A Case study on
Energy Management and Control System
Target Greensborough Store

1.0 Introduction

Target's Greensborough store is the largest Target department store in Victoria. Previously a Myer department store, the three level site with two levels of retail and one level for administration was upgraded and turned into a major Target outlet in 1998.

Enman had been engaged in 2006 on an energy management project to assess the economic viability of implementing the site's Heating, Ventilation and Air Conditioning (HVAC) in order to improve energy efficiency and reduce greenhouse gas emissions as part of a DIIRD government funded pilot project.

Fig 1: View of the chiller plant

2.0 The Project

2.1 Electricity Demand and Consumption

During the audit it was observed that the sites maximum electricity demand was observed to be 1,218 kVA at an average power factor of 0.75. The site has no demand management system or power factor correction units. The annual consumption for that year was found to be 2,533.2 MWh.

It was found that approximately 49% of the site's electricity consumption has been used in the HVAC system as shown in Fig: 2

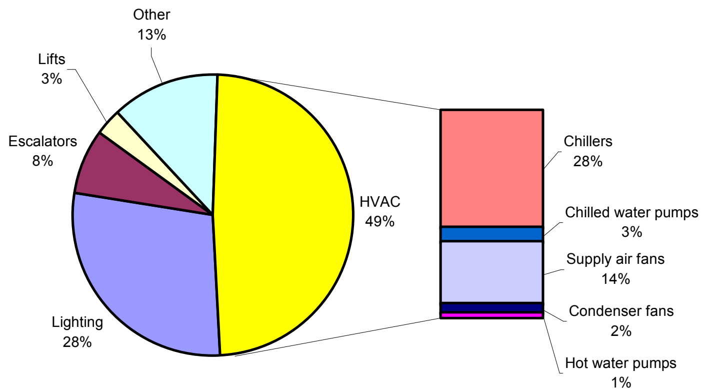

Fig 2: Energy use pie chart of the store.

The original control system was based on an Andover conventional DDC building management system (BMS) which was installed during the early stages of the site's building upgrades. The BMS system operated as a monitoring system as well as a standard control for air handling units, chillers, boilers and pumps.

2.2 Air Handling Units

There are a total of 10 AHUs on site with 8 being the main units. Each of the main units are driven by an 11 kW fan motor which is run at fixed speed by the site BMS as per the programmed scheduling system. Typically these fans operate 7 days a week at an average of 91 hours per week of operation.

The building cooling is provided by a central chiller with a chilled water system. The heating is provided by a central hot water system which consists of two gas fired hot water boilers.

2.3 Chillers

2 × York chillers
Condenser type: Air-cooled
No. of compressors: 3 per chiller
Compressor sizes: 2 × 112 kW + 1 × 134 kW per chiller
Fan size: 2.2 kW
Chiller pump: 1 × 30 kW

2.4 Condenser – Air Cooled

A dedicated York chiller control panel controls the chillers directly and also allows for start/stop and chilled water temperature monitoring by the existing BMS. The BMS system does not use the remote chilled water temperature control. The chilled water temperature was set at 6 ^{0} C. The BMS system calls for a chiller when the return chilled water temperature exceeds a certain temperature for a period of time. It was found that on medium to high demand there is always a possibility that two chillers will be staged while their corresponding compressors will be partly loaded. The York control panel doesn't facilitate any remote monitoring and control of the chiller compressors. Also the condenser pressure was set at a fixed pressure which could not be reset remotely. The number of fans to operate at any time would be controlled by the local panel to maintain the hot gas pressure within the certain band of the set point.

It was recommended that an optimal chiller control system should be implemented, thus upgrading the existing BMS system. This will involve interfacing the remote chilled water temperature reset on the facility as well as installing new monitoring devices to determine compressor loading. The system did not have the facility for a remote condenser pressure control. Hence the condenser fan control has been modified to be controlled directly by the BMS.

3.0 Technology

An energy management control system together with a power factor controller was designed and installed by Enman in mid 2007 to reduce energy consumption, greenhouse gas emission and demand of electricity.
The control system provided the following control and optimisation functions:

3.1 Demand management and Control

This is to monitor electricity demand from the electricity meter in real time, interfacing with the BMS and with the two electricity supply meters. The BMS would calculate demand every minute by reading energy and synchronisation pulses generated by the meters. Should the demand exceed a target demand set in the BMS system, it would reduce electricity load for a short duration of time. This would also provide comprehensive reporting on its demand and energy usage.

