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Design and Analysis of Air Conditioning System for An IT Office Building

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Abstract : *The research is about the design and analysis of air conditioning system for comfort application in an I.T. Office Building located in Mumbai. The different types of air conditioning systems have been studied initially. The problem statement is provided by ISHRAE, that is; floor plans of the building. This is a new project, and so building envelope design is also left to the researchers. Air conditioning or HVAC systems are a major source of energy consumption in the building. So, it is necessary to design the right system of air conditioning and install energy efficient equipment. Initially the building envelope has been researched and selected, then cooling load calculations have been done. Based on the cooling demand a suitable air conditioning system is being researched, after which the equipment selection is done. Energy calculations and life cycle cost analysis has been done for the systems, and a suitable system has been selected for energy efficiency. Based on the research and analysis, VRF system is recommended for air conditioning of this IT office building.*

Keywords*–* *Air Conditioning, Cooling Load, Energy Efficiency, Thermal Comfort, VRF.*

I. INTRODUCTION

Air conditioning is the process of cooling and dehumidifying indoor air to meet the requirements of thermal comfort or other purposes like process cooling in industries or factories. Air conditioning is used in many sectors like commercial properties, ranging from small shops and cafes to large office building and even. To meet this pool of varying applications, air conditioning system have different heating and cooling capacities and come with various setups and layouts.

It is observed that air conditioning systems contribute up to 60% of the total energy demand in buildings. Therefore, energy efficiency is a very important factor when designing air conditioning systems and selecting air conditioning equipment for a building. For selecting air conditioning equipment, it is mandatory to comply to building codes of that region. In India, the National Building Code of India (NBC), is to be followed. There is also the Energy Conservation Building Code (ECBC), by Bureau of Energy Efficiency (BEE), which is applicable to buildings having a connected load of 100 kW or greater load. BEE rates equipment based on their energy consumption. Equipment rated 3 star and above are a good choice for air conditioning equipment. Other standards include ASHRAE 90.1 for energy efficiency is applicable to commercial and high-rise residential buildings. ASHRAE 90.1 is recognized globally for its energy efficiency ratings for HVAC systems.

II. PROBLEM DEFINITION

2.1 Problem Statement

Design air conditioning system for an IT Office building. The IT Office has a capacity of approximately 500 occupants. It comprises of 15 Off-shore Development Centres (ODCs), 1 Training room, 1 Conference room, 8 Meeting rooms, 1 General Manager room, 1 Admin Manager room, 1 Server room, 4 Breakout Rooms and 1 First Aid room. The building is located in Mumbai, India and working hours are from 9 A.M. to 9 P.M.

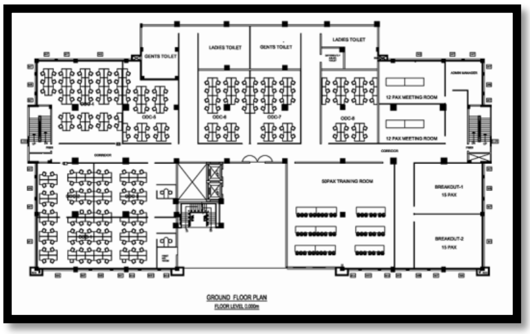

Figure 1: Ground floor plan

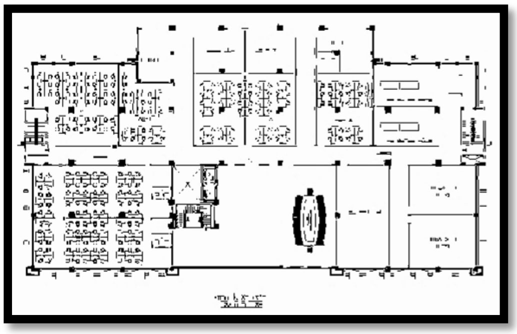

Figure 2: First floor plan

2.2 Objectives

1. Design complete air conditioning system with subsystems ensuring thermal comfort for the occupants.
2. Ensuring good indoor air quality, to prevent suffocation.
3. Design energy efficient air conditioning system.
4. Analysis of proposed system.
5. Providing recommendations for overall energy efficiency.

