- Measure supply air quantities and re-balance where necessary.

The existing BMS system was reconfigured and reprogrammed to provide these additional automatic control features:-

- Review HVAC operation and configuration to match space occupied and unoccupied time
- Reset the temperature set points on 24 hour units serving 12 hour areas
- Temperature set back control to unoccupied areas

The installation of the air conditioning modifications commenced in June 2006 and was completed in January 2007. An energy saving of 142,363 kWh per month was realised. This figure equates to around 15% of the hospital's electricity usage and an annual saving of $106,000 giving an Internal Rate of Return of 36%. The Energy Conservation Measures (ECMs) resulted in the reduction of 1807 tonnes of CO2 per annum. A small but noticeable improvement to the Power Factor was also achieved.

1 Introduction

Ipswich is a large provincial city approximately 40 kilometers west of Brisbane, Queensland. The Ipswich Hospital is the largest public hospital serving the local population of over 110,000 people in the West Moreton South Burnett Health Service District of Queensland. The hospital boasts a total number of 363 beds and employs around 1400 staff. The hospital has been located on its current site atop Denmark Hill in the centre of Ipswich for well over a century. The site has seen many changes in that time. The hospital is the largest facility in the West Moreton South Burnett Health Service District.

2 Existing air conditioning installation

The last refurbishment undertaken at the Ipswich Hospital was a major re-build and update of clinical and patient areas in the late 1990's. Needless to say not all areas were to benefit from this refurbishment and some of the older areas retained their unique charm. This included their building's services. This hospital is an excellent place to follow the advances made in building services through the 20th century.

As a proactive proponent for positive change, the (then) West Moreton Health Service District was among the first to participate in the Queensland Health Energy Performance Contracting (EPC) program.

3 HVAC upgrade details

3.1 Convert the constant air volume systems to variable air volume systems

The supply air quantity to each zone in the multi zone systems had been designed to satisfy maximum load conditions. However, the maximum load conditions in each zone in these systems do not occur simultaneously due to various factors such as solar heat gain and internal loads.

Before EPC modifications, the supply air quantity into each zone of more modern areas of the hospital was kept constant while varying the supply air temperature using a chilled water valve, face and by-pass dampers and electric duct heaters. In the older air conditioning systems, the temperature of supply air delivered to each zone was varied using only electric duct heaters. Thirty-seven existing air-handling units were modified (see DIAGRAM 1 and 2 attached) as follows:-

- the bypass dampers to each zone (where existing) were disconnected. Linkages were fixed in the closed position
- new volume control dampers were installed in the existing ductwork in the very old air handling units where no suitable control dampers existed prior to these works
- Variable Speed Drives (VSDs) were installed on the supply and return air fans