3.2 Chiller Optimal Control

This required a number of optimisation and control functions which are:

3.3 Chilled water temperature reset

This is to calculate the optimal set point of the chilled water supply temperature and remotely adjust the set point from the BMS. The set point is adjusted as a function of cooling load.

3.4 Condenser Pressure Set-point and Fan Control

There are 4 cooling air fans per bank each rated at 2.2 kW. There are three banks for 3 compressors per chiller set. The BMS system will stage condenser fans based on optimal condenser pressure and control band algorithm. The pressure band will be a function of ambient conditions which will determine the upper and lower pressure limits for running and stopping of each condenser fans. This condenser pressure set point and its band of control was set to minimise combined power/energy consumption of compressors and fans together.

3.5 Optimal Chiller Selection

The EMS system provided an intelligent chiller selection based on lead and lag chiller control system. A leading chiller will be started upon call for cooling on a typical day to day operation. If the cooling demand is increased then the lag chiller will be called. At a very low load condition the lead chiller will cycle to a high chilled water temperature condition.

The BMS will select one, two or no chillers to run to meet the cooling demand of the building. The algorithm ensures the minimum part load operation of chillers and takes advantage of raising chilled water temperature further at low cooling load condition.

3.6 Feed forward (supervisory) variable speed drive to supply air fans.

Variable speed drives were installed to all supply air fans. As the system is not VAV (variable air volume system) the conventional method of supply pressure control was not possible. The system therefore used Enman's well proven supervisory control algorithm. This supervisory control algorithm sets the speed as a function of cooling load. There are different techniques in controlling the speed as a function of load which are to be selected depending upon the control system used by the air handling units. This algorithm used the ambient air temperature as a control parameter.

The power consumption by fans achieved at different speeds from this function is shown in fig3. The actual speed varied from 50 to 100% of full speed resulting in around 45% reduction in fan energy.

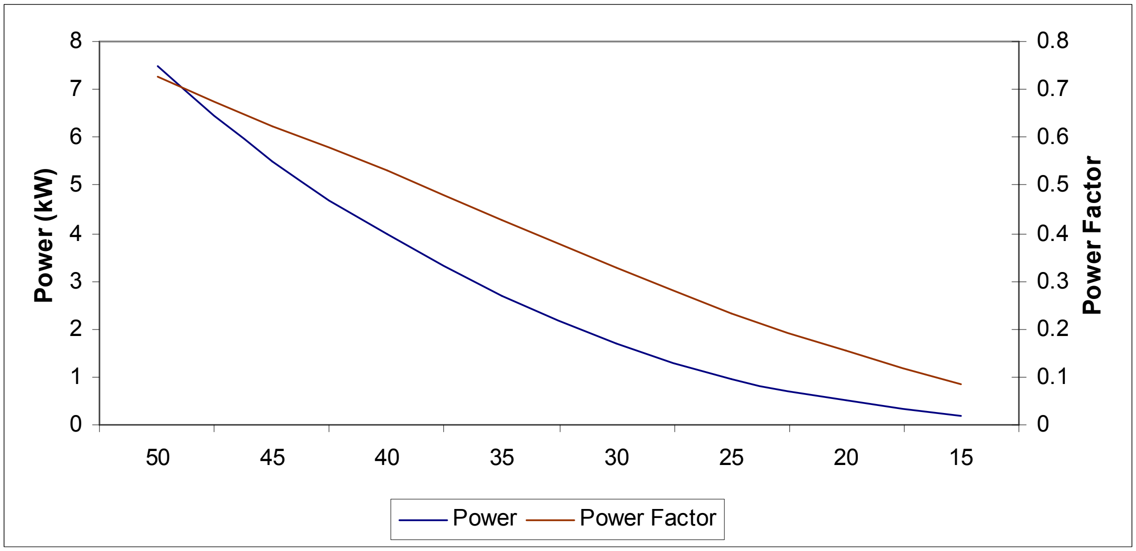

Fig3: Power factor and absorbed power at various speed for AHU fans.

3.7 AHU Night purge

This is to utilise outside air to pre-cool the building after hours utilising the purging technique when the outside air temperature is less than building room temperature. Normally such purging takes place very early in the morning before the start of the air conditioning system.

