CUTTING ENERGY IN A COMMERCIAL OFFICE BUILDING

ANWAR AHMED, M.AIRAH
M Eng (Hons), M Eng Sci, B.E, BEng Sc, MIE, CP Eng
Enman Pty Ltd
anwar@enman.com.au

ABOUT THE AUTHOR

Anwar is the principle of Enman Pty Ltd and has been working as an energy consultant for the last 30 years. In his earlier years Anwar worked as an R&D engineer on the development of a solar air-conditioning system. Prior to forming Enman Anwar worked as a general manager for the energy management division of combustion engineering in the U.S.A primarily working on energy saving through advanced control in power and industrial organisations. During the past 2 decades Anwar concentrated more on the development of advanced and optimal control systems to improve energy efficiency for chillers, HVAC, VSD, demand management, boilers and air compressor and refrigeration systems.

ABSTRACT

This article describes the achievement in energy savings through advanced optimal control of a medium sized commercial office building with a poor energy star rating. The building started with a conventional HVAC system without a centralised DDC control system. Implementing a BMS advanced optimal control improved the NABERS energy rating of the building from 0 to 3.5 stars. The potential of actual energy savings or improvement of the energy star rating for commercial buildings in general greatly varies with the current energy efficiency of the building; obviously, less savings are expected for a well performing HVAC system with a higher energy star rating.

1. HVAC SYSTEM

Heating Ventilation and Air Conditioning (HVAC) is the primary energy user of most commercial buildings; 440 Elizabeth Street is no exception.
In this particular building each floor has its own Air Handling Unit (AHU) with a centralised cooling and heating system for chilled water and hot water throughout the building. Chilled water is provided through two reciprocating water cooled chillers with two cooling towers. Hot water is provided from a central gas fired boiler. The hot and cold water are circulated through the building via pumps associated with the system. The chiller plant room is shown in Figure 1.

The office space temperature is controlled through a mixture of VAV and CAV systems. The entire system was controlled by a stand alone discreet control system without any centralized BMS (Building Management System). The control system had temperature based conventional economy cycle control. The chilled water flow rate was controlled by partially closed valves in order to control the flow through the building with no variable speed control of the pumps.

Figure 1: Chiller plant view

2. NEW CONTROL SYSTEM

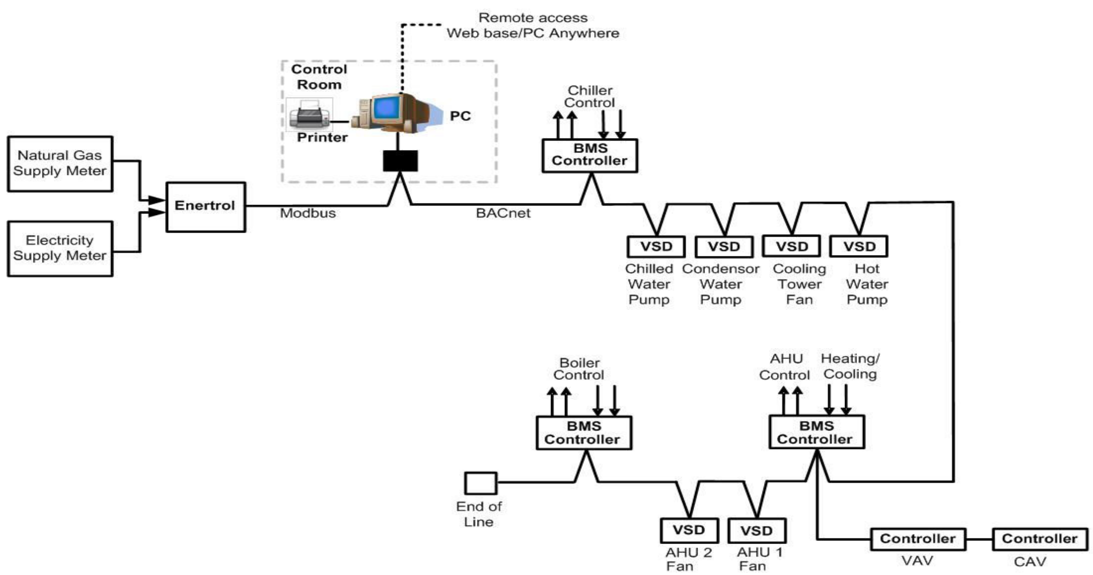
The overall building control system has been replaced by an Energy Management Control System (EMCS). This used a complete new centralised BMS integrated with the EMCS controller as shown in Figure 2.

The BMS provides the front end control that interfaces to the building facility managers through graphical representations of the entire system. The BMS also monitors and controls all of the field devices; from the sensors to the VAV/CAV and AHU controllers which control the entire HVAC system.

