Continuous Commissioning: A Valuable Partner to Retrofit Projects

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ABSTRACT

Continuous Commissioning (CC) or HVAC system optimization is not only a valuable stand-alone energy saving measure for commercial buildings, but it is also an important escort solution to retrofit projects. Energy retrofit projects typically achieve projected savings. But in cases where savings goals are not being met, optimizing HVAC system performance can be the difference in an underachieving versus a successful project.

This paper presents a real-world study of pairing a CC project with an energy retrofit in a 107,000 square foot hospital building. Applying the CC strategy to an underperforming retrofit, projected energy savings were achieved and *even increased*. Additionally, by increasing supply air capacity, patients, staff and visitors now enjoy improved comfort conditions.

This paper also explores the working relationship between an ESCO and a university research laboratory, whose combined efforts led to this remarkable turn around.

INTRODUCTION

For commercial buildings, modifications in the existing HVAC system is one of the highest recommended energy measure. The scope of the HVAC system retrofit mainly includes VAV conversion of the fans and pumps, using variable frequency drives on constant speed motors and installing/modifying the DDC control system to control and optimize operation and to improve the system efficiency. In most cases, the retrofit projects realize their projected energy savings and payback on time. However, in some cases, the retrofit projects may not achieve the projected goals. Application of post-retrofit system commissioning into the overall energy conservation project can achieve the savings' goal and considerably speeds up the payback. In most cases, system optimization can also improve the building comfort conditions. Post-retrofit commissioning of the HVAC system can be a stand alone energy solution for existing buildings and can also act as an escort solution and valuable partner to the retrofit project.

This hospital located in central Texas was retrofitted with energy efficient measures including VFD conversion of fans and pumps, chiller and boiler replacement and lighting and EMCS upgrade. However, after the retrofit, almost all of the AHU fans were running at full speed. The energy consumption was higher than the pre-retrofit measured data. By applying the CC strategy to this underperforming retrofit, projected energy savings were not only achieved but also increased considerably. Increasing the supply air capacity has allowed patients, staff and visitors to enjoy a much improved comfortable building environment.

The commissioning audit, energy analysis and energy solution measures build into CC were applied to five major variable air volume (VAV) air handling units (AHUs), chiller and boiler plant and the water loops at this hospital at Fort Worth, Texas. The overall operation of the HVAC systems was investigated in detail. Improved measures were also implemented in the plant. Since the implementation of the suggested measures, the air capacity has increased significantly for all the five AHUs. The capacity and lack of air flow for AHU-2 has been totally solved. Optimized operational schedules were also developed for the chiller, boiler, chilled water loop, hot water supply temperature and terminal boxes. Finally, recommendations for improving the maintenance of the terminal boxes and AHUs were also provided.

BUILDING AND HVAC SYSTEM INFORMATION

The hospital is located in central Texas, and was built in 1986. It is a two-story, 106,841 square foot building. There is a separate 3,969 square foot central plant building. The plant provides chilled water, hot water and steam to the building. Two water-cooled chillers, hot water and steam boilers are located at the central plant. The pumps at the central plant are used to pump chilled water and hot water through all the cooling and heating coils in the building. Eight (8) single duct AHUs provide conditioned air to the hospital. As a part of the retrofit project, VFDs were installed on the pumps, AHUs and cooling towers. Chiller replacement and lighting system upgrades were also completed in the Spring of 1999. Table 1 shows a list of installed VFDs.

