Design of HVAC System Using Solar Energy and Natural Convection

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Abstract— **This paper includes the study of non-conventional methods in HVAC&R system. An attempt has been made to gather different techniques together and design a collaborative system which reduces the power requirement considerably. This paper includes a comparative study of between the conventional methods and modern methods through simulations.**

***Keywords*— Thermally active building systems (TABS), smart grid, building prediction model, GEOTABS, solar HVAC, natural convection, heat load calculation, 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.

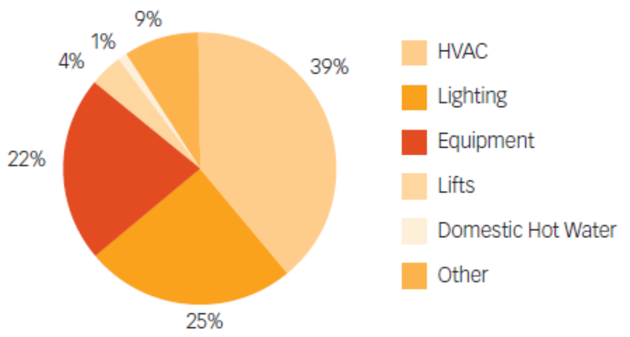

Fig1: Energy consumption of general commercial building

II. Problem Definition

A brief description of the work done with the aim to reduce energy consumption effectively. The concept of **ISAAC** is introduced in this concept. **ISAAC** stands for **Innovative Solar and Air Convection**.

- 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. 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

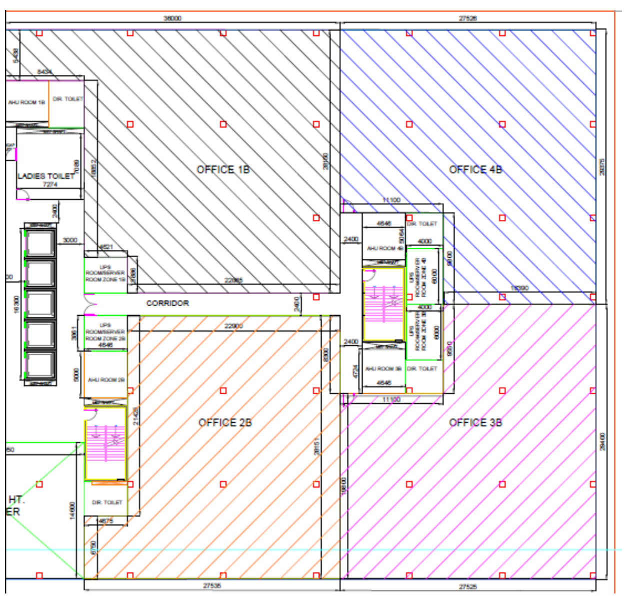

Fig2: Architectural plan of office building

Cooling Tower:

A cooling tower is a heat rejection device used to dispose of unwanted heat from the chiller. The warm water from the chiller 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 chiller.

B. Non Conventional Methods

1)Solar VARS:

It is a solar heat operated system, which is quite similar to vapour 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.

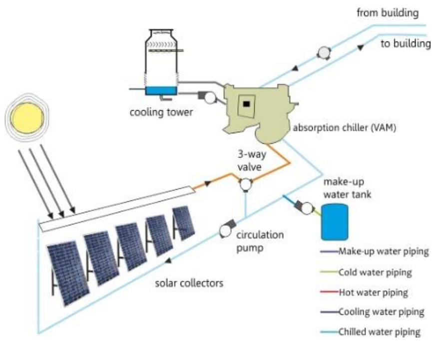

Fig3 :Solar VARS

2)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. However, a slightly more in-depth explanation may be what you require to make informed project planning decisions.

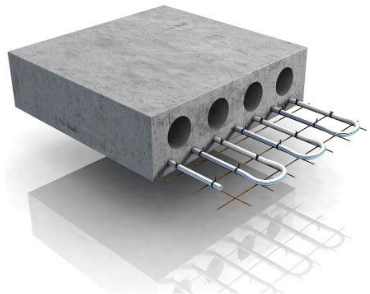

Fig4: TABS

3)Adsorption Chillers:

Adsorption chiller, any device designed to cool interior spaces through adsorption, a process that uses solid substances to attract to their surfaces molecules of gases or solutions with which they are in contact. Instead of using large amounts of electricity, the cooling process in an adsorption chiller is driven by the evaporation and condensation of water. Adsorption chillers provide an energy-efficient alternative to conventional refrigeration and air conditioning, because energy to drive the cooling system comes from water warmed by waste heat, such as exhaust or steam from industrial processes or heat directly generated from solar panels or other devices.

