Solar Thermal Air Conditioning System

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Abstract. A solar thermal air conditioning system was designed to reduce energy costs at CAMTEC in Guelph, Ontario. This system utilizes flat plate collectors, an absorption chiller and a cooling tower with the existing air conditioner units. The projected yearly energy savings of this system are $15,400. The total capital cost of this system is $1,041,590. The total installation cost is $1,635,000. With a government subsidy, this gives a payback period of 51 years without installation costs and 131 years with installation costs. Therefore, a solar thermal air conditioning system is not a feasible solution to reducing energy costs in Guelph.

Key words: solar energy, flat plate collectors, absorption chiller, air conditioning

1 Introduction

Solar energy is a virtually unlimited, environmentally friendly and clean energy source [1]. This is important as energy consumption is the main source of pollution in any developing or developed country [1].

Flat plate solar collectors transform solar radiant energy to thermal energy via a transport medium [2]. The main elements are a black base, a metallic absorber and a well insulated casing [2] [1]. The surface of the collector should be perpendicular to the solar radiation direction for maximum energy collection [1].

Absorption chillers take the energy from the solar collectors and use this energy to create chilled water that can be used for air conditioning. An absorption chiller uses an evaporator, absorber, generator and condenser in a modified refrigeration cycle [3].

Cooling towers reject collected heat by further cooling water passed to them from the absorption chiller, increasing system efficiency [4]. A counterflow induced draft cooling tower (CIDCT) distributes input water through the fill while a fan blows air over it, decreasing the water temperature [4].

A solar thermal air conditioning system was developed for two temperature-controlled assembly rooms in CAMTEC. The CAMTEC plant is a Linamar manufacturing facility. A major assumption made in developing this system is that the air conditioning units are running when the outside temperature is greater than 10°C. All cloud types were assumed to absorb a negligible amount of solar radiation.

In order to determine the feasibility of this system, the payback period was minimized by increasing the savings and decreasing capital and installation costs. The capital value of existing technologies was sustained to prevent losses in the current capital value of equipment. Finally, the system could not decrease productivity at CAMTEC due to installation or system operation.

2 System Overview

The system overview can be seen in Figure 1. The solar collectors are installed on the roof at an angle of 45° in a S-SE direction [5]. The solar collectors will be connected in three equally sized arrays and the output directed to three absorption chillers. The absorption chillers will be located on the plant floor: one in the smaller assembly room and two in the larger assembly room. Each absorption chiller will be connected to two HVAC units.

2.1 HVAC Units

The HVAC units for the temperature-controlled assembly rooms are 25 ton gas heating and electric cooling systems. There are four LGC300S2BH1J Lennox HVAC units, for the larger assembly room, and two LGC300SH1J units, for the smaller assembly room.

2.2 Solar Collectors

The flat plate collectors are the Vitosol 100 model SH1 manufactured by Viessmann Manufacturing Company Inc. The SH1 has an absorber surface area of 2.30 m²
and a total area of 2.53 m². The SH1 uses a Tyfocor heat transfer medium. The capital cost for the Vitosol 100 is $924 CAD per collector and the installation cost is $2,000 CAD per collector. [5]

2.3 Absorption Chiller

Three LT-5 50 ton absorption chillers were obtained from Thermax Inc. The dimensions of this unit are 94.5”x59.1”x98.4” (length by width by height). The total cost for each unit is $90,000 CAD. With a cooling tower, the coefficient of performance (COP) is 0.60. COP is the fraction of the energy going into a system that is delivered out of the system. The installation cost for each unit will be approximately $45,000 CAD. [6]

2.4 Cooling Tower

Three AT 19-56 CIDCTs were obtained from Evapco Inc to meet the requirements of the LT-5 absorption chiller. The overall dimensions of this unit are 72”x101.5”x119” (length by width by height). The total capital cost of each unit is $10,000, and three cooling towers are required, one for each absorption chiller. The installation cost for each unit will be approximately $5,000. [7]

The total capital cost of this system is $1,041,590. The total installation cost is $1,630,000. This gives a total cost for the system and installation of $2,671,590.

3 Analysis of the System

In order to determine the energy produced by the system, the solar energy at Guelph was calculated using the following equation:

\[
R_{\text{max}} = \frac{1}{\pi} I_{\text{SC}} E_{\alpha}(\cos \lambda \cos \sigma \sin \bar{\omega}_s + \frac{2\pi \bar{\omega}_s}{360} \sin \lambda \sin \sigma)
\]  

where \( R_{\text{max}} \) is the maximum solar radiation (kW/m²), \( E_{\alpha} \) is the eccentricity correction factor of the earth’s orbit, \( \lambda \) is the latitude, \( \sigma \) is the declination angle and \( \bar{\omega}_s \) is the sunset hour angle [1]. In order to calculate the average solar radiation at Guelph for each month, the monthly cloud cover was determined with data from the International Satellite Cloud Climatology Project database. At Guelph, the average solar radiation is 207 W/m².

The COP of the solar collector was determined using the following equation:

\[
COP_{\text{SC}} = \frac{F_R(\tau \alpha)_L}{F_R U_L(T_m - T_a) / I_T}
\]  

where \( COP_{\text{SC}} \) is the coefficient of performance of the flat plate solar collector, and \( F_R \) is the collector heat removal efficiency factor, \( \tau \) is the transmittance, \( \alpha \) is the absorbance, \( U_L \) is the overall heat loss rate for the collector in W/m²°C, \( T_m \) is the entering collector fluid in °C, \( T_a \) is the ambient air temperature in °C and \( I_T \) is the insolation [8]. The COP for the absorption chiller is 0.60.

An air conditioning energy demand model was developed in which the air conditioning units are running when the outside ambient temperature is greater than 10°C. It was assumed that the air conditioning units would be running at 90% capacity in the summer and that this would decrease to 10% in the winter. The average energy used per month is 21,373 kWh. The total energy used per year is 256,478 kWh. The cost of energy at CAMTEC is $0.06/kWh, giving a total savings of $15,388.69 per year. A government subsidy will offset 25% of capital and installation costs. With the government subsidy, this gives a payback period of 51 years without installation costs and 131 years with installation costs.

4 Conclusion

A solar thermal air conditioning system for Guelph is not a feasible design. The energy savings do not adequately compensate the initial capital costs as the best payback period is 51 years.

There are some potential inaccuracies in the energy and savings models. The assumptions inherent in the air conditioner energy demand model are a simplification of the actual energy demand. Furthermore, there could be slight fluctuations over the years in solar radiation reaching Guelph. Also, energy costs could change from $0.06/kWh over the payback period.

References