Table1: List of Equipment with Installed VFDs

AHU #	Supply fans HP	Supply fans VFD	Return fans HP	Return fans VFD
Air-side VFD				
AHU-2	60	Yes	15	Yes
AHU-3	25	Yes	5	Yes
AHU-5	5	Yes	None	
AHU-6	15	Yes	5	Yes
AHU-7	15	Yes	8	Yes
AHU-8	25	Yes	5	Yes
Water-side VFD				
P-1 (Condenser Water Pump)	15	Yes		
P-2 (Condenser Water Pump)	15	Yes		
P-3 (Chilled Water Pump)	40	Yes		
P-4 (Chilled Water Pump)	40	Yes		
P-5 (Hot Water Pump)	15	Yes		
P-6 (Hot Water Pump)	15	Yes		
CTF-1 (Cooling Tower Fan)	15	Yes		
CTF-2 (Cooling Tower Fan)	15	Yes		

COMMISSIONING ACTIVITIES

Pre-Continuous Commissioning (CC) Operational Conditions

The data collected from the energy management and control system (EMCS) indicated that the majority of the VFDs (especially AHU fans) were running at a constant speed and were not modulating with the load. Most of the VFD fans were running continuously between the speed 90 to 100%, though the outside air temperature was below 45°F.

Figure 1 shows the graphics for AHU-2. Note the fan speed for the supply air (SA) and return air (RA) fans in the lower left-hand corner. Prior to commissioning, any changes in the duct static pressure or discharge air temperature setpoints did not affect the VFD speed.

The operation of five AHUs was analyzed using the data collected through the EMCS. Table 2 presents summarized information for each AHU. Operational data for 20 terminal boxes was also collected by checking the position and the response of the dampers and the steam valve by changing the space temperature from 55°F to 85°F.

It was also noticed that the natural gas consumption has significantly increased. No apparent reason was given by the facility personnel for this increase.

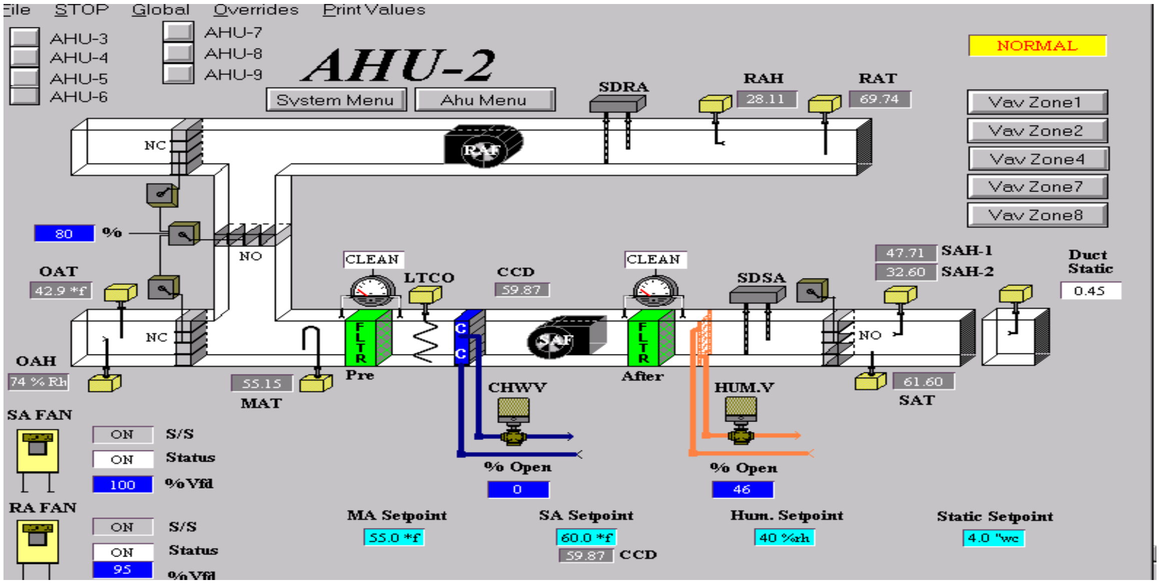


Figure 1. Pre-CC Operation of AHU-2

Table 2. Operation Status of VAV AHUs on 10/23/00

AHU #	S-fan speed %	R-fan speed %	P-setpoint (“H2O) SF	P-setpoint (“H2O) RF
2	100	95	4.0	0.3
3	100	95	2.0	0.97
5	95	N/A	N/A	N/A
6	100	93	1.0	0.94
7	97	97	1.0	1.0
8	100	100	1.5	1.12

