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Energy Auditing of a Commercial Building – "Optimization of HVAC System & Solar Assisted Heat Pump"

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Abstract: ***Energy auditing imparts an effective way of energy conservation and reduction of energy bills in commercial as well as residential buildings. The instruments running on conventional fuels can be replaced by energy efficient equipment which relies on non-conventional energy resource. This research paper emphasize on utilization of solar assisted heat pump for heating and cooling purpose and also focus on methods of reducing yearly electricity bills.***

Keywords: energy auditing, solar assisted heat pump, non-conventional energy resources, HVAC system, hybrid solar technology

1. Introduction

At the present age of electricity crisis and oil crisis it is very important to make the commercial building efficient by applying energy efficient methods. To reach the correct baseline of improvement we need to check the old electrical bills, test the performance of equipment and then formulate the energy audit report for the implementation of the energy conservation steps. This study is about the optimization of HVAC system through solar assisted heat pump of a commercial building. The study contains the Energy Auditing of building to find out the opportunities of energy conservation and increasing the efficiency of the equipment

2. Literature Review

2.1 HVAC System

Heating, Ventilation and Air Conditioning (HVAC) considerably accounts for a significant portion of energy use of commercial building and represents an opportunity for considerable reduction of bills and energy savings. The data Sheet used for auditing acts as a significant source on energy efficient HVAC systems and proven technologies and design concepts which can be used to follow with the HVAC provisions in Energy Conservation Building Code.

2.2 Heat pump

The heat pump is a cyclic device which is able to extract energy at a low temperature heat source and upgrade it to a high temperature heat source, enabling it to be used more effectively. Low grade rejects heat available at allow temperature may be upgraded to a high temperature source by a heat pump. Heat pump system has many features in common with the refrigeration system and may be of vapor-compression or absorption type.

2.2.1 Basic heat pump principle

Heat pumps are devices that can accept heat from low temperature sources and produce an output of a much higher and useful temperature and in all cases needed some form of energy to run the system. Heat pumps and refrigerators are deemed to be thermodynamically equivalent however the operating temperatures are different. A refrigerator takes heat from the cold body inside the fridge and is released through a condenser at the back at temperatures in a range of 0 to -30°C. Sources of heat for heat pumps are within the range of 0-50°C, which can be found in the air, ground water or waste heat streams from industrial sites. The heat pumps works by taking this heat and upgrading it to a much higher temperature usually ranging between 50-90°C. The difference between the two systems is that a heat pump would not be used to extract heat to maintain a cold climate but would be used to extract heat to an already warm climate, crook et al. 2003.

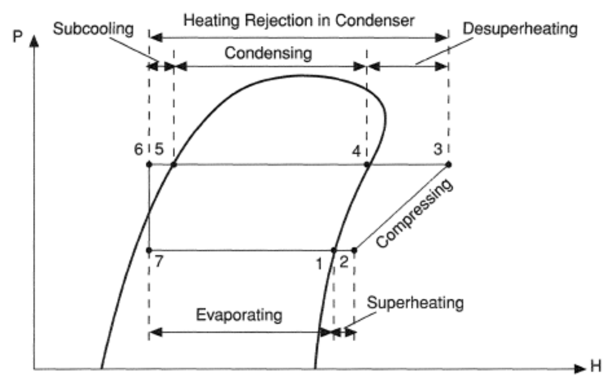

Figure 1: Carnot Vapour Refrigeration Cycle (Tuohy, 2013)

2.3 Hybrid Solar

Among the works conducted on SAHP in recent years, new ideas related to the integrations of solar-thermal, photovoltaic (PV) and heat pump have been conceived to yield novel hybrid systems. This is primarily due to sustained interest in employing renewable energy to improve heat pumping processes. Pei et al. have described a novel photovoltaic solar-assisted heat pump (PV-SAHP) system whereby a Photovoltaic Thermal (PVT) was incorporated onto the evaporator to realize an evaporator–collector plate. In their setup, a portion of the solar energy received was converted to electricity while the rest was converted as heat. The heat energy was then absorbed by the refrigerant and carried over to the condenser. The generated electricity serves to augment the compressor power.

