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Design of Heating Ventilation and Air-conditioning System for Health Care Facility

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Abstract : *A good healthcare system is a necessity that we cannot disregard in the ever-evolving and rapidly-evolving modern world. A good HVAC system is not only important for delivering comfort, but it may also be used to control infection.*

This project aims to an efficient HVAC system for a multispecialty hospital to provide optimum comfort and control the spread of harmful pathogen. There are several innovations taking place in HVAC systems this project also aims to integrate them to improve the comfort, overall efficiency and minimize the impact on the environment. The methodology followed is a step-by-step approach in which first the heat load of the entire building as given in plan is calculated and according to the heat load the systems are selected, and comparison is done between VRF, and Chilled water systems and the feasible system is recommended. Special features to improve energy efficiency and IAQ are also discussed.

Keywords - *Chilled Water System, Efficiency, Healthcare, Heat Load, Hospital, HVAC, VRF, Chilled Water System, Chiller.*

I. INTRODUCTION

The project aims at designing an efficient HVAC system for a Multi-specialty Hospital building which provides optimum comfort as well as to control the spread of harmful pathogens in the building. The project location is selected to be in Nagpur, Maharashtra, the building consists of 2 floors. From 2019 to 2035, Nagpur is expected to be the world's sixth fastest expanding metropolis. As a result, the city's rapid growth necessitates the rapid construction of health-care facilities like as hospitals and other health-care services.

Additional Constructional Features assumed are: -
Outside Wall: 230mm (brick wall + plaster).
Partition Wall: 115mm (brick wall + plaster).
False Ceiling: 1000mm (Gypsum false ceiling at 1 meter from bottom of slab).
Roof: 200mm (RCC + plaster + nitrile rubber insulation).

II. PROBLEM DEFINATION

Hospital is a place where people from all walks of life as well as different health categories are present. As the hospital is full of different people of different kind, thus providing optimum thermal air condition as per human comfort as well as excellent IAQ (Indoor Air Quality) is very essential. Our project focuses on designing a suitable HVAC system to achieve these conditions integrating newer innovative technologies and maximizing energy efficiency.

III. LITERATURE REVIEW

[1] Muzaffar Ali 08-UET/PhD-ME-4 Supervised by Prof. Dr. Mukhtar Hussain Sahir Optimization of Heating, Ventilation, and Air-Conditioning (HVAC) System Configurations. A methodical simulation-based

optimization approach for the effective and efficient evaluation of various HVAC system alternatives at the initial system design stage to result in an optimal configuration.

[2] Gonzalo Sánchez-Barroso and Justo García Sanz-Calcedo. This paper analyzes indoor environmental conditions and technical and hygienic requirements for the design of heating, ventilation, and air-Conditioning (HVAC) systems for high performance operating theatres.

[3] Sai Saran, Mohan Gurjar, Arvind Baronia, Vijayalakshmi Sivapurapu, Pralay S. Ghosh, Gautham M. Raju & Indubala Maurya stated that Knowledge and understanding of proper functioning of HVAC systems is crucial for critical care physicians, infection control committee members and the administrators to provide optimal safety and comfort to the ICU patients, staff and visitors, while reducing the spread of airborne infections.

[4] Energy-Efficiency in Air-Conditioned Buildings: The Green Buildings Dream presented by Essam E. Khalil, presented the different designs of the HVAC systems and energy consumption should concern with the optimization of airside design as the expected target to enhance the indoor environment.

IV. METHODOLOGY

As per the requirement the design selection was based on two different systems i.e., VRF (Variable Refrigerant Flow) system and Chiller System.

After the complete understanding of the floor plan our first approach was to step forward with heat load calculations. The next step in the design procedure is system selection. The selection of VRF systems has been done with the help of available standards in the market. Then total requirement of the tonnage and CFM has been calculated for the selection of AHUs in the Chiller System.

Next approach was to calculate and design the duct system for all the AHUs. Duct sizing was done with the help of software by consideration of flow rate (in CFM) and head loss (inch*water column per 100 ft). The next step was to select further additional features such as UV light, filters, bi-polar ionization, etc. as it plays vital role in controlling the air quality as it can kill cells and harmful pathogens by modifying the genetic material of microorganisms and destroying their ability to reproduce.

The next and the final step was to make energy estimation and calculate its consumption cost for the final selection of the systems as it shows the affordability over the complete year of usage of selected equipment.

V. HEAT LOAD CALCULATION

Based on selected location,

The outdoor design conditions are DBT = 109.20F, WBT =82.20F, RH=32.4% The indoor design conditions for rooms are DBT = 75.2F, RH=50%

As per NABH standards and ISHRAE standards the indoor design conditions for OT, Cath lab and are DBT = 69.8F, RH = 55%.

U values calculation:

Outside Wall: 0.58
Partition Wall: 0.74
Windows: 0.39
Doors: 0.55
Roof: 0.042
Solar Heat Gain Factor for Glass:.58

Temperature Difference calculations for different times of day was calculated as per ISHRAE handbook. Summary of the heat load calculations for each floor is given below.