Problems Identification

The HVAC operation was reviewed in detail by collecting the trend data from the EMCS. During the initial visit, the commissioning engineers took detailed field measurements, performed air-restriction analysis and made sure that all the sensors were reading the correct values[1]. It was found that AHU-2 had insufficient airflow both in the summers and in the winters. According to the facility personnel, there were a high number of hot call complaints during the summer period. The supply air fan was running at 100% speed and was not modulating with the load. The actual static pressure was less than 0.3”H_2O even though the setpoint was set at 4.0”H_2O.

Similar type of investigation was conducted on all the AHUs. The detailed measured results are presented in Table 3. The three major problems identified from the field measurements were a) the air resistance from the filters and the coils, b) errors in the static pressure sensor and c) high static pressure set-points.

It was also found that for some of the VAV boxes, the damper actuator that controls the amount of the cold air to the boxes was leaking and unable to hold the pressure. As a result of these leaks, dampers in the VAV boxes remained open allowing high volume of cold air to the boxes even in the heating mode, resulting in simultaneous cooling and heating. It was also noticed that some of the reheat valves and controls were not working properly. In some cases, the reheat was on continuously and in other instances, the reheat came on before the dampers started to close.

Air balance problems were also noticed. Difference in the supply air temperature for terminal boxes served by the same AHU, high air velocity and noise were indications of air balance problems.

[1] Some static pressure sensors were found to be out of calibration. The sensors were either replaced or were calibrated.

Table 3. Detailed measured results of air-side resistance (inch H_2O) for AHUs

	AHU 3	AHU 7	AHU 8	AHU 2	AHU 6
Pre-filter ΔP	1.3	0.5	0.5	0.4	0.46
Cooling coil ΔP	0.8	0.9	0.9	0.6	1.02
Final filter ΔP	1.0	0.34	0.32	7.6	0.3
Duct condition	Good	Good	Good	Good	Good
Static pressure sensor offset	-0.39	-0.27	-0.36	-0.3	-0.39
Current setpoint	2.0	1.0	1.5	4.0	0.8
Actual setpoint needed for operating condition	0.7 to 0.8	0.7 to 0.8	0.7 to 0.8	0.6 to 0.7	0.8
Operating condition	70°F to 75°F	70°F to 75°F	70°F to 75°F	40°F to 55°F	45°F to 55°F
Special Problems				The high static pressure caused a rupture on the fan discharge flexible duct	

__Recommended Measures__

1. ***Clean & Replace Air Filters for all AHUs***

Recommended measures for each of the AHUs are summarized in Table 4. Pressure sensors were also recommended for all the filters. This arrangement would allow the hospital staff to receive a signal from the EMCS to change the filters.

Table 4. Recommended measures for AHUs to solve the air resistance problems

	AHU 3	AHU 7	AHU 8	AHU 2	AHU 6
Pre-filter	Replace	Replace	Replace		
Cooling coil	Clean	Clean	Clean		Clean
Final filter	Replace			Replace	
Static pressure sensor offset	Calibrate	Calibrate	Calibrate	Calibrate	Calibrate
New static pressure setpoint at operating conditions	0.84	0.9	1.0	0.7	0.8
Special issue				Fix the flexible duct	

Note: This static pressure setpoint is for the existing weather condition. The reset schedule will be presented later.

2. **Optimized Control Scheme-Reset Schedules on Air-side**

The optimal static pressure and discharge air temperature reset schedules were also developed. These suggested schedules were approved by the hospital and were recently incorporated in the control strategy of the EMCS. Electrical and thermal savings from these measures are not available at this time. Data collection is in progress and will be analyzed soon to calculate the savings.