3.8 AHU Optimal start/stop

Conventionally the air conditioning system starts earlier than it is required. This is to pre-cool the building before the start of occupancy. Conventionally this pre-cooling time is preset by the operator. Since the pre-cooling time is fixed there are times that the pre-cooling time is much more than is required to cool the building, resulting in a waste of energy. The optimal start time function calculates the required pre-cooling time based on weather conditions and therefore reduces the unnecessary waste of energy

3.9 Power Factor Correction Unit

There was no power factor control equipment on the site and the power factor was between 0.75 and 0.85. Power factor control equipment with capacitor banks was installed to improve the power factor to around 0.96 or above. The power factor before and after the installation of pf correction equipment are shown in fig4 and fig5.

4.0 Predicted energy and demand reduction

The demand and energy saving was predicted during the technical study before the implementation of the system. These predicted savings are as follows

4.1 Predicted demand reduction.

Demand management and control
Demand control was inhibited during the initial stage of operation to avoid any unnecessary inconvenience in load shedding.

Power factor control

The demand of this site was 1218 KVA at a p.f of 0.75 the recommended p.f correction system to improve p.f from 0.75 to 0.95 reducing demand by 244KVA.

4.2 Predicted energy saving

The energy saving from the EMS predicted for different energy management control functions are as follows.

Energy savings estimated during the technical study are as follows

- Chilled water temperature reset = 71,651 kWh/Year
- Optimal chiller loading control =108,290 kWh/Year
- Condenser set-point temperature adjustment = 55,383 kWh/Year
- Variable speed drive for AHU Fans = 143,247 kWh/Year
- Optimal building pre cooling and night purge = 31,512 kWh/Year
- Inhibit heating and cooling based upon load prediction = 21,607 kWh/Year

Total predicted electricity reduction = 431,690 kWh/ Year

5.0 Achieved energy and demand reduction saving

5.1 Demand reduction

The p.f of the electricity was around 0.8 before the implementation of the p.f correction equipment which was increased to nearly unity after the p.f correction equipment. The p.f before and after p.f correction equipment is shown in Fig: 4 and Fig: 5

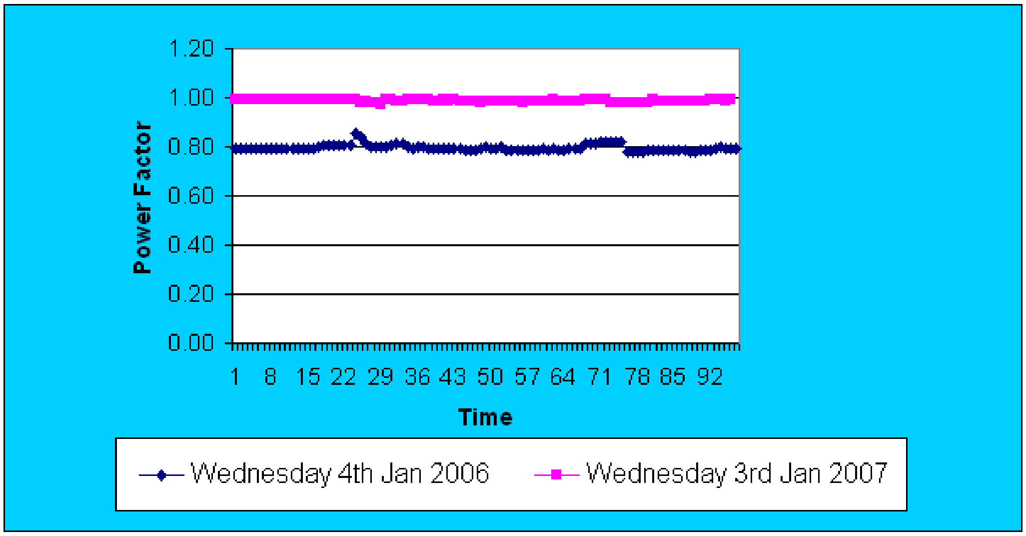

Fig4: Power factor before and after the installation of p.f correction equipment during weekdays