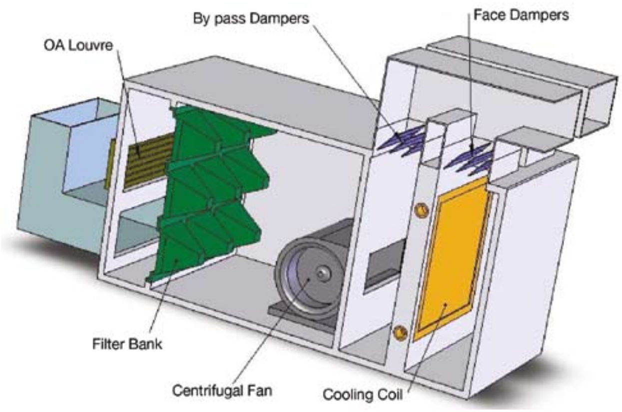

Diagram 1. Typical Zone Air Handling Unit before modification

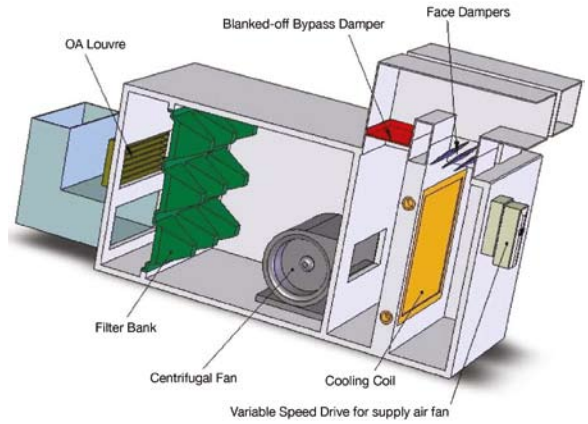

Diagram 2. Typical Zone Air Handling Unit after modification

The newly installed or existing motorised face dampers on zone supply air ducts are now used to modulate the supply air quantities according to the space conditions in each zone. The Building Management System (BMS) controls the fan speed according to the static duct pressure to each conditioned zone.

The VSD's were installed with shielded electrical cable and earth wires. The types of VSD installed were ABB brand ACH550-01 and ACS 400 low voltage AC drives.

3.2 Ensuring required outdoor air quantities.

The outdoor air quantities in air conditioning systems were designed for the maximum occupancy level in conditioned spaces based on the gross floor area. The outdoor air supply requirement for healthcare facilities varies between 10 and 50 L/s per person according to the latest standards (AS 1668.2-2002). The outdoor air quantities were re-measured and altered where necessary. The quantity of outside air entering the air handling unit was kept constant by the opening of the economy cycle damper in response to a detected decrease in fan speed.

4 Controls / building management system (BMS)

4.1 Existing BMS

The BMS installed at Ipswich Hospital is the t.a.c. I/net 7 system which was upgraded for this project. The BMS has been evolving since the mid 1980's when the first elementary BMS was installed. Some of the original Digital Control Units (DCU) is still in service. Several generations of hardware technology have been integrated into the present functional set-up.

The BMS control system philosophy was discussed at length with the Ipswich Hospital engineering staff during the design stage. The control system was then installed and commissioned with extensive consultation with senior Health Service Building Engineering and Maintenance Service (BEMS) staff.

4.2 Alterations to controls and control functions

The existing BMS system was reconfigured and reprogrammed to provide additional automatic control including the following [AHU = air handling unit (or air conditioner)]:-

- Optimum start control - 22 AHU's
- Resetting temperature set points using occupancy sensors - 14 AHU's
- CO2 monitoring and control - 4 AHU's
- Automatic seasonal adjustment of temperature set points – 43 AHU's
- Match fan loads to cooling or heating loads using new variable air volume (VAV) system and reduce supply air in response to reduced load and regulate supply air fan speeds through the differential pressure sensor – 37 AHU's
- Monitor and regulate the space's cooling and heating loads – 55 AHU's.
- Installation of after hours push button controls – 6 AHU's

The BMS also monitors temperature and some humidity conditions and provides equipment status and performance reports of the air conditioning system.

4.3 Indoor condition system operation

4.3.1 Optimum start and stop

The start and stop times had been programmed to get the conditioned spaces at comfort conditions well before the spaces are occupied and well after the spaces are vacated.

The installed optimum start program calculates the optimum time to switch on the air handling unit serving a particular space in order to bring the space conditions to comfortable levels just in time for occupation. The optimum start program calculates the latest possible time to start air handling units using indoor and outdoor temperature, historical data and a sophisticated computer algorithm.

For areas with an irregular need for after hours use, an after hours push button inputs to the BMS to activate the appropriate unit for an agreed time period.

4.3.2 CO_2 sensors to control the outdoor air supply

The outdoor air quantities to open spaces are designed for the maximum occupancy level based on the seating/room capacity eg outpatient clinics. The actual number of people in these spaces varies widely and continuously. CO_2 sensors are installed in the return air ducts to modulate the outdoor air supply quantity to the actual occupancy of the room. The system will always supply the minimum outdoor air quantity required to maintain air quality standards by the control of the outdoor air damper according to the CO_2 level in the return air duct, using the BMS.