Table 5. Optimized reset schedules for AHUs

AHU No.	Reset Schedule for Static Pressure	Reset Schedule for Supply Temperature
3	0.7" H_2O if OAT ≤ 50°F and ramped to 1.1"H2O if OAT ≥ 90°F	61°F if OAT ≤ 50°F and ramped to 55°F if OAT ≥ 90°F
7	0.8" H_2O if OAT ≤ 60°F and ramped to 1.2"H2O if OAT ≥ 90°F	61°F if OAT ≤ 50°F and ramped to 55°F if OAT ≥ 90°F
8	0.8" H_2O if OAT ≤ 60°F and ramped to 1.3"H2O if OAT ≥ 90°F	61°F if OAT ≤ 50°F and ramped to 55°F if OAT ≥ 90°F
2	0.7" H_2O if OAT ≤ 50°F and ramped to 1.2"H2O if OAT ≥ 90°F	61°F if OAT ≤ 50°F and ramped to 55°F if OAT ≥ 90°F
6	0.8" H_2O if OAT ≤ 50°F and ramped to 1.3"H2O if OAT ≥ 90°F	56°F if OAT ≤ 40°F and ramped to 55°F if OAT ≥ 90°F

3. Improved Operation of Chiller Plant and Chilled Water Loop

The CC team recommended that the manual balance valves to be opened, and also made recommendations to isolate the chiller loop to run one chiller. With this measure, the chilled water pump power consumption will be further reduced.

4. Optimized Reset Schedules for Chilled Water Loop ΔP Setpoint

The chilled water loop **ΔP** setpoint was set at 26 psi. After the detailed measurements, optimized schedule was generated as follow:

7 PSI if OAT ≤ 60°F and ramped to 14 PSI if OAT ≥ 90°F

5. Improved Operation of Boiler and Hot Water Loop

The recommendation to run one boiler when the outside air temperature is higher than 45°F was provided to the hospital. This measure cannot be programmed in to the EMCS, but it can be accomplished by plant operators due to the existing 24 hour shift operation.

6. Optimized Reset Schedules for Hot Water Supply Temperature Setpoint

Optimized reset schedule for hot water supply temperature setpoint was also provided to the facility.

155°F if OAT ≤ 20°F and ramped to 110°F if OAT ≥ 80°F

7. Improved Operation for Terminal Boxes

As mentioned in the previous section, it was discovered that there was simultaneous cooling & heating consumption at the majority of the terminal boxes. Almost all the boxes had a 1°F deadband for cooling and heating setpoints. The CC team recommended increasing this deadband to 4°F to 5°F. This will reduce simultaneous cooling and heating. Accomplishing this task was very time consuming, as the only way to change the deadband was to adjust the AUX port in each individual terminal control board at the terminal box location in the ceiling. The CC team successfully adjusted the deadband for 39 terminal boxes. The adjustments on the remaining 205 terminal boxes are in progress and will be achieved by the facility personnel.

Commissioning Results

The commissioning team and the hospital were able to fix most of the problems by implementing the suggested measures. The new setpoints were implemented immediately at the site. The performance of the AHUs improved significantly. Table 5 presents some of the immediate results.

Table 5. Results for VAV AHUs

	AHU 3	AHU 7	AHU 8	AHU 2	AHU 6
Fan speed	65% to 75%	70% to 85%	65% to 75%	55% to 65%	55% to 65%
OAT (°F)	65 to 80	65 to 80	65 to 80	35 to 55	35 to 55

Figure 2 presents a graphic layout for AHU-2 after the implemented measures. Notice the reduced fan speed for the supply air fan (SA Fan) and the return air fan (RA Fan). The reduced static setpoint and the alarms on the filters are also noticeable.