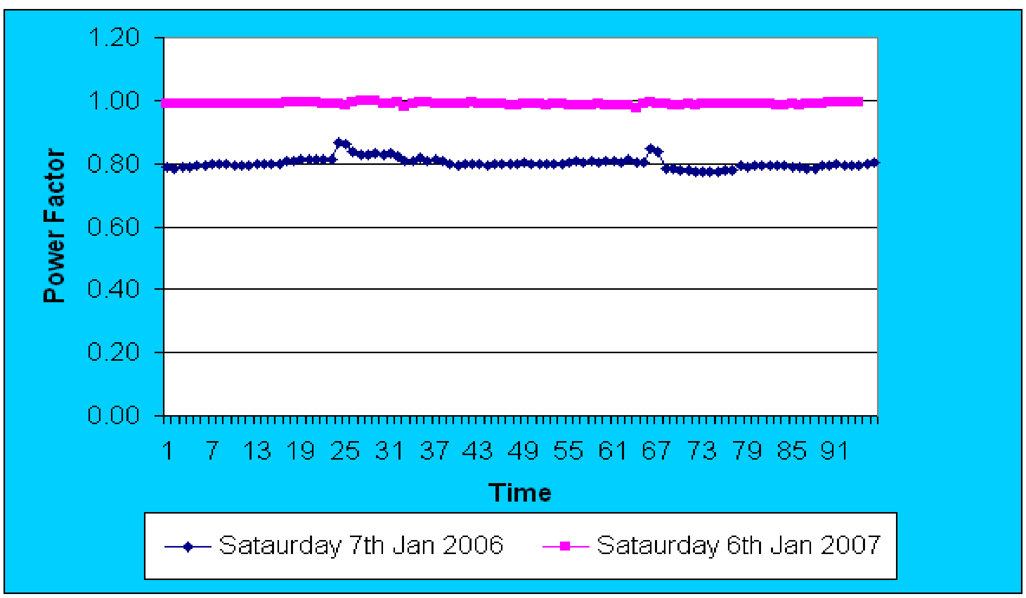

Fig5: Power factor before and after the installation of p.f correction equipment on the weekend

5.2 Energy Reduction

Energy use by the chiller and HVAC system before the energy management system was 1,255,886 kWh/ Year
Energy saving from the implementation of the EMS system is 523,350 kWh/Year
The achieved energy saving represents 41.6% of total chiller and HVAC energy use in the shopping centre.

The adjusted achieved energy saving from the actual operation of the energy management control system is 523,350 kWh which is 22.3% of the original energy use of the building. This represents a financial gain of $34,540/year. The achieved energy saving is found to be 21.2% more than predicted saving in the technical study.

6.0 Greenhouse gas reduction

There is a substantial GHG emission reduction both from the p.f controller and the energy management control of the HVAC system. The total GHG reduction is 746.57 of CO_2 -e per year estimated as follows.

6.1 Greenhouse gas emission reduction from power factor improvement

GHG reduction due to p.f improvement is due to the less current draw through the transmission and distribution lines.

CO_2 reduction due to power factor improvement (Tonnes/Year)
= 0.1444 x 8% x 1255.86 MWh/Year x (1-.8 /.99)2
= 0.144 x .8 x 1255.86 x (.1919) 2
(The transmission and distribution loss is around 8%)
= 53.27 Tonnes/Year

6.2 Greenhouse gas emission reduction from energy management Control system

= 523,250 kWh/Year x 1.325 kg CO_2 -e /kWh

= 693.3 tonnes of CO_2 /Year

7.0 Conclusion

The project out come clearly demonstrated the benefits of implementing an advanced and optimal control HVAC system which not only reduces energy costs but also reduces the greenhouse gas emission that is crucial for our environment.

The other advantages and benefits of such a system is the reduced maintenance cost of chillers due to reduced operational run hours of the compressors. The extent of energy saving will always depend upon the intelligent, optimisation and tuning of the control system. The return of investment of such a system normally varies from 1.5 to 4 years depending on the size and existing control system.

In summary the benefits have been:

- Energy reduction for the site of 22.3%
- Greenhouse Gas Emission reduction from HVAC and Power Factor Correction of 746.5 tonnes per annum
- Case study that will allow Target to establish strategies for energy reduction in similar stores

In addition to the advanced and optimal control for the HVAC system, power factor correction has been installed using a unit designed and installed by Enman to achieve additional operational cost savings for the site.

A key outcome identified from this case study was the benefit of completing a technical study before implementing such a control system strategy. The technical study allowed the actual situation to be totally analysed so as to obtain the most appropriate outcomes and results.

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