Design of HVAC system using Solar energy and Thermally Active Building System

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***Abstract*—This paper includes the design of HVAC&R using innovative techniques. An attempt has been made to gather different techniques together and design a collaborative system which reduces the power requirement considerably.**

Keywords— Thermally active building systems (TABS), smart grid, building prediction model, GEOTABS, solar HVAC, geothermal cooling.

I. Introduction

Energy consumption reduction efforts in the residential buildings sector is very important as a major chunk of energy provided to a building is utilized in it. Various techniques such as TABS, solar VARS, **aDsorption chillers**, etc. have been collaborated into a single unit building system (ISAAC) to satisfy the heat load requirements.

II. Problem definition

- Selection of existing (practical) HVAC system.
- Calculation of Heat load and energy consumption using conventional HVAC system.
- Study of latest available non-conventional HVAC system.
- Mathematical modelling of selected techniques.
- Design of a collaborative system.

III. Objective

Modern day HVAC systems use a considerable amount of energy out of the total energy provided to a building system. Also the use of commercial refrigerants used in such systems is a big threat to the environment. Use of high grade energy sources for such low grade applications is not advisable. Hence there is a need for introduction of a better system which is more eco-friendly, more energy efficient and sustainable

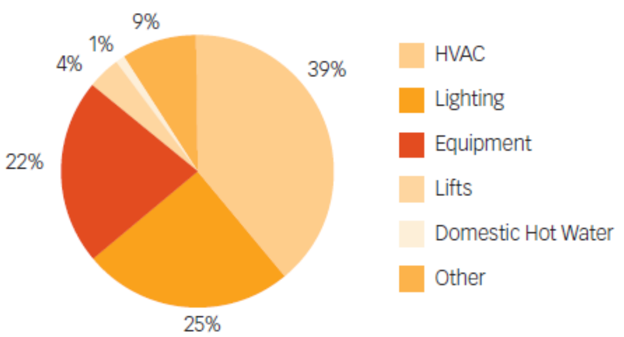

Fig1: Energy consumption of general commercial building [8]

IV. Literature Survey

The literature survey of this project has been divided into two majors i.e. Non-conventional and Conventional methods

A. *Conventional Components of HVAC*

Chillers:

A cooling tower circulates cold water or air to the chiller. Heat exchange occurs between this cold fluid and the warm refrigerant in the chiller. The refrigerant, after being cooled, cools the water entering the chiller. The chilled water is then circulated to the AHU. Chillers are classified as air-cooled and water-cooled chillers

Cooling Tower:

A cooling tower is a heat rejection device used to dispose of unwanted heat from the chillers. The warm water from the chillers is circulated through the cooling tower where evaporative cooling causes heat to be removed from the water and added to the outside air. The cooled water is then piped back to the chillers.

B. *Non Conventional Methods*

TABS (Thermally Active Building System):

When it comes to controlling the indoor temperatures of complex environments such as modern buildings, innovative solutions are required. HVAC systems are relatively climate sensitive, and so the need for modern temperature regulation systems to function reliably in all climates becomes greater.

The reason for the upsurgeance of TABS as a priority green design element in modern commercial construction is a simple two-fold one: they are far more cost-effective and energy-efficient than their counterpart systems. That alone should be reason enough to consider them for any and all building projects you plan to undertake.

Solar-VARS:

It is a solar heat operated system, which is quite similar to vapor compression system. In this system compressor is replaced by pump, generator and absorber. In this Ammonia is used as a refrigerant i.e. R-717. Heat in generator is supplied by solar electrical power stored in battery. The basic objectives of this system are as follows:

1. To make effective refrigeration using solar energy.
2. One-time investment with minimum running expenses.
3. Pollution free system.