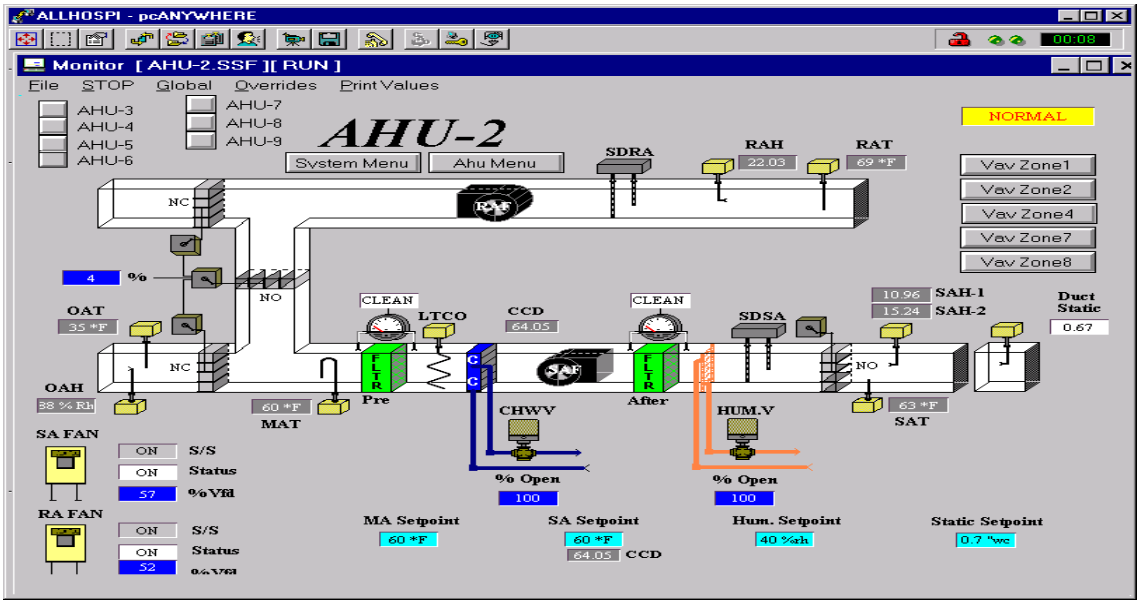
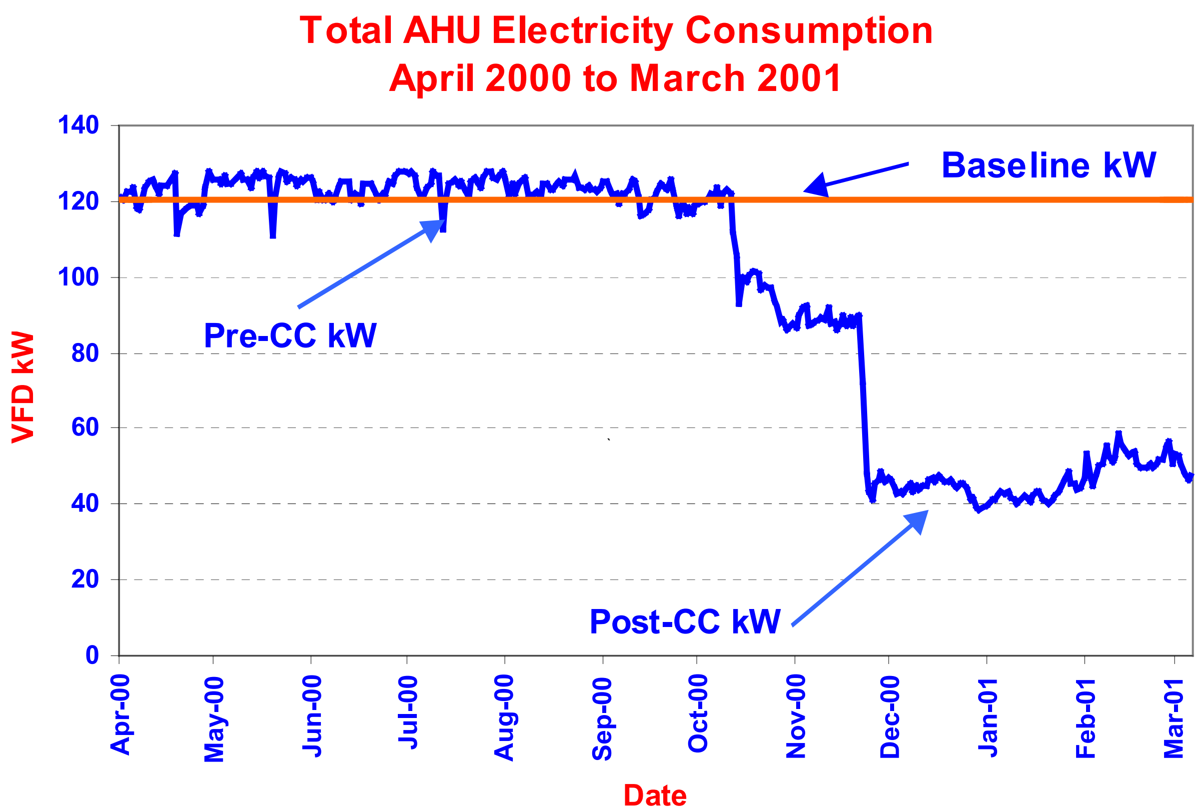