The EMCS provides all of the intelligence to perform the calculations for optimisation of the system. The EMCS has mathematical models which are continuously monitoring and optimising the plant and services in real time to minimise overall energy usage whilst maintaining the comfort level of the building. The mathematical models are tunable through a series of configuration displays contained in graphical representations within the BMS to adapt to the specific building control requirements.

The EMCS interfaces to the BMS gathering all the required information needed for the decision making process including weather conditions, status of all of the field equipment as well as the incoming electricity and gas information. After the EMCS collects all the information and performs the calculations and reaches the decisions it then commands the BMS to control the entire HVAC system for optimal control scenarios. The EMCS also provides a comprehensive energy and performance reporting system through the BMS operator interface.

Figure 2: Schematic of the control system



3. EMCS CONTROL FUNCTIONS

The energy management control functions provided are:

- Chiller optimal control
  - Variable optimal chilled water temperature control depending upon building cooling demand.
  - Optimal chiller selection and loading which provides required cooling at minimum energy input by chiller.
  - Chiller lock out based on weather conditions to minimise simultaneous or cycling of heating and cooling.
- Boiler optimal control
  - Variable hot water temperature mainly high and low hot water temperature depending upon heating load.
  - Boiler lock out based on weather conditions to minimise simultaneous or cycling of heating and cooling.
  - Boiler loading and selection for multiple boiler operation.
- Cooling tower control
  - This utilises water circulation for all the cooling towers all the time when any of the chillers are running.
  - Variable cooling water temperature to minimise the fan and chiller combined energy use. This uses a two speed fan on the cooling tower fans.
- Optimal pre and post cooling of the building

  The starting time of the air conditioning plant is variable. Depending upon the weather conditions and building space temperature it calculates the start time of the HVAC system for a pre defined occupancy time. It also stops the chiller and boiler ahead of HVAC stopping time to utilise stored latent energy which reduces thermal waste at the end of the building operation.
- Night purge
  - This is a control algorithm to pre cool the building at night when the ambient temperature can cool the building.
- Enthalpy based economy cycle

  It is an intelligent optimal economy cycle control algorithm replacing the conventional temperature based economy cycle; also the economy cycle can be complimented with CO_2 control. CO_2 control can provide further savings in areas where the number of occupancy changes substantially such as the conference room.

4. DEMAND MANAGEMENT AND CONTROL

It monitors both incoming electricity and gas meters. It monitors the electricity demand and controls the demand to a set target in order to maintain a contract demand and hence reduce electricity cost.

5. ENERGY REPORTING SYSTEM

The EMCS provides a comprehensive energy reporting function in order to create reports highlighting the energy performance of the building with regard to energy usage and greenhouse gas emissions. Chiller performance (KPI) report can further assist in operating and maintaining chillers more efficiently by highlighting inefficiencies from the report which would enable immediate further investigation to rectify.

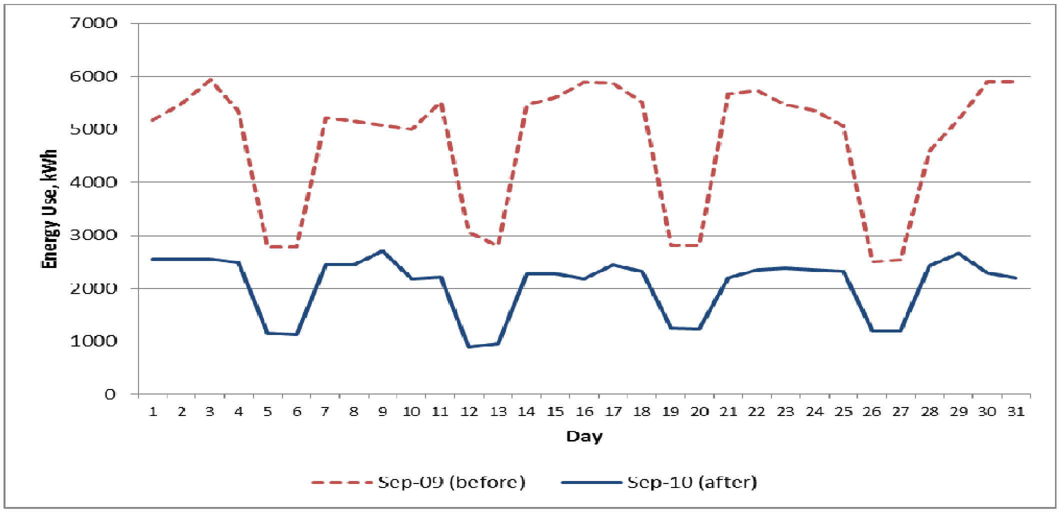
6. ENERGY SAVING

This control system of the building has been operational for two years. Table 1 and Figure 3 show the energy savings for 12 months. The month of September shows the energy savings after the EMCS was fully implemented.

