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Comparative Analysis of Different Cooling Options for Building Cooling Requirements

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***Abstract*— Cooling Load Temperature Difference (CLTD) and Solar Heat Gain Factor (SHGF) methods which are well-known cooling or heating load estimation procedures used in this paper to predict the hourly and daily average cooling and heating load through different types of walls, roofs, fenestration ,occupancy and equipments for a building of single wall construction. As per the cooling load requirements of a building a comparative analysis for various chiller systems of different combinations such as water based screw chiller, magnetic chiller and magnetic chiller with free cooling and each system with thermal energy storage tank and without thermal energy storage tank is carried out in order to evaluate yearly operating cost. By this comparison between various options a best option for a building cooling is a magnetic chiller with free cooling and thermal storage tank.**

Keywords*— *Cooling Load, Screw Chiiler (S.C.); Magnetic chiller (M.C.); Free Cooling(F.C.); Thermal Energy Storage Tank(TES);Tonnes of Refrigeration(TR).

I. INTRODUCTION

Selection of energy-efficient air conditioner (A/C) depends on two factors, namely, energy-efficiency of the equipment and correct size or cooling capacity of the equipment for any particular application. Chiller having a more electricity power consumption in a HVAC system so to evaluate performance of chiller is crucial for reduce power consumption. Aim of this paper is to demonstrate, standardize the operating schedule and compare operating cost of screw chiller, magnetic chiller and magnetic chiller with free cooling in cost efficient manner. The required cooling area of the building space is 40242 m_2 and operating schedule of the building is from 8:00 a.m. to 6 p.m. with the working of 275 days per year.

II. METHODOLOGY

Heat gain is the rate at which energy is transferred to or generated within a space. It has two components, sensible heat and latent heat, which must be computed and tabulated separately.The Cooling Load Temperature Difference[1] (CLTD) Method has been a popular method for estimating fabric heat gain through and Solar Heat Gain Factor (SHGF) is for estimating the heat gain through fenestration. These methods are widely used by air conditioning engineers as they yield reasonably accurate results and estimations can be carried out manually in a relatively short time. As per calculated cooling load through out the year selection of the screw chiller and magnetic chiller of appropriate size and capacity as per required the peak cooling load of space is carried out. Then compare three systems screw chiller, magnetic chiller and magnetic chiller with free cooling in terms of operating schedule and cost of operation through out the year. Calculated peak cooling load is 548 TR at 21st may 3:00 p.m.

So, for this required cooling load four chillers of 150 TR for screw chiller and magnetic chiller are selected. During off peak cooling demands usually at nights chillers are operated and store this cooling load in thermal energy storage tank of capacity 1600 TR. During peak hours demand this cooling load is distributed to conditioned space until it discharges.

III. BUILDING DESCRIPTION

TABLE I . BUILDING DESCRIPTION

Sr. No.	PARTICULARS	DESCRIPTION
1.	Building Type and Orientation	$21^0$10'N Latitude / $72^0$52'E Longitude and it's a commercial Building.
2.	No. of Floors	A ground floor and five above five floors
3.	Total Area of a Building	82143 ft^2
4.	Conditioned Space area	40,224 ft^2
5.	Inside Design conditions	25^0C temperature with 50% RH
6.	No. of Occupants	2453
7.	No of Appliances	1070
8.	No. of Hours of Operation	10 hours / day (8 a.m. to 6 p.m.)
9.	Total Working days per year	275 (Excluding Sunday and government holidays)

IV. CLTD METHOD

The Cooling Load Temperature Difference / Cooling Load Factor (CLTD / CLF) Method has been a popular method for performing cooling load calculations as per Cooling and Heating Load Calculation. This method was developed as a hand calculation method, which would use tabulated CLTD and CLF values. Heat gain generally occurs in form of :

a. Heat gain through walls and Roofs

b. Heat gain through Windows/Fenestrations

c. Heat energy generated within Space
(Lights, Occupants, Appliances ,Motors etc.)

d. Ventilation and Infiltration air

e. Heat gain by duct (5% of sensible heat gain)

V. COOLING OPTIONS

A. SCREW CHILLER

The Water-cooled Screw Chiller selected in this paper for comparison is a chiller with variable frequency drive (VFD). It having a recumbent shell-tube condenser and a fin-tube shell evaporator, stable heat exchange or cooling tower. It having endurable efficiency and easy maintenance and has a refrigerant R-134a. The Water-cooled screw Chiller is well known as an ideal unit for central air conditioning system.

TABLE II. POWER CONSUMPTION BY SCREW CHILLER

% LOAD	kW/ TR
100	0.672
75	0.573
50	0.520
25	0.695

B. MAGNETIC CHILLER

A Magnetic Chiller consisting a bearing that supports a load using magnetic levitation. Magnetic bearings support moving parts without direct contact and they are able to levitate a rotating shaft and allow relative motion with low friction and low abrasion. Major advantage of magnetic bearing is oil for lubrication is not required.

TABLE III. POWER CONSUMPTION BY MAGNETIC CHILLER

% LOAD	kW/ TR
100	0.669
75	0.505
50	0.525
25	0.784

C. FREE COOLING

Free cooling is where one can utilize the lower outside air temperature for chilling water in a process or air conditioning, rather than part or all of chiller plant. When the ambient air drops to a set temperature - a modulating valve allows all or part of the chilled water to by-pass your existing chiller and run through the free cooling system, which uses less power and utilize the lower ambient air to cool the water in your system.

