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Comparative Analysis of Energy Consumption and Cost of Different Air Conditioning Systems for Commercial Building

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Abstract: The quick ascent in temperature because of an Earth-wide temperature boost and environmental change has raised worries over the ecological effects. These impacts can have significant consequences for the indoor condition. Climate changes will influence different aspects of the indoor condition and in addition the partners of that indoor condition. Buildings will require less heating in the winter and additional cooling in the summer, bringing about an increased utilization of Ventilation and cooling system. In the present situation significance of Air Conditioning and Ventilation systems plays a significant part in giving comfort conditions to the inhabitants of building. With developing threats of global warming and green house gas emissions, the need for equipment selection is very much important which impacts energy consumption, the initial cost of installation, and there by recurring operating and maintenance costs. The main objective of the present project is to evaluate energy consumption of HVAC System for a large commercial building with two major air conditioning methods which are Chiller air conditioning system and variable refrigerant flow air conditioning system. The task of design of a building is conducted by estimating the cooling load requirement, selection of equipment based on the use of areas inside building, to evaluate the energy consumption of HVAC equipments and net energy savings.

I. INTRODUCTION

Air conditioning system configuration is a sub train of mechanical designing, in light of the standards of thermodynamics, liquid mechanics, and heat exchange. Heating, Ventilating and Air Conditioning, (HVAC) is a tremendous field. Central air systems incorporate a range from the simple system to complex systems, utilized for comfort cooling and heating, to a great degree solid aggregate ventilating and cooling systems found in submarines and air transports. Cooling differs from the little local unit to refrigeration machines that are 10,000 times the size, which are utilized as a part of modern procedures. Contingent upon the multiphase nature of the necessities, the HVAC designer must consider numerous of issues than just keeping temperatures agreeable. The expression "ventilating and cooling" has bit by bit changed from significance simply cooling to the aggregate control of Temperature, Moisture noticeable all around (stickiness), Supply of outside air for ventilation, Filtration of airborne particles, Air development in the involved space. These are principal ideas that are utilized by originators to settle on choices about system outline, activity, and upkeep. Central air (meaning for Heating, Ventilation and Air Conditioning) makes an atmosphere that takes into consideration greatest solace by adjusting for evolving conditions. The reason for HVAC configuration is to keep up both high indoor air quality and comfort conditions for occupant to work. These double contemplations require incorporated outline effectiveness or configuration approach. (Central air) hardware needs a control system to direct the activity of a heating and cooling system with large coverage area and energy saving.The three elements of heating, ventilation, and cooling are interrelated, particularly with the need to give warm solace and adequate indoor air quality inside sensible establishment, activity, and upkeep costs. Central air systems can give ventilation, decrease air infiltration, and keep up weight connections between spaces. Central air is a vital piece of private structures, for example, structures, lodgings and living offices, medium to extensive modern and places of business, for example, high rise building, locally available vessels, and in marine situations, where protected and sound conditions are managed as for

A. Maintaining indoor air quality (expulsion of waste vapor)
B. maintaining inside room temperature (acquires cool air and exhaust hot air)
C. Remove humidity (get drier air and fumes wet air)
D. Change the air continuously (higher velocity gives cooling)

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The development of the segments of HVAC systems ran as an inseparable unit with the mechanical and new strategies for modernization, higher proficiency, and system control are always being presented by organizations and innovators around the world.

II. OBJECTIVES OF THE PROJECT

A. Selection of reasonable HVAC system for the proposed multi story building.
B. Cooling Load calculations utilizing E20 Excel sheet
C. Detailed Design of HVAC system, for example, Ducting and piping.
D. Evaluate the Energy utilization of HVAC systems for different HVAC systems
E. To make bill of materials and assess cost of the systems.
F. To show the performance of different air conditioning systems.

III. PROJECT METHODOLOGY

A. Conducting a study and exploring the related contextual investigations, distributed universal papers, related to ASHRAE.
B. Selection of HVAC system in view of the measure of the building and Energy productivity.
C. Equipment determination according to ASHRAE measures.
D. HVAC system configuration utilizing HAP, diverse ideas and ASHRAE, SMACNA measures for finish plan of the HVAC system according to codes.
E. To evaluate energy consumed and cost determination of both Chiller system and VRF system.