III. METHODOLOGY

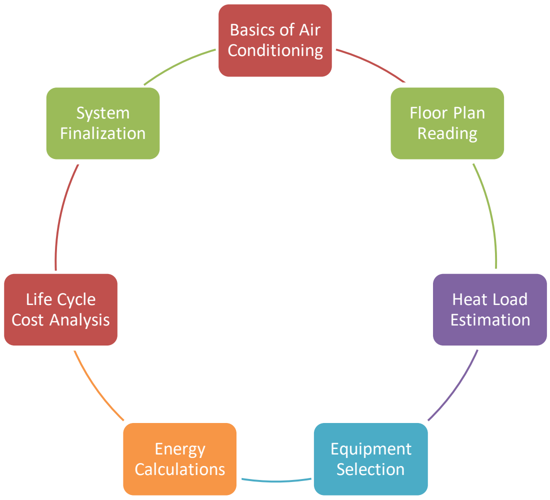

Figure 3: Research Methodology

3.1 Floor Plan Reading

This is the fundamental step to start working on the problem statement. There are various spaces, it is necessary to understand which are the different spaces as per which the building is to be divided into zones. The orientation of the building is specified in the floor plans along with the locations of the windows. The researchers first went through the floor plans are and dimensioned the drawing for openings, walls, partitions which are required in further steps like heat load estimation.

3.2 Heat load Estimation

Heat load estimation is the process used to calculate the amount of heat that needs to be either added or removed from a space to ensure comfort conditions for occupants, and to maintain the required conditions of other spaces like cold storages or server rooms. There are various factors which need to be considered for heating or cooling load estimation.

The major parameters required for heatload estimation are :-

1. Location.
2. Architectural plan.
3. Building material details.
4. Building use case and operational hours.

The researchers have gone through case studies, ECBC and have selected the following materials for building envelope, following compliance of ECBC mandatory requirements:

1) The exposed walls are made up of 150 mm AAC Block with 50 mm Extruded Polystyrene (XPS) insulation, having 20 mm cement plaster outside and 10 mm cement plaster inside, calculated U value is 0.4 W/m^2K or 0.07 Btu/hr ft^2 °F.
2) Internal walls of 200 mm thickness are made up of AAC Blocks with 10 mm of cement plaster on both sides. Calculated U value is 0.8 W/m^2K or 0.14 Btu/hr ft^2 °F.
3) Internal walls of 100 mm thickness are made up of AAC Blocks with 10 mm of cement plaster on both sides. Calculated U value is 1.3 W/m^2K or 0.23 Btu/hr ft^2 °F.
4) Windows selected are Double Glazed Openable units having low emittance e = 0.2 coat, having air space of 13 mm between the 6 mm thick glasses. The windows are light green tinted, having thermally insulated fiberglass frame. The properties are SHGC: 0.34, VLT: 0.49, U Factor: 2.07 W/m^2K or 0.364 Btu/hr ft^2 °F.
5) Roof is made up of 150 mm RCC with sandwich insulation panel of 90 mm thick extruded polystyrene insulation and 5 mm FRP sheets on both sides. The U value is 0.3 W/m^2K or 0.05 Btu/hr ft^2 °F.

The proposed conditions for thermal comfort are 50% Rh and room temperature of 75 °F or 23.88 °C. The building is located in Mumbai which does not require heating. Hence, the cooling load calculation has been done and it is found that the peak cooling requirement of the building is 160.48 Tonnes of Refrigeration or 556.35 kW. A cooling load calculation sheet has been attached in Table 3.1 which shows the various loads in ODC 1 zone of the building.

3.4 Equipment Selection

Once the cooling load is determined the next step is to select the equipment for providing the cooling.
There are various systems available for HVAC which are from small window type packaged air conditioners to big central chilled water system. For the IT building, the researchers have selected to go for a comparative study between multi-split air conditioning system and the VRF or Variable Refrigerant Flow system.
The multi-split system is similar to split air conditioners with the only difference that one outdoor unit can be connected to 3 or more indoor units. This ensures reduced number of outdoor units as compared to split systems and better diversity in terms of loads, thereby saving energy.
The VRF system is latest technology in air conditioning brought into the market by Daikin with its patented technology VRV. As the name suggests Variable Refrigerant Flow, in this system the compressor works on inverter technology, it can vary the speed of the compressor as per the requirement of the load in the zone, thus by varying the speed what it actually does is; vary the amount of refrigerant that is supplied to each evaporator coil. Due to this capability, it has tremendous energy saving potential when compared to constant air flow systems which cannot vary the amount of refrigerant supplied to the evaporator coil. It is similar to multi-split systems, having one outdoor unit and multiple indoor units. One outdoor unit can be of various sizes ranging 10 HP to 50 HP (varies as per manufacturer), up to 50 indoor units can be connected to a single outdoor unit. Also, indoor units connected can be of different types, like Hi-wall units, cassette units, ductable units.
The equipment selection has been done through manufacturer's catalogue as per cooling load and required airflow rate in each zone of the building.
Precision air conditioners or PAC units are installed in server rooms which have typically high sensible loads and less of latent load and no occupancy. These units are operational 24 by 7 for all days in a year. The units selected for this project are 2 units of 53.3 kW and 1 unit of 30 kW cooling capacity. A redundant unit of 53.3 kW is also selected to ensure continuous operation of the server room.