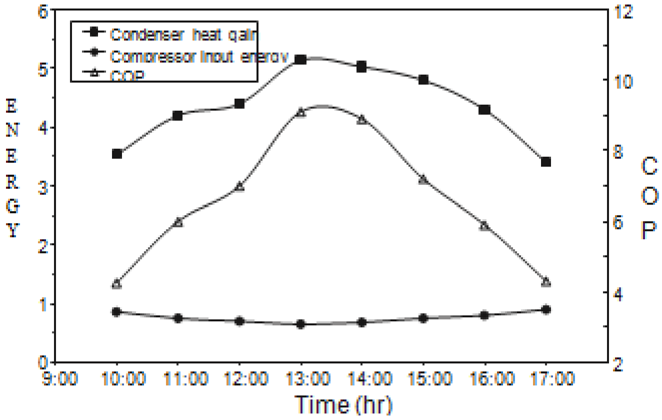

Figure 2: Variation of condenser heat gain, compressor input power and system COP during winter system of a direct-expansion solar-assisted heat pump for water heating.

The COP of the heat pump was also substantially improved because of the solar energy absorption. As far as the application of SAHP for drying of agricultural products is concerned, it has been calculated that coupling the heat pump to a solar collector improved the thermal efficiency of the air collector with values between 0.7–0.75 while efficiencies of the evaporator and collector were found to vary between 0.8–0.86. Improved efficiencies were mainly due to the reduction of losses from the collector.

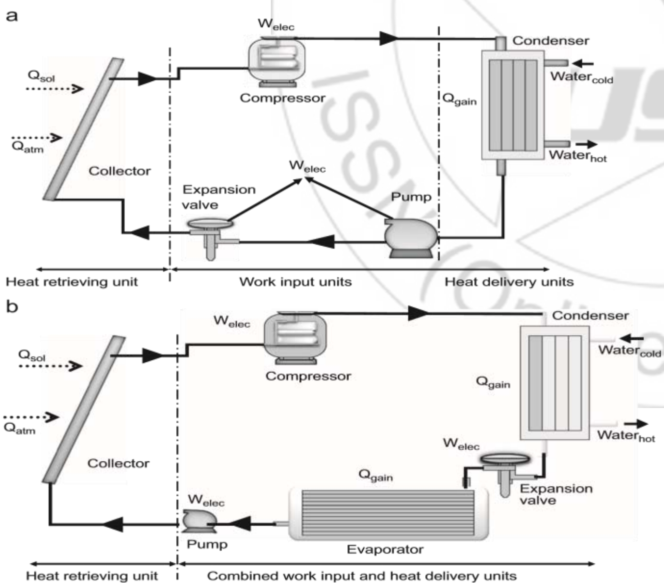

Figure 2.4: Schematic view of a direct expansion solar assisted heat pump system, (a) heating and (b) cooling

3. Methodology

A commercial building in Lucknow whose expenditure on Power & Fuel is about Rs. 4.23INR Cr per year. Commercial buildings are endeavoring for cost leadership in the industry and as the Power & Fuel cost are significant and offers good cost reduction opportunities, focused initiative has been taken to identify techno-economically feasible energy cost reduction measures through conducting Energy Audit, as an initial step. Energy Audit of the plant is been done thereby, after completion of the field studies, detail energy balance, identification and quantification of losses have been estimated and thereafter energy conservation opportunities and actual measures have been identified.

This Energy Audit Study (Energy Conservation Potential Assessment Study) has been focused on all the electrical energy consuming equipment's, which includes Air Conditioning, Lighting, Hot water generator, Boiler and Tariff related matters for energy cost reduction. In this audit, specific attempt has been made to evaluate organization's approach and infrastructure/capacity available for energy cost reduction, results achieved so far and pathway ahead to maximize the gains from energy cost reduction opportunities.

3.1 Approach of energy audit

In order to achieve the desired objectives of the assignment, team of consulting engineers has been deployed to carry out the required observations, tests and checks at site. It includes data collection, site observations and measurement of power of different electrical equipment's. In order to make the audit systematic and methodical, based on scope of work, detail formats for recording measurements has been developed and used during the audit.