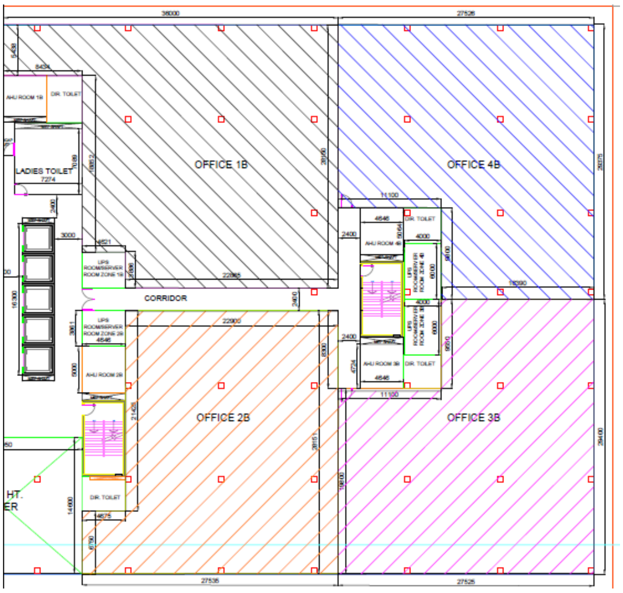

Fig2: Architectural view of the building

V. Design of the System

Collaborative Design:

The project deals with designing an HVAC system for a site at Nagpur considering all the climate conditions and factors according to standard procedures [1]. The design and working of the following techniques for the given architecture are enlisted as follows:

1. Glass selection (to reduce heat load only)
2. TABS (Thermally active building systems)
3. Solar VARS (Vapour absorption refrigeration system)

TABLE I [1]

Sr. No.	**Building Structure**	
1	No. Of floors	6
2	No. of offices on each floor	8
3	No of stair cases	4
4	No of wings	2

A. *Glass selection:*

Heat load assumptions:

While calculating heat load summer conditions were considered and corresponding values were selected from ISHRAE handbook [1].

1. Considering may as the month of design.
2. Considering 4:00 pm as the time of day.
3. Considering double vertical glass with u factor 0.55 btu/hr sqft.
4. Ups load is taken as 20% of the computer load.
5. Considering one coffee maker and one water cooler in each office.
6. 4thfloor is not air conditioned but is ventilated by open windows and fans as it is the refugee area.
7. Psychometric charts were used for calculating all temperatures
8. Bypass factor is taken as 0.1.

It would be advantageous to reduce the energy consumption of building to a more environmentally friendly level and to a more energy cost efficient level by using Solar Control Window Film (SCWF). These films help to keep the summer heat out and help to lock the heat inside in winter. The summer period in Nagpur is about 4 months long starting from February till May with the hottest period from mid-April till end of May. Similarly, winter period is also for around 4 months starting from October till January with the coldest period from mid-December till mid-January.
In this part we will be calculating the Solar Gain coefficient, the net annual cost saving due to sticking SCWF on the window and simple payback period.

In conventional method we use normal glass with SHGC value of 0.76. But in our hybrid technique we use a film which gives the SHGC value of 0.2. That means the difference becomes 0.5. The effect of that change is very significant in terms of efficiency, savings, and payback period.

Specification of Glasses Used:

- The actual glass used insulated DGU with SHGC (Solar Control window film) value= 0.76.
- The new glass with film which is to be proposed SCWF (Solar Control window film) with SHGC value= 0.264mm

Calculation:
The procedure for calculation is as follows.
Procedure
• Calculate the total solar heat flux incident on the glazing during summer and winter months.
• Then cooling load decrease and heating load increase are determined.
• After that decrease in cooling cost and increase in heating cos are calculated.
• After that cost saving is determined.

TABLE II

Wall no.	**Area (m^2)**	**Decrease in cooling load (KWH/yr)**	**Decrease in cooling cost (KWH/yr)**	**Annual cost saving Rs/yr**
1	125.45	50616.56	39462.81	115547.47
2	117.70	47489.59	37024.88	108408.53

Total implementation cost = 450* total area in ft^2= 1177758 Rs
(Considering cost of installation per ft^2 of glass panel = 450 Rs)

Thermally Active Building System:[2],[3],[6]

Thermal properties:

TABLE III [4]

Material	Conductivity (W/mK)
Screed	2.5
PEX (cross link polyethylene)	0.41

Structure description:

The following illustrations show cross-sections and examples of wall and ceiling applications of the WW-10 system.