Ground Floor

Table 01. Ground Floor Heat Load Summary

AREA (SQFT)	18,543.75
CEILING (FT)	8.5
OCCUPANCY (NOS)	364.00
LIGHT LOAD (WATT)	19,578.53
EQUIPMENT LOAD (KW)	91,073.50
FRESH AIR CFM	7,081.32
DEHUMIDIFIED CFM	19,807.65
REFRIGERATION TR	98.80

First Floor

Table 02. First Floor Heat Load Summary

AREA (SQFT)	22,011.60
CEILING (FT)	8.53
OCCUPANCY (NOS)	393.00
LIGHT LOAD (WATT)	26,016.17
EQUIPMENT LOAD IN KW	29,774.00
FRESH AIR CFM	6,338.74
DEHUMIDIFIED CFM	26,664.37
REFRIGERATION TR	106.48

VI . SYSTEM SELECTION

6.1 Variable Refrigerant Flow (VRF)

Variable refrigerant flow (VRF) systems adjust the refrigerant flow to indoor units according to demand. VRF technology is perfect for applications with fluctuating loads or where zoning is necessary because it allows you to manage the quantity of refrigerant delivered to fan coil units across a building. VRF systems provide design flexibility, cost-effective installation, and energy savings.

Multiple indoor fan coil units can be coupled to one outside unit in a VRF system. The outdoor unit has one or more inverter-driven compressors, which can be controlled by adjusting the frequency of the compressor's power source. The amount of refrigerant delivered by the compressor fluctuates as the compressor speed changes. Each interior fan coil unit has its own metering device, which may be regulated by either the indoor unit or the outdoor unit. The outdoor unit distributes the amount of refrigerant required to meet the particular requirements of each indoor unit as each indoor unit transmits a demand to it.

6.1.1 Merits: -

- Various IDU choices, such as hi-wall units, cassette units, concealed units, ducted type units, and so on, can be used.
- Using the current options that are feasible, one can get a LEED-Gold rating.
- Controlling the system is quite straightforward, perhaps as simple as operating a split air conditioning system, therefore no additional staff is necessary.
- Good alternative for providing air conditioning to flats and villas, as well as small installations where the system's complexity (a major flaw) can be maintained to a minimum.

6.1.2 Demerits: -

- If bigger capacities are desired, more room is required to install a large number of ODUs.
- Will not be of significant relevance where the cooling load diversity is minimal, such as in IT/ITES offices, malls, multiplexes, etc.
- Can be harmful to inhabitants since refrigerant is pumped through pipes, which are prone to leaks and allow refrigerant to enter the conditioned room.
- Installation, commissioning, and maintenance require highly experienced labour, particularly to discover and rectify leaks.

6.2.1 Indoor unit and outdoor unit selection: -

Ground Floor:

Number of units used:

Hi-Wall units 20
Four Way Cassette units 04
Compact cassette unit 02
Ductable IDU units 07
Total no. of equipment's: 33

Selection of indoor unit and outdoor unit based on TR and CFM for Ground floor

Table 03. Ground Floor IDU and ODU selections

Ground Floor					
Tonnage	0.8	1	1.3	1.5	1.7
Hi-Wall (Qty)	8	5	3	1	3
KW	23.2	17.5	14.1	5.3	18

Tonnage	2.3	3.2	4	5	
Four-way Cassette (Qty)	1	1	1	1	
KW	8.1	11.3	14.1	17.6	
Tonnage	0.6				
Compact Cassette (Qty)	2				
KW	4.2				
Tonnage	5	8	20		
Ductable IDU (Qty)	1	5	1		
KW	17.6	140.5	70.3		
Ground Floor Outdoor Unit					
`ODU1	Consulting Area+ Lab Area+ X Ray Room+ Dining Area			19.2	67.5
ODU2	Kitchen + Dark Room + Dry Room			20.8	73.1
ODU3	Male Ward + Female Ward + Changing Rooms + Nurse Stations			20.8	73.1
ODU 4	Reception Corridor Accounts			20.8	73.1
ODU 6	Scan + Physio + Eeg + MD + House Keeping +Pharmacy + Restrooms			16	56.3
TOTAL				97.6	343.1

First Floor: -

Number of units used:

Hi-Wall units	17
Four Way Cassette units	06
Compact cassette unit	02
Ductable IDU units	11
Total no. of Equipment	36

Table 04. First Floor IDU and ODU Selection

FIRST FLOOR				
Tonnage	0.8	1	1.5	1.7
Hi-Wall (Qty)	1	1	14	1
KW	2.9	3.5	74.2	6
Tonnage	2.8	3.2	4	
Four-way Cassette (Qty)	2	1	3	
KW	19.6	11.3	42.3	
Tonnage	0.6			
Compact Cassette (Qty)	2			
KW	4.2			
Tonnage	3	4	8	
Ductable IDU (Qty)	2	8	1	
KW	21	112.8	28.1	

FIRST FLOOR OUTDOOR UNIT			
ODU_F1	8 Bed Rooms	12.5	45
ODU_F2	7 Bed Rooms + Nurse Station + House Keeping Room 2 + Visitor's Room	19.2	67.5