3.2 Scope of work

1. **Review of Electricity Bills**
   a. Review of present electrical distribution like Single Line Diagram, transformer loading, electricity distribution in various areas / floors etc.
   b. Exploring the Energy Conservation Options in electrical distribution system.
2. **Air-Conditioning System**
   a. Review of present AC system like central AC, VRVs etc.
   b. Performance assessment of central AC, VRV system.
   c. Performance Assessment of Chillers, Cooling Towers, Air Handling Units (AHUs)
   d. Analysis of AC Performance like estimation of Coefficient of Performance (COP), Specific Energy Consumption (SEC i.e.KW/TR), Performance of Chilled Water Pumps, Condenser Water Pumps, etc and comparison of operating data with design data.
3. **Diesel Generator (DG) Sets**
   a. Review of DG set operation
   b. Performance Assessment of Diesel Generator sets in terms of Specific Fuel Consumption (i.e. KWH/Liter),
   c. Exploring the Energy Conservation Options in DG Sets.
4. **Pumping System**
   a. Review of chiller water pumping and distribution systems.
   b. Performance assessment of all major water pumps i.e. power consumption vs. flow delivered, estimation of pump efficiency etc.
   c. Exploring the Energy Conservation Option in Water Pumping System.

5. **Hot Water Generator & Boiler**
   a. Performance evaluation of Hot water generator & Boiler
   b. Study of Specific Energy Consumption of present Hot Water System

3.3 Brief Description of the Building & Its Energy Cost

Total gross area is 2,03,763 Sqft. Built up area of the building (air conditioned) is 84,441 sqft. Three major sources of energy, Rs. 2.25 Cr/ year for electricity, Rs. 1.32 Cr/ year for HSD & Rs. 66.24 Lacs/ year for LPG). In energy consumption terms these are 2.98 MU of electricity per year, 224.8 KL of HSD per year and 74.6 MT of LPG per year.

4. Result and discussion

4.1 Energy consumption and its cost for last one year are as follows:

Table 1: Energy Cost for commercial building

Sr. No.	All Utilities (April-13 to March-14)	Value per year	Unit per year	Amount, INR.	% Distribution
1	Annual Electricity Consumption (MVVN)	29,84,320	kVAh	2,24,45,976	53.09%
2	Annual HSD Consumption (DG, HWG, Boiler)	2,24,876	Liters	1,51,27,409	31.24%
3	Annual LPG Consumption in Kitchen	74,594	KG	66,23,947	15.67%
4	Annual water consumption	1,19,548	KL		
	TOTAL			4,22,79,091	100%

4.2. Following table shows there percentage contribution in the annual electricity bill:

Table 2: Percentage contribution in the annual electricity bill

Sr. No.	Utility	kWh per Year	% Contribution
1	HVAC (Chiller, Condenser & Chiller Pump)	10,42,217	34.33%
2	Air Handling Units (AHUs)	2,08,066	6.85%
3	Main Kitchen	3,03,438	10.00%
4	Public Area Lighting	3,25,658	10.73%
5	Guest Area Lighting	2,68,800	8.85%
6	External Lighting	42,460	1.40%
7	Kitchen Lighting	1,38,546	4.56%
8	Public Area (Excluding Lighting)	1,17,765	3.88%
9	Pump Room	61,920	2.04%
10	Business Center & Banquet (Excluding Lighting)	73,021	2.41%
11	Service Area	59,160	1.95%
12	Cold Storage & Deep freezer	75,884	2.50%
13	Others & Unaccounted	3,18,734	10.50%
	Total	30,35,669	100.00%

4.3 In Energy Audit Study, identified energy saving potential is **23.49%** of total energy cost. Over the years it has been observed that to achieve and maintain this savings year on year only capital investment is not sufficient. Operation and maintenance (O&M) of the energy conservation measures along with monitoring and verification (M&V) of the savings is also necessary. This costs around 15 to 20% of the capital investment needed.

5. Conclusion

- The performance of the HVAC system and heat pump may be increased by preheating the water. The hot water from the flat plate collector may be obtained at 35^{o}C which is further utilized as preheated water to the heat pump
- The heat pump increases the hot temperature to 55^o C , which then supplied to the hotel rooms, kitchen, gym & spa center, and swimming pool (in winter). The return water from AHU at increased temperature of 15^o C is send to heat pump where 5^o C is obtained as temperature difference . From the earlier research done in the field of refrigeration system, for every 4^o C decrease in chilled water there is increase of 1 % of efficiency in refrigeration.
- The energy efficiency in HVAC is done by using solar assisted heat pump which save the conventional fuel such as coal, wood, diesel and lpg. In this thesis it is clear that by using heat pump we can optimize the performance of HVAC system and saved the fuel from 1000 ltr/day to 0 ltr/day.
- Future recommendation after doing this research is that we must use solar assisted heat pump at commercial as well as domestic level. By using solar assisted heat pump we can save conventional fuel, reduce carbon emission to our environment and optimize the HVAC system.

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