4.3.3 Temperature set back control to unoccupied areas (occupancy sensors)

Air conditioning units were maintaining optimum conditions during the entire time periods scheduled in the BMS, even when these areas were not occupied. Such areas include operating theatres and birthing suites.

Sensors now signal to the BMS the occupancy status of the controlled space. The set point of the associated air conditioning zone is reset according to the current ambient temperature when an UNOCCUPIED signal is received from the occupancy sensors by the BMS.

4.3.4 Reset the temperature set points on 24 hour units serving 12 hour areas

The air handling units in some areas of the main buildings serve a mixture of areas operating for 24 hours and 12 hours a day. The set point of the supply air serving the particular zones that operated only 12 hours per day is reset according to the outside temperature during after hours times and on unoccupied days, controlled from a BMS time clock.

5 Difficulties encountered during installation

5.1 Duct heater protection

The reduced air flows from the VSD-controlled supply air fan caused the duct heater over-temperature protection to trip. This occurred in the coldest part of the morning when the heaters were required. The problem was overcome by adjusting the sensitivity of the heater protection to avoid tripping at lower flows. If the sensitivity adjustment alone would not prevent the heater tripping, then the flow of supply air was increased as the space temperature fell below set point.

5.2 Additional fire relay

The response to fire in the hospital required that the zones around the fire alarm zone pressurise in order to contain the smoke to that fire zone. To achieve this pressurisation, an additional fire relay was fitted to the fire control switchboard to force the supply air fan VSDs to run to 100% speed upon receipt of a fire alarm.

5.3 Return air fan VSD

The fitting of a VSD to the supply air fan led to the fitting of a VSD to the return air fan (where installed on the AHU). However, the centrifugal SA fan has a different air delivery characteristic from the axial RA fan. This difference in the delivery characteristics was overcome by installing an algorithm in the RA fan VSD, so that this fan slowed at a faster rate than the SA fan. This algorithm was tuned to maintain a constant amount of fresh air over the entire range of speeds of both fans.

6 Technical evaluation

The installation phase took considerably longer than was originally envisaged. While there were many reasons for this situation, what actually happened (although not planned) was a phased installation with the different ECMs being installed in separate time periods (see GRAPH ONE in the Appendix). This allowed the possibility of assessing the actual effect of the various ECMs individually.

6.1 Expected magnitude of energy savings

To estimate the magnitude of the energy savings, some assumptions need to be made. Let us assume that the major contribution to the savings will come from speed reductions in supply air and return air fans. This is reasonable due to the numbers of these fans involved (37), and the fact that most of these fans are 24 hour operation. The total power rating of the 37 fans = 364 kW.

From the Fan Laws (*Marks Standard Handbook for Engineers,* p 15-55) we know that the power consumed by a fan is proportional to the cube of its speed. If we assume that the fan speed is likely to be reduced on average by around 15% then the power used in the new installation would be $(0.85 / 1)^3$ or 0.51 of the original power used. Thus the power saving is likely to be 0.49 of 364 kW = 178 kW.

If the average running time of all fans is 20 hours per day, the average energy saving is 107,000 kWh per 30 day month.

If we then assume that all the other works of ECMs 1 and 2 will save another 15% of the total power used by the AHU fans, the additional predicted energy saving is 33,000 kWh per month.

The total predicted monthly saving from these ECMs is 107,000+33,000 = 140,000 kWh per month.

6.2 Actual energy savings

The installation of the air conditioning modifications commenced in June 2006 and was completed in January 2007. From Table 1 Appendix B, the savings from other ECMs in June 06 relative to June 05 was 83,215 kWh. In January 07 the savings were 225,578 kWh relative to January 06.

An energy saving of 142,363 kWh per month was realised over this period. This figure equates to around 15% of the hospital's total electricity usage.