ODU_F3	Change Rooms + Doctor Room + Staff Room + Sub sterile Service + House Keeping	17.6	61.9
ODU_F4	Corridor Area	16	56.3
ODU_F6	Urology + ENT	8	28.1
ODU_F7	OT1	4.7	19.7
ODU_F8	OT2	5.6	19.7
ODU_F9	CATH	3	19.7

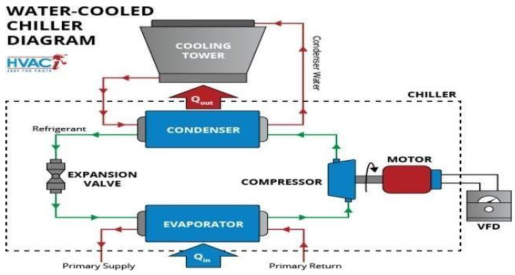
6.2.1 Chiller

Chillers transfer heat away from a space that requires climate control much like a traditional split system or package unit does, but they use water (or a water solution) to do so instead of air.

There are two types of chillers: -

I. Water Cooled Chiller
II. Air Cooled Chiller

We are using water cooled chiller for our project as water from the primary return enters the evaporator, where heat is transferred from the water to the refrigerant, starting the cooling process. The now-chilled water is then sent through the primary supply to the water tank, where the water pump distributes it to the various climate-controlled rooms. Because the second rule of thermodynamics states that heat always flows from hot to cold, the chilled water in the air handler absorbs the ambient heat from the conditioned room. The cooled air is then forced into the space via the ducting by a fan. The hot water is then returned to the chiller, where it is cooled once more. Meanwhile, the heat received by the refrigerant in the evaporator must be transmitted so that the refrigerant can absorb even more heat. The low-pressure, high-temperature refrigerant travels from the evaporator to the motor-driven compressor, where pressure and temperature are increased. The refrigerant then enters the condenser. Water-cooled chillers suck heat in by surrounding the refrigerant lines with water. The heat is subsequently released by pumping the water into a cooling tower. After condensing, the refrigerant passes through an expansion valve to lower pressure (and temperature) before returning to the evaporator to repeat the process.



6.3.1 Merits

- The most advanced technology, with a history spanning more than six decades.
- For performance evaluation, the AHRI 550/590 international standard is used.
- Highly energy efficient, allowing it to easily meet LEED Platinum requirements.
- Because of their high efficiency even at half load situations, chillers become a good option with correct system design and installation of many chillers, especially in cases of significant diversity.

6.3.2 Demerits:

- Availability of water is a must.
- Requires additional space for plant room for chillers, AHU rooms and space for mounting the cooling towers.
- Trained manpower is required for operating the central chiller plant.

6.3.3 Our Selection:

Chiller package: water cooled flooded screw chiller Capacity: 240 TR
Compressor: 2 Semi Hermetic Screw Pumps: 7.35 HP and 6.9 HP

The System will consist of AHUs which will supply the air through ductwork in some areas Fan Coil Units (FCUs) are used

Table 05. AHU Summary

Ground Floor				First Floor			
AHU	Tonnage	Kw	Cfm	AHU	Tonnage	Kw	Cfm
1	8.5	1.8	2400	1	19.5	4.95	5570
2	9	0.73	1710	2	5.6	0.73	1000

3	21.7	2.32	5060	3	4	0.63	820
4	6.5	1.14	1350	4	6	0.9	1275
5	7	1.14	1100	5	7	1.45	1900
6	22	3	4300	6	11	1.45	2000
7	30	3	3650	7	9.4	1.86	2650
				8	13.1	3	3700
				9	23	2.87	4300
Total	104.7	13.13	19570	Total	98.6	17.84	23215

Filtration: -

We are using HEPA filters in critical areas and MERV 13 filters in all areas as per ISHRAE and NABH guidelines. Additionally, we will be using UV lamp in each AHU to provide additional infection control.

Duct Design: -

Rectangular Aluminium Duct is selected and sizing is done using software. Square and Rectangular Diffusers are used to provide airflow. Laminar Diffusers are used in OTs. Other components included in the ductwork are fire and smoke dampers as well as air terminals.

VII. ENERGY ESTIMATION AND CONSUMPTION COST

Table 07: Energy Consumption Cost

Sr. No.	System	KW.hr	KW.hr (monthly)	KW.hr(yearly)	Cost Estimation yearly (in ₹)
1	VRF	680.94	490276.8	5965034.4	59650344
2	Chiller	220.5	158760	1931580	19315800

As per yearly usage of the equipment's, the running cost of Chiller system is much less then VRF system. Installation Cost of VRF system is more than the installation cost of Chiller system. Chiller system has much higher efficiency as compared to VRF system. Hence, we recommend Chiller system as a better option for Air Conditioning usage for this project.

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CONCLUSION

We conclude that, Chiller systems give advantages to certain facility. The initial equipment price for a chiller system is lower than VRF, with high COPs, making them the most cost-effective option for larger facilities. Chillers are the best choice for dependable operation and lower energy costs in areas where electricity supply is unreliable and expensive, or where there is a readily available source of chilled water for cool-water systems.

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