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Process of designing efficient, emission free HVAC systems with its components for 1000 seats auditorium

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ABSTRACT

Heating, Ventilating and Air Conditioning Systems (HVAC) are applied for primarily cooling purpose as well as to maintain quality of air. Since, most of the HVAC company has lack of data for the designing purpose – leads to uncomforting. Less standardization in designing criteria of HVAC Systems (Except ASHRAE which provides data for refrigeration systems) leads to write this paper. There is no any sources available that can exactly says how to design an energy efficient HVAC Systems. This paper provides the mathematical aspects for designing the HVAC Systems. This paper includes the process of designing HVAC with components by using mathematical framework – confirmed by software. This paper provides proper selection of capacity of systems and life cycle cost analysis too. For the simplicity of understanding, we have provided a demonstration with the example of 1000 seats auditorium situated at Vadodara, Gujarat. As the result of this designing, we got an emission free HVAC Systems with low GWP (Global Warming Potential) and ODP (Ozone Depletion Potential) – providing best comfort condition with reduction trunk duct arrangement and low life cycle cost. However production side of the Ducting Systems will become more expensive and complex due to numbers of joints and duct sizes but after applying it properly – better performance and less frictional losses lead the system to high Energy Efficiency Ratio (EER).

1. Introduction

HVAC- Heating, Ventilating and Air conditioning, is a branch of mechanical engineering that is concerned with achieving both indoor and vehicular human comfort by providing adequate and acceptable heat and fresh air. Apart from residential applications, the HVAC system is also very important and essential in many industries and laboratories in cold storage and preservation purposes, pre-cooling and Pasteurization of milk, in various manufacturing processes in rubber industries, textile industries, etc. It involves the process of exchanging or replacing air in any place to provide high quality indoor air, which involves temperature control, oxygen replenishment, and removal of moisture, odours, smoke, heat, dust, etc. from the air.

With rise in temperature because of global warming [1], the increase in the unavailable energy (increase in entropy) and unusual climatic changes seen in recent years [2] has caused an increased demand for heating and cooling technologies, which is what HVAC systems do and so these systems have a wide applicability ahead.

HVAC design is a critical component and if performed carefully, energy efficient system at affordable cost can be developed. Although, designing an HVAC system is a complex task since there are various parameters which need to be taken care. There parameters include the selection of proper tonnage and specifications because, if not selected properly, then the required comfort cannot be achieved and the design efforts are wasted.

2. Location details

HVAC systems depend on the larger number of factors, oh which the location specific climate conditions is the most important. Therefore, for the proper design conditions, we use standard climate data. Climate is mostly dry in India, so, we consider the summer as a design condition. Cold northerly winds are responsible for a mild chill in winter and the southwest monsoon brings a humid climate from mid- June to mid- September.

Table 1 shows the temperature details of Vadodara [3,4].

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Abbreviations

HVAC	Heating, Ventilating and Air conditioning
DBT	Dry Bulb Temperature
WBT	Wet Bulb Temperature
%RH	Relative Humidity
CLTD	Cooling Load Temperature Difference
RCC	Reinforced Cement Concrete
SC	Shading Coefficient
SHGF	Solar Heat Gain Factor
ACR	Air Change Rate
VCR	Vapour Compression Refrigeration
VAR	Vapour Absorption Refrigeration
Li–Br	Lithium–Bromide
ODP	Ozone Depletion Potential
GWP	Global Worming Potential
LCC	Life Cycle Cost
EER	Energy Efficiency Ratio

Table 1
Outside and inside conditions for Vadodara.

Condition	Outside (°C)	Inside (°C)
DBT	43.33	23.83
WBT	26.4	17.77
%RH	37	55
Daily range	19 °C	

3. Building plan

The orientation and planning of a building has a significant effect on the space heat gain, which must be considered for the optimal design of an auditorium. The plan view as well as the section and side elevation of an auditorium for 1000 people is shown in Figs. 1 and 2, respectively, and the electrical designing of the auditorium is shown in Fig. 3. These designs are developed according to energy conscious building design [5,6]. Table 2 shows the lighting systems in the auditorium.

4. Load calculation

To find the tonnage capacity of the HVAC system, a load calculation is required. Load is the amount of heat transfer to the system which must be removed to obtain the desired comfort and temperature levels. It also provides information for equipment selection, system sizing and system design. There are two types of loads:

1) Cooling load-cooling load calculations are carried out to estimate the heat gain of the building in the summer to arrive at the required cooling capacities.
2) Heating load-heating load calculations are carried out to estimate the heat loss from the building in the winter to arrive at required heating capacities.

As discussed previously, our main intention is to design the HVAC system for summer, which requires calculating the cooling load. For cooling load calculations, the system must be divided into several parts such as [7,8].

1) Heat gain through the walls and roof.
2) Heat gain through the windows and doors
3) Heat gain due to people
4) Heat gain due to lighting
5) Heat gain due to appliances

4.1. *Heat gain through walls and roof*

Heat gain through the walls and roof is given by …

$$Q = U * A * (CLTD)$$

here,
U = overall heat transfer coefficient
A = area of the walls and roof through which heat is passing
CLTD = cooling load temperature difference
As seen from the equation, the heat transfer is dependent on U, A and CLTD.

4.1.1. *Overall heat transfer coefficient (U)*

Heat gain through the walls and roof is dependent on overall heat transfer coefficient (U), which can be written as [9].

$$\frac{1}{U} = \frac{1}{h_1} + \frac{l_1}{k_1} + \frac{l_2}{k_2} + \frac{1}{h_2}$$

here,
U = overall heat transfer coefficient (W/m^2K)
h_1 = outdoor convective heat transfer coefficient (W/m^2K)
h_2 = indoor convective heat transfer coefficient (W/km^2K)
l_1 and l_2 = thickness of layers (m)
k = conductive heat transfer coefficient (W/mK)
Values of conductive heat transfer coefficient for the different types of materials are as described below. While as the construction of walls are as shown in Fig. 2.

- Galvanised iron = 61.06 W/mK
- Brick = 1.32 W/mK
- Fibreglass = 0.04 W/mK
- RCC = 1.58 W/mK
- Gypsum board = 0.17 W/mK

Values of h for the different conditions are

- Outside condition = 22.7 W/m^2K at 12 km/hr wind speed
- Inside – Vertical Heat flowing down = 6.13 W/m^2K

So, that for the wall and roof (Ceiling) construction as shown in Fig. 2, the values of the overall heat transfer coefficient (U) are

1) Wall – $0.566 \frac{W}{m^2K}$
2) Roof – $0.312 \frac{W}{m^2K}$

4.1.2. *Area*

The area of walls and roof are major factors which affect the heat transfer. Table 3 shows the area of different orientated walls and the roof.

4.1.3. *CLTD (cooling load temperature difference)*

The CLTD is a theoretical temperature difference that accounts for the combined effects of the inside and outside air temp difference, daily temperature range, solar radiation and heat storage in the construction assembly/building mass. It is affected by orientation, tilt, month, day, hour, and latitude.

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