D. THERMAL ENERGY STORAGE

Thermal energy storage stores chilled media such as water, ice, phase change material etc. during periods of low cooling demands and far use later to meet air conditioning load, then withdrawn and distributed through facility during peak rate demand hours. Warm and chilled water enters and exits the tank through diffusers located at the top and bottom of the tank. These diffusers are designed to eliminate turbulence and provide a stable, sharply defined transition layer. This allows for the natural stratification of warm water at the top of the tank and chilled water at the bottom of the tank, due to the varying densities of water.

VI. OPEARTING COST

Operating cost of the each option is calculated by calculating the cost of following :

- Power consumption by chiller compressor
- Power consumption by chilled water pump
- Power consumption by condensing pump
- Power consumption by cooling tower fan
- Cost of water

VII. RESULTS

By the cooling load temperature difference (CLTD) method calculated maximum cooling load during peak hours as per previously recorded data of temperature and relative humidity (RH) is 548 TR is on 21st may 3:00 p.m.. Simultaneously cooling load for different months during particular hours is also calculated as per the previously recorded data of temperature and relative humidity(RH).

Fig.1 shows the maximum average cooling load required for each month. And as per the required cooling load at particular hour simplify the operating schedule of each chiller system for comparison. Operating cost of the particular system can be calculated by considering power consumption by chiller compressor, pumps, cooling towers and cost of required water.

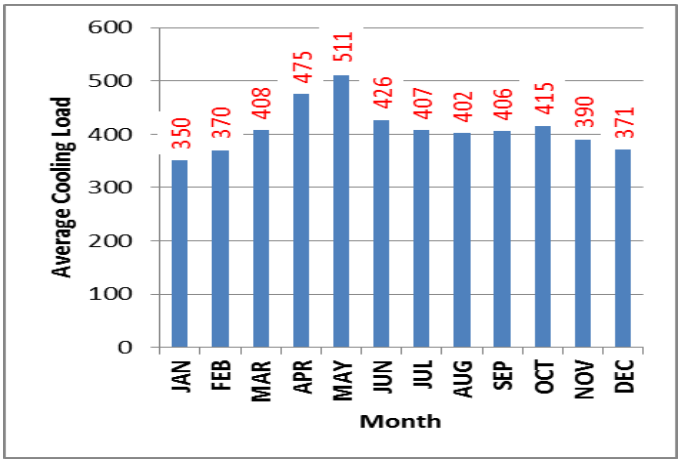

FIGURE 1. AVERAGE COOLING LOAD VS MONTH

Yearly operating cost comparison for various options such as screw chiller with thermal energy storage and without thermal energy storage, magnetic chiller with thermal energy storage and without thermal energy storage and magnetic chiller with free cooling, thermal energy storage and without thermal energy storage are discussed below :

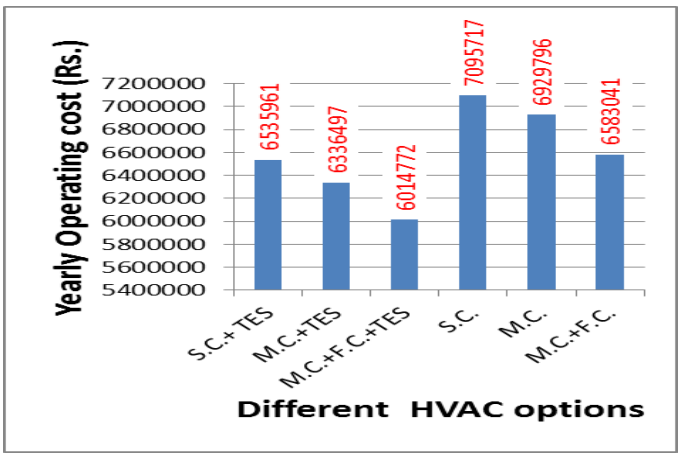

FIGURE.2 YEARLY OPERATING COST VS DIFFERENT HVAC OPTIONS

From the Fig.2, there is a best option for the conditioning of the building is magnetic chiller with free cooling and thermal energy storage tank. Compared to other options savings per year by using magnetic chiller with free cooling and thermal storage tank is tabulated below :

TABLE IV. SAVING IN (RS.) PER YEAR COMPARED TO OTHER SYSTEM BY USING M.C.+F.C.+T.E.S

Different systems	Saving per year with M.C.+F.C.+T.E.S (Rs.)
S.C.	1080946
M.C.	915025
M.C.+ F.C.	568269
S.C.+T.E.S.	521189
M.C.+ T.E.S	321725

VIII. DISCUSSION

In order to adopting the different energy saving options, compared to a simple screw chiller system about 24.21% saving in an operating cost can be obtained with the magnetic chiller with free cooling and thermal energy storage system. Water cost of magnetic chiller system is slightly higher than screw chiller system but power consumption by magnetic chiller compressor, pumps and fans are considerably reduced compared to screw chiller system. Generally during the winter season when the outside atmospheric temperature is lower than 25^0C then a free cooling system is available without any actual operation of chiller which circulate the outside air in the conditioned space of the building . Operation of free cooling during hours of lower outside temperature saved considerable amount of energy.

IX. CONCLUSION

Here by comparing the quantitatively measured and calculated data for each system throughout the year for a building cooling conclude that magnetic chiller with free cooling and thermal energy storage is best option for tropical climate.

- 13.20% saving in operating cost with this system is obtained compared to a magnetic chiller without free cooling and thermal storage.
- Also from the operating schedule of the each system one can say that if the operation of each chiller system carried out within the load range 50% to 75% optimum performance of the chiiler system can be obtained with minimum operating cost compared to other load conditions.
- A magnetic chiller with free cooling and thermal storage tank having higher capital cost compared to a system without thermal storage tank, but it can be recovered within payback period of 1.5 year.

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