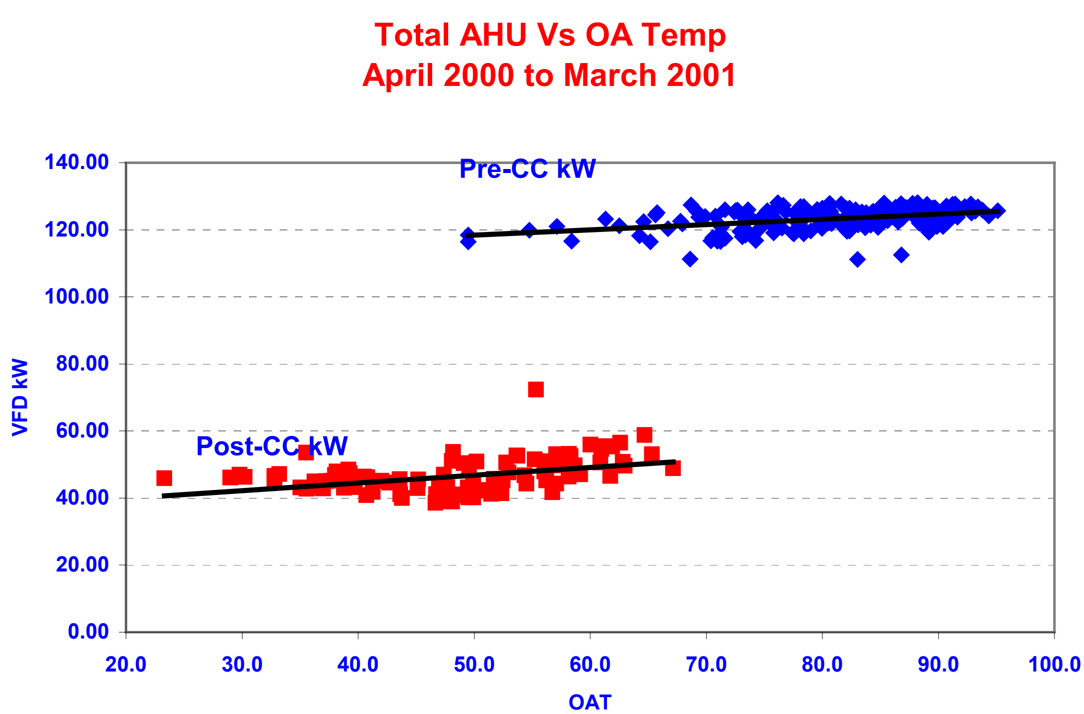
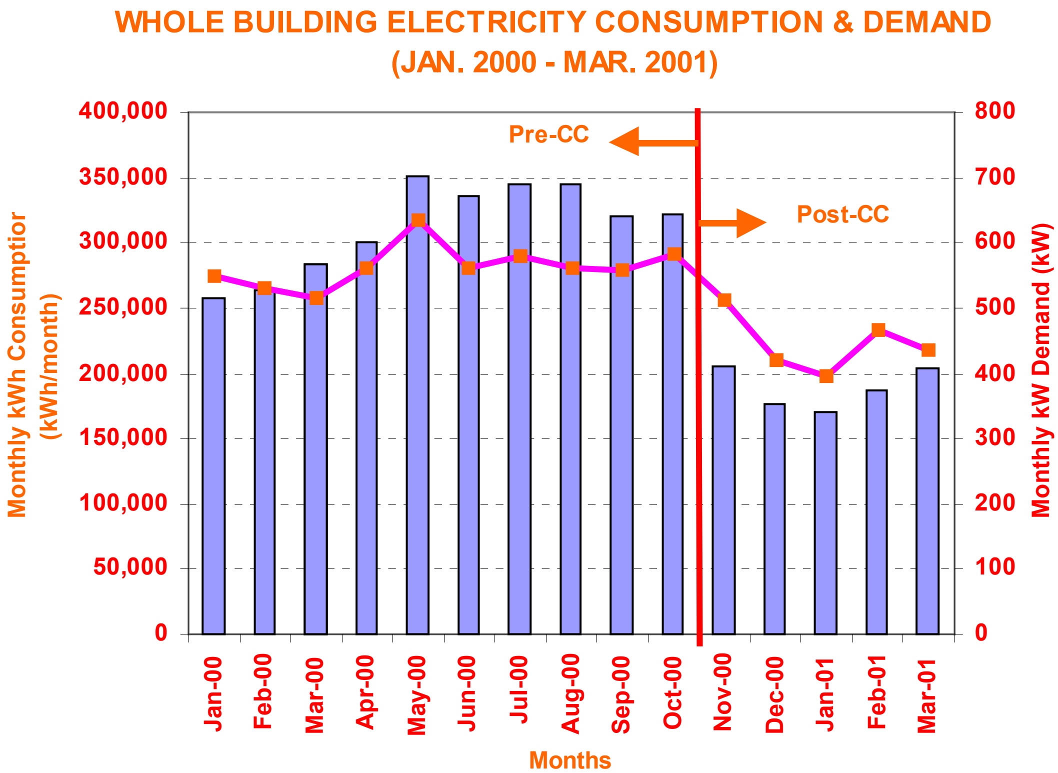