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 Intelligent HVAC System will control Heating, Ventilation and Air Conditioning (HVAC) of the Building Structure with 6 Floor, Basement and Terrace, having 2 wings. The project also consists of Full height atrium in between the wings, 4 stair cases and 8 Offices on each floor.

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

Studies regarding heat loads and various installation equipment, along with glass study were put together into this project considering the economic advantage of client as well as the safety of the occupants.

A) Glass selection: [7]

1) Single glazed glass

A single glazed window is constructed using a single plane of glass.

Range: 3 – 10 mm
Efficiency: 20 times less than Double-glazing.

2) Double glazed glass

Good sound dampening quality
Reduces heat and UV entry
Provides good light and reduces outward heat loss
Outside glass as low e glass.
Inside glass as laminated glass.
Argon layer in between for better acoustics.
Pristine white-code PLTT, transmission 74%, SHGC 0.54

Fig5: Double Glazed and Single Glazed Glass

Advantages:

1) Reduce dew formation.
2) Reduce sound transmission.
3) Provides more visible light.
4) High strength.

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 0.26. that means the difference becomes 0.5. the effect of that change is very significant in terms of efficiency, savings, payback period.

Specification of Glasses Used

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

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

Average Direct Normal Irradiance (Monthly Average)		**Average Global Horizontal Irradiance (Monthly Average)**	
JAN	6.17	JAN	4.92
FEB	6.96	FEB	5.87
MAR	6.69	MAR	6.58
APR	6.71	APR	7.16
MAY	6.64	MAY	7.22
JUN	3.86	JUN	5.61
JULY	2.60	JULY	4.84
AUG	2.23	AUG	4.36
SEPT	4.65	SEPT	5.43
OCT	6.30	OCT	5.64
NOV	6.46	NOV	5.12
DEC	6.51	DEC	4.78

(Latitude: 21.15 Longitudes: 79.05)

Design considerations:

- As on 15th October 2018 unit cost of fuel = 1.16$ =85.33 Rs

- Assuming Efficiency =0.8
- COP=2.5
- Unit cost of electricity (for 100 units and above in Nagpur) = 12.8 Rs

Payback period = 5.26 yr

TABLE III

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 sqft = 1177758 Rs
(Considering cost of installation per sqft of glass panel = 450Rs)

Payback period = 5.26 yr

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

Components and materials of TABS

This section defines the various components and materials that are available to help you identify them:

- Modules
- Pipes
- Pipe clamps and supports
- Fittings
- Manifolds

Thermal properties:

TABLE IV [4]

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

Structure description

The following illustrations shows 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 Brick wall

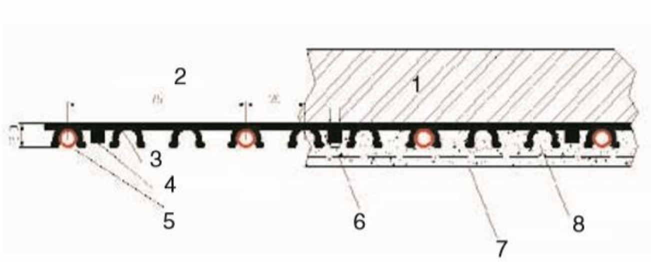

Fig6 Schematic view of TABS WW-10 [2]

TABLE V
(Cooling load achieved by TABS) [5]

Office no.	No. Of modules		Q(kW) (reqd)	Q(kW)(TABS) (achieved)
	1800	2000		
1B	424	202	147	162.3
2B	180	335	124	137.8
3B	570	0	166	143.07
4B	570	0	139	143.07

Drawing legend:

The drawings use the following colours:

- red: flow pipe to modules
- blue: blue dotted lines are the return pipes from the modules
- diagonal lines are used to indicate groups of modules.

The following example explains what the drawings means. The upper part shows a view of the wall. The lower part shows how this is indicated on the drawing. This is a top view of the wall with modules. The modules are indicated as diagonal lines with an indication of the connections of the flow and return lines. In each module, the text indicates the size of the module, for example: "625 x 2000" means 625 mm (63 cm) wide and 2000 mm (200 cm) high.

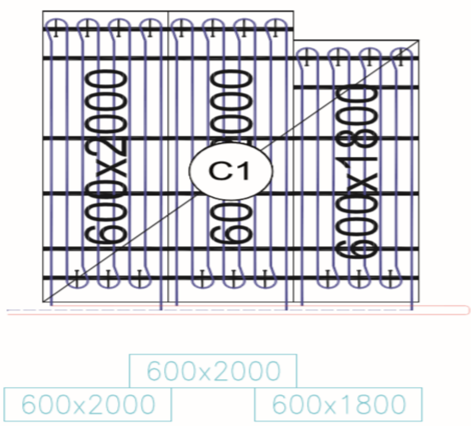

Fig7: Drawing Legends [2]

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