Table 1: Energy & Greenhouse Reduction

ENERGY				**GHG CO_2-e Tonnes**	**DEMAND KW**
	On Peak kWh	**Off Peak kWh**	**Total kWh**		
Sep-09	94,991.88	46,305.48	141,297.36	193.6	440.52
Sep-10	43,619.64	17,606.16	61,225.8	83.9	306.72
Saving	51,372.24	28,699.32	80,071.56	109.7	133.8
	54.08%	61.98%	56.67%	56.67%	30.3%

Figure 3: Energy Use Profile Before and After EMCS Implementation



The energy savings estimated prior to the project implementation were exceeded due to the success of the EMCS system. The pre project estimated and post project actual savings are given below.

- Estimated energy (electricity) saving before project implementation: 39%
- Achieved energy (electricity) saving: 45% as per the NABERS rating done in the second year of operation. This saving is less than the initial stage of operation due to relaxing the control to provide a better comfort level in the building.

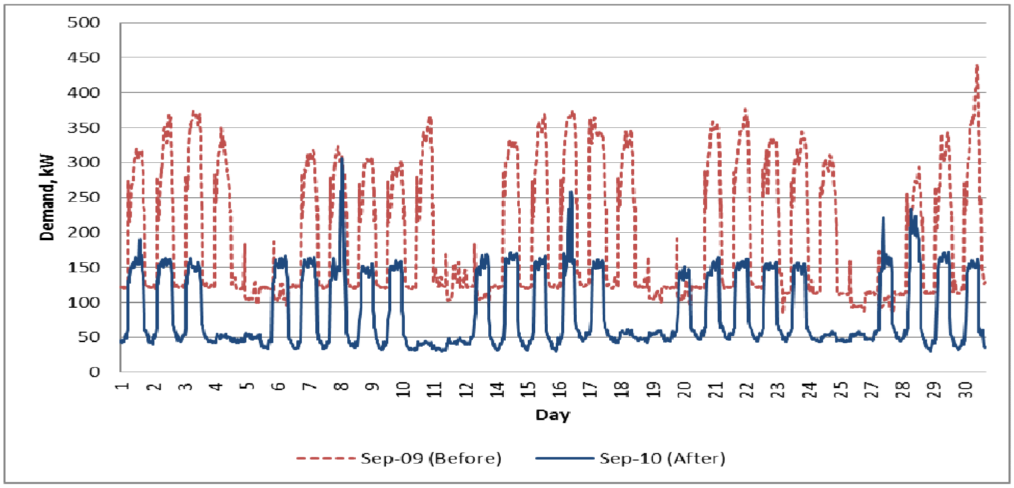
Prior to the EMCS implementation the building NABERS rating was zero. A NABERS rating was carried out in early 2012 and found to be 3.5 star.

7. LESSONS LEARNT

Building energy efficiency can be significantly improved through control system upgrades and introducing VSD technology without undergoing major equipment changes such as chillers etc. However the success in energy savings largely depends upon the optimisation and tuning the control system.

Figure 4 shows the electricity demand for the month of September 2009 vs. 2010.

Figure 4: Demand Profile Before and After EMCS Installation



Initially the energy saving was very high. Subsequently the energy savings were reduced by relaxing the control to provide a better comfort level in the building. Initially the energy saving was around 56% in September 2010 and finally 45% in the NABERS rating in 2011

The savings from several functions as part of the EMCS system have been estimates and are listed below. These savings apply to the affected equipment.

- AHU fan optimal speed control - 43%
- Pump optimal speed control - 33%
- Chiller and boiler optimal control - 20%
- Economy cycle advanced control - 25%
- Optimal pre and post cooling – 5%
- Night purge – 2-3%

The equipment operation run hours have been drastically reduced and hence reduced the maintenance cost and increased the life of equipment. The chiller run hours were reduced by over 40% together with reduction of start/stop operation. This gain in reduced maintenance and repair costs is substantial.

CONCLUSION

Building energy efficiency can be improved in many ways such as; energy efficient HVAC configuration, replacing the chiller with new energy efficient models, lighting upgrades, lift control upgrades etc.; however energy efficiency improvement through advanced optimal control provides one of the most economic returns of investment. To achieve the maximum benefit it is imperative that the control system be commissioned and tuned properly to match the building applications.

To achieve the maximum benefit it is important that all the regulatory control systems such as room temperature control be tuned properly and the air supply be balanced for zone control in order to avoid heating and cooling the building to maintain room comfort level.

As with any BMS and EMCS the need for proper supervision and functionality needs to be monitored to ensure optimal control functions are maintained to ensure continuity and enhancement of on-going energy savings.