Figure 2. Post-CC operation of AHU-2

Continuous Commissioning was also successful on the remaining AHUs. Now all of them modulate with the load changes. The air-side capacity for AHUs has also been increased significantly. Figure 3 and 4 shows the decrease in the electrical demand for all AHUs. The first drop in the electricity demand is in October (1st trip) and then a much larger decrease can be noticed in November (2nd trip). Figure 4 shows the electricity demand versus average outside air temperature. Figure 5 shown the decrease in the whole building electricity energy consumption and demand. A significant drop is noticeable after October 2000.


Total AHU Electricity Consumption
April 2000 to March 2001
140
120
100
80
60
40
20
0
VFD kW
Baseline kW
Pre-CC kW
Post-CC kW
Apr-00
May-00
Jun-00
Jul-00
Aug-00
Sep-00
Oct-00
Nov-00
Dec-00
Jan-01
Feb-01
Mar-01
Date


Total AHU Vs OA Temp
April 2000 to March 2001
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
VFD kW
Pre-CC kW
Post-CC kW
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
OAT



CONCLUSION

The successful combination of Continuous Commissioning and retrofit project has been presented here. The combination transforms this under-performing project to an energy efficient project. The building environment and the productivity have also been improved significantly. The total measured savings for the period of December 2000 to April 2001 are approximately $20,000. The estimated annual savings will be more than $50,000.

ACHNOWLEDEGMENT

The authors would like to express thanks to Mr. Jack French, Mr. Brian Barton, and Mr. John Riddle from All Saints Health Care System. The audits and commissioning went very smoothly and everything was well organized during our visits.

REFERENCE

- ESL, *Continuous Commissioning*^SM^ *Audit Report for All Saints Health Care System/Cityview Hospital*, ESL-TR-00/12-02