1) Brick wall
2) Pipe distance
3) Pipe clamp rail
4) Fastening option
5) PB-pipe 10 x 1,3 mm
6) Needle point screw
7) Reinforcing fibre
8) Mineral plaster 20-25 mm

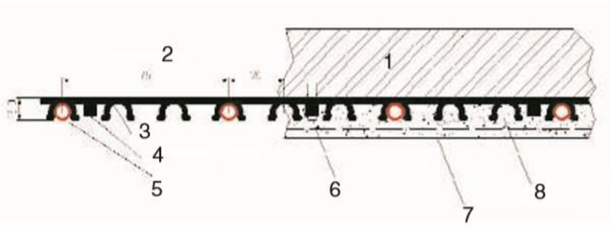

Fig 3 Schematic view of TABS WW-10 [2]

Solar-VARS (Vapour Absorption Refrigeration System):
The design of following components is involved in Solar VARS:

1. Flat plate collectors
2. Water storage tanks
3. Absorption/A**d**sorption Chillers

Also it is necessary to consider the following modes of operation:

TABLE IV

Solar Energy	Cooling status	Hot & Cold water Storage	Action
Available	Required	May/may not be present	Direct use of Solar energy
Available	Not required	May/may not be present	Storage of energy
Not available	Required	Available	Directly from storage
Not available	Required	Not available	Using auxillary system
Available	Not required	Not required	Dumping mechanism is used

Technical specifications for the site:

- Location : Nagpur (21.15 degree North)
- Day and time : 15 MAY at 12:00 noon N=135
- Annual average intensity of solar radiation (H_b) = 462 W/m^2
- Hour angle = 0^0
- Tilt angle = 30^0
- No of glass covers = 2 , ρ_d = 0.22
- Heat removal factor F_r = 0.8
- Transmittance of glass = 91%
- Absorptions of glass = 95%
- Overall loss coefficient = 7 W/m^{2}K
- Ambient temp = 298 K
- Collector efficiency = 6%

The formula for average annual solar radiation is as shown below:

H_0 = 33.99 MJ/m^2

The useful energy gain (q_u):

q_u = 196.49 W/m^2

i.e. q_u = 196.49×5876 W (available area)

i.e. q_u = 1154.398 kW

i.e. q_u = 1154.398×3600 kJ/h

i.e. q_u = 4155.84 kJ/h (Static calculation)

VI. Conclusion

The following results were obtained by the calculation of the refrigerating effect of the new system. The cooling provided by the new system is restricted to temperature difference of 6-8˚C. Hence the basic system cannot be replaced completely; however the power requirement of current system can be reduced significantly. The simulation result for the complete system was obtained from TRNSYS©. The graphical representation of the same is shown below. However the simulation contains only the useful heat gain simulation due to the shortcomings of the demo software used. Final results will include the cooling load results for the building to verify the same with the static calculations.

TABLE IV Cooling load achieved by TABS

Office no.	No. Of modules		Q(kW) (reqd)	Q(kW)(TABS) (achieved)
	Type I	Type II		
1B	424	202	147	162.3
2B	180	335	124	137.8
3B	570	0	166	143.07
4B	570	0	139	143.07

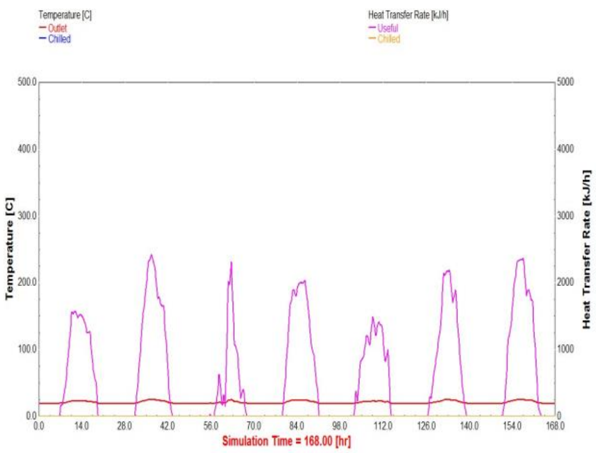

Fig 4 Simulation results obtained from TRNSYS

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