6.3 Actual reductions in CO_2 emissions

The reduction in the amount of energy used means that there is a reduction in the amount of CO_2 produced. The ECMs discussed here resulted in the reduction of 1807 tonnes of CO_2 per annum (coal based conversion of 1.058 kg per kWh).

6.4 Agreed cost savings

The agreed cost of each kilowatt-hour of electricity at the commencement of the project was 6.2259 cents.This equates to an annual saving of $106,000. The cost of both ECMs was $474,285, giving a payback period of 4.5 years.

6.5 Improvement in power factor

The reduction in reactive power used by the AHU motors also had a desirable result in improving the power factor of the electrical supply from 0.82 to 0.89. There is no immediate saving financially from this improvement. There is little doubt that in the future when billing will ref ment will be valued greatly.

7 Consumer satisfaction

At the completion of installation, a general email was sent to every person in the address book at Ipswich Hospital stating that the air conditioning part of the project was complete and asking for feedback from the addressee's area. Only sixteen responses were obtained. Fourteen were too hot (and possibly stuffy) and two were too cold. This is considered a good result as the survey was through the entire facility and taken in the middle of summer. Fine tuning will continue for the next twelve months, to ensure that the winter (and spring and autumn) conditions will be satisfactory.

8 Conclusion

In these times of increasing demands to reduce the use of energy, and in particular electricity, the reduction in the energy usage of 15%, along with a high consumer satisfaction rate, is considered a good outcome. Agreed cost savings of $106,000, representing an Internal Rate of Return of 0.36 were achieved. The ECMs discussed here resulted in the reduction of 1807 tonnes of CO2 per annum. All the works of the installation phase were achieved with little disruption to the operation of the hospital due to the co-ordination between contractor and hospital.

9 Credits

Credit must be paid to the skilled designers, tradesmen and technicians (staff and contractors) who took on the task of imposing a new generation of technology onto an existing installation which, in parts, was thirty plus years old (but still in excellent condition). The task of integrating the different technologies into a workable unit was, at times, challenging.

Credit must also go to all the health service staff that professionally carried on in spite of the changing conditions around them. The vast majority recognised the benefits to be gained economically and environmentally by the completion of these works.

11 Bibliography

1. Marks Standard Handbook for Engineers, Baumeister et al, McGraw-Hill, 1978
2. Energy Performance Contract Work Specification – Ipswich Hospital, Energex, 2005

12 Appendix

Electricy Consumption Data

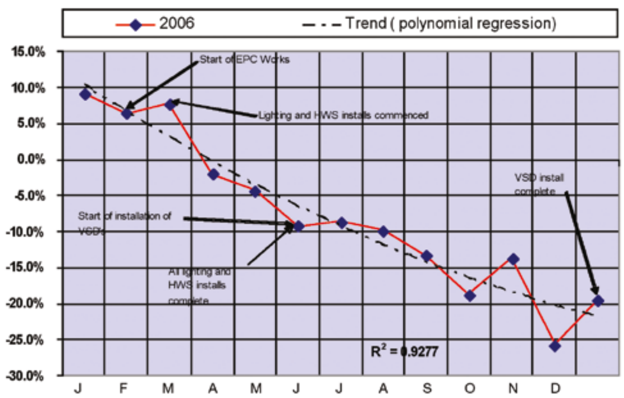

Chart One: *Ipswich Hospital Electricity Consumption*

Electricity (kWh)		Variance from same month of previous year	
		kWh	Percent
2006	January	98,274	9.3%
	February	63,492	6.4%
	March	77,077	7.8%
	April	-18,285	-2.0%
	May	-38,384	-4.3%
	June	-83,215	-9.2%
	July	-78,748	-8.6%
	August	-89,666	-9.8%
	September	-117,933	-13.3%
	October	-188,929	-18.7%
	November	-135,787	-13.6%
	December	-291,173	-25.7%
2007	January	-225,578	-19.5%
	February	-253104	-24.1%

Table One: Ipswich Hospital Electricity Consumption