3.5 Energy Calculations

HVAC equipment consume huge amounts of electricity to provide cooling to the building, hence it is important to calculate the energy demand of equipment. A simple method to do so is by multiplying the wattage of the equipment to the number of operational hours multiplied to the number of days; which is usually taken as 300 days, unless specified like in case of server rooms which are operational continuously throughout the year. The power consumption of the equipment is stated in manufacturers' catalogue. Actual values may vary from rated value as per usage.

Outdoor Unit				UHXM55MA1
Compressor	Type			Twin Rotary
Capacity *	Cooling	Min/Norm/Max	kW	1.35/5.27/6.33
	Heating	Min/Norm/Max	kW	1.41/6.33/7.27
Power Input *	Cooling	Min/Norm/Max	kW	0.14/1.29/2.08
	Heating	Min/Norm/Max	kW	0.18/1.53/2.64
Running Current	Cooling	Min/Norm/Max	A	0.6/6.0/9.0
	Heating	Min/Norm/Max	A	0.8/7.0/11.5
EER				4.57
COP				4.15

Fig 4: Power consumed by a multi-split outdoor unit

Table 1: Heatload calculation sheet for ODC 1 space

Job Name :	NSDC 2020 as per May 21 at 4pm				
Floor :	Ground				
Space :	ODC 1 with 2 person meeting room				
SENSIBLE HEAT					
	SOLAR GAIN GLASS				HEAT GAIN
	Item	Area	Sun Gain	SHGC	Btu/hr
		(Sq ft)	(Btu/hr.sq ft)		
	N-Glass				0
	NE-Glass				0
	E-Glass				0
	SE-Glass				0
	S-Glass	182.04	12	0.34	742.72
	SW-Glass				0
	W-Glass	113.01	163	0.34	6263.01
	NW-Glass				0
	Skylight				0
	SOLAR & TRANS. GAI WALLS & ROOF				
	Item	Area	Eq. Temp. Diff.	U Value	
		(Sq ft)	(°F)	Btu/hr sq ft °F)	
	N-Wall				0
	NE-Wall				0
	E-Wall				0
	SE-Wall				0
	S-Wall	623.11	32.6	0.07	1421.94
	SW-Wall				0
	W-Wall	246.15	44.42	0.07	765.38
	NW-Wall				0
Outdoor Infiltration	Room Sun				0
	Roof Shaded				0
	TRANS. GAIN EXCEPT WALLS & ROOF				
	Item	Area	Eq. Temp. Diff.	U Value	
		(Sq ft)	(°F)	Btu/hr sq ft °F)	
	All Glasses	295.05	18.6	0.364	1997.61
	Partition Wall	199.56	13.6	0.07	189.98
	Ceiling				0
	Floor				0
	INTERNAL HEAT GAIN				
	People	52	Nos ×	245	12740.00
	Light (W/sq ft)	0.88	area	1756.87	5256.56
	Equipment.	50 desktops w	W	3909	13290.60
	ROOM SENSIBLE HEAT				
	Supply Duct heat gain +	Supply Duct leak loss +		7.50%	3200.08
	Heat Gain From fan HP (%)			5.00%	2133.39
	OUTSIDE & INFILTRATION AIR				
	CFM	Δ°F	BF	FACTOR	
	548	18.6	0.1	1.08	1101.06
	EFFECTIVE ROOM SENSIBLE HEAT (ERSH)				49102.33
LATENT HEAT					
	People	52	Nos ×	205	10660
	OUTSIDE & INFILTRATION AIR				
	CFM	Δ Grains	BF	FACTOR	
	548	80.6	0.1	0.68	3003.48
Outdoor Infiltration	ROOM LATENT HEAT				
	Supply Duct leakage loss +		afety Factor (%	7.50%	1024.76
	EFFECTIVE ROOM LATENT HEAT (ERLH)				14688.24
	EFFECTIVE ROOM TOTAL HEAT (ERTH)				63790.57
OUTDOOR HEAT					
	CFM	Δ°F / Grains	CF=1-BF	FACTOR	
SENSIBLE	548	18.6	0.9	1.08	9907.40
LATENT	548	80.6	0.9	0.68	27031.31
HEAT SUB TOTAL					
	Return Duct Heat Gain & Leak Loss +	HP Pump +	5.00%		5036.46
GRAND TOTAL HEAT					105765.74 Btu/hr

Area	ft²	1756.87		
Volume	ft³	22470.37		
Height	ft	12.79		
Condition	DB (°F)	WB (°F)	% RH	GR / LB
Outside	93.6	81.7	60.64	145
Room	75		50	64.4
Difference	18.6			80.6
OUTSIDE AIR (VENTILATION)				
Fresh Air	(cfm/person × No. of persons) + (0.06 × Area sq			
Fresh Air	5	52	105.41	365.41
Fresh Air				Benchmark CFM
EFFECTIVE SENSIBLE HEAT FACTOR (ESHF)				
Indicated ADP		59	°F	
Selected ADP		59	°F	
Effective Room Sensible Heat Factor				
ESHF				0.77
Dehumidified Rise				
Dehumidified Rise				14.40
Dehumidified Air Flow				
Dehumidified Air Flow (CFM)				3157.30
Tonnage				
TR				8.81
Correction for exposed surface : 6.6				
Coil Bypass Factor : 0.1				
Due to Fresh Air				

3.6 Lifecycle Cost Analysis

LCCA is a process of evaluating the economic performance of the building or major components like HVAC system of the building over its entire lifecycle. LCCA helps to determine the amount that will be spent over the complete lifecycle of the building from cradle to grave. It takes into consideration the initial capital or capex, installation costs, operational costs or opex, regular maintenance costs, and disposal cost. Generally, HVAC systems LCCA is done for a period of at least 10 – 15 years. The initial costs of proposed systems are shown below.

Table 2: Initial Costs of Systems

System	Sr No	Model No	Cost per unit	No of Units	Incurred Cost
Multi-split System	Indoor Units	MS07AH2	₹ 25,900.00	3	₹ 77,700.00
		MS12AH2	₹ 31,160.00	5	₹ 1,55,800.00
		MS18AH2	₹ 34,000.00	75	₹ 25,50,000.00
		MS24AH2	₹ 40,650.00	7	₹ 2,84,550.00
	Outdoor Units	UHXM55MA1	₹ 1,22,000.00	12	₹ 14,64,000.00
		UHXM70MA1	₹ 1,47,555.00	2	₹ 2,95,110.00
		UHXM90MA1	₹ 1,64,700.00	2	₹ 3,29,400.00
		UHXM110MA1	₹ 2,01,700.00	37	₹ 74,62,900.00
Total Cost					**₹ 1,26,19,460.00**
VRF System	Indoor Units	AUXA30GALH	₹ 1,21,100.00	2	₹ 2,42,200.00
		AUXA36GALH	₹ 1,41,250.00	2	₹ 2,82,500.00
		AUXB07GALH	₹ 94,850.00	1	₹ 94,850.00
		AUXB12GALH	₹ 99,850.00	1	₹ 99,850.00
		AUXD18GALH	₹ 1,04,000.00	34	₹ 35,36,000.00
		AUXD24GALH	₹ 1,12,900.00	20	₹ 22,58,000.00
		AUXK030GLAH	₹ 1,36,150.00	3	₹ 4,08,450.00
		AUXM018GLAH	₹ 1,03,900.00	12	₹ 12,46,800.00
	Outdoor Units	AJH378LA*BHH	₹ 32,42,250.00	3	₹ 97,26,750.00
		AJH288LA*BHH	₹ 25,35,200.00	1	₹ 25,35,200.00
Total Cost					**₹ 2,05,25,350.00**
Precision Air Conditioning Units	Self-Contained Units	SV18D049-X100-0/1	₹ 4,95,900.00	3	₹ 14,87,700.00
		SV12D026-X100-0/1	₹ 4,27,350.00	1	₹ 4,27,350.00
Total Cost					**₹ 19,150,50.00**

3.7 System Finalization

In this process, a suitable system is selected for the conditioning of the building. Considering the capital costs, installation cost, maintenance cost and operating costs (energy consumption). The chosen system in VRF system which has a total of 79 units as over multisplit system where the total number of units would be 143, which would significantly increase the installation cost. Also, it is known that air conditioning equipment don't always run at design capacity, therefore load diversity plays a major role when deciding air conditioning equipment. It has been observed time and again, that the part load efficiency of VRF system is higher compared to split and multisplit air conditioning systems.

IV. CONCLUSION

The system selected for air conditioning of the IT office building in Mumbai is Variable Refrigerant Flow (VRF) system comprising of three outdoor units of 42 HP model AJH378LA*BHH, one unit of 32 HP model AJH288LA*BHH, and various indoor units. The cooling capacity of outdoor unit is a total of 449.4 kW, while the maximum cooling capacity of indoor units is 473.2 kW. In the server room precision air conditioning units are installed as follows; three units of SV18D049-X100-0/1 and one unit of SV12D026-X100-0/1, of which one unit is on standby in case of failure of any other unit. Thus, the total conditioned area is 32492.64 ft^2 and designed cooling capacity is 586 kW or 166.67 TR. The VRF system offers excellent energy savings due to inverter technology and its capability to the modulate the fan speed as per the cooling demand, thus performing better than other systems. The control system and sensors play a major role in this and need to be designed and installed properly.

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