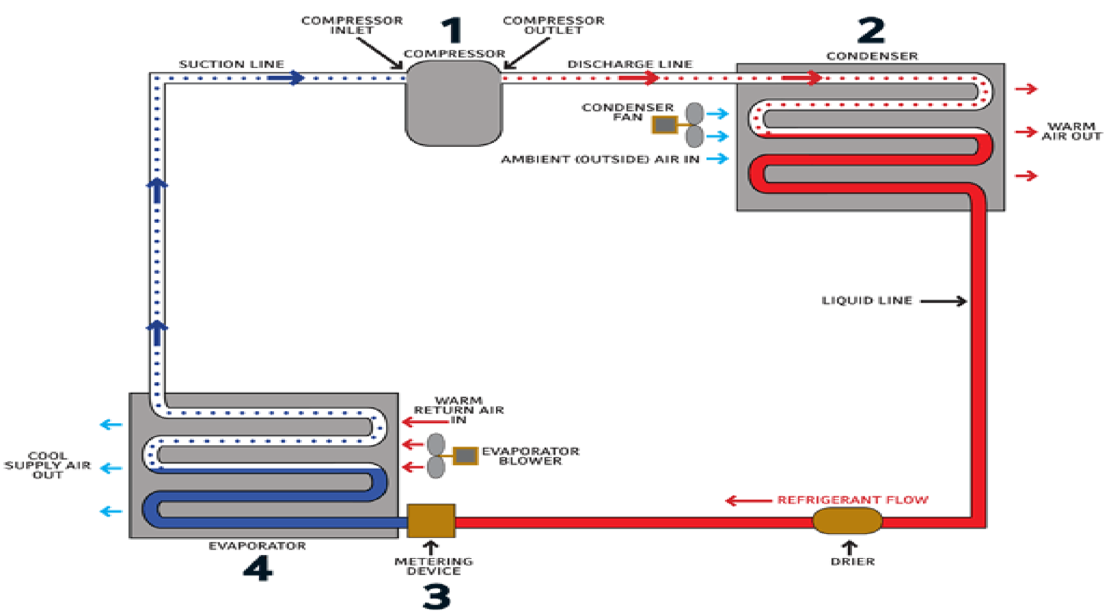

Figure -1 Schematic Diagram Of How An Air Conditioning System Work

IV. TYPES OF HVAC SYSTEMS

A. Different Types Of Hvac Systems
1) Window Air conditioners
2) Split Air Conditioners (through the wall air conditioners)
3) Unitary / Packaged air conditioners
4) VRF / VRV Air conditioners
5) Chiller Central Air-conditioning system (Air / Water Cooled)

When we discuss the HVAC system, first we have to know the most widely recognized term used to characterize the limit of the HVAC system i.e. TR. Since heating and cooling systems accessible in the market are characterized regarding TR. In this project we are going to compare two famous air condition methods case-1 Variable refrigerant flow system and case-2 Chilled water air conditioning system.

B. Vrf / Vrv Air Conditioners

VRFs are typically installed with an Air conditioner inverter which adds a DC inverter to the compressor in order to support variable motor speed and thus variable refrigerant flow rather than simply perform on/off operation. By operating at varying speeds, VRF units work only at the needed rate allowing for substantial energy savings at load conditions. VRFs come in two system formats, two pipe and three pipe systems. In a heat pump two pipe system all of the zones must either be all in cooling or all in heating. Heat Recovery (HR) systems have the ability to simultaneously heat certain zones while cooling others; this is usually done through a three pipe design, with the exception of Mitsubishi and Carrier, whose systems are able to do this with a two pipe system using a branch circuit (BC) controller to the individual indoor evaporator zones.

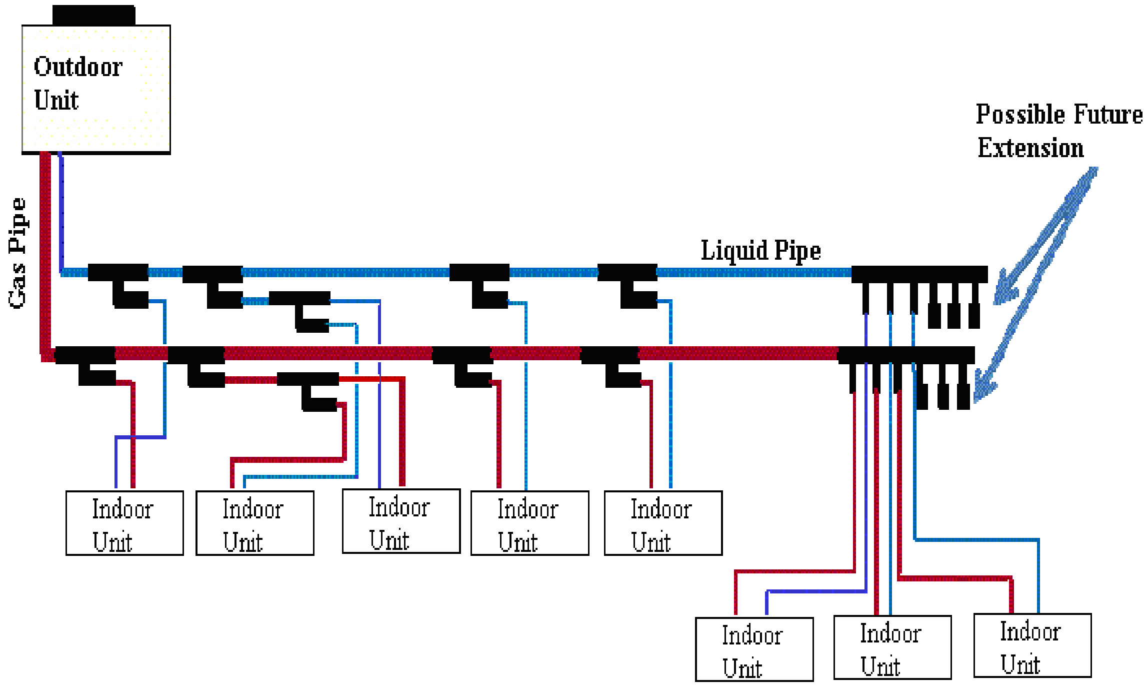

Figure-2 A Typical VRF/VRV Air Conditioner System

1) Advantages of VRF/VRV Air Conditioners:
a) VRF systems are suited to any building where there are countless rooms to be aerated and cooled.
b) Variable refrigerant stream (VRF) system has capacity to react to variances in space stack conditions
2) Disadvantages of VRF/VRV Air Conditioners:
a) The cooling limit accessible to an indoor unit area is diminished at bring down open air temperatures. This constrains the utilization of the system in chilly atmospheres to serve rooms that requires year around cooling, for example, Telecom rooms.
b) The outer static weight accessible for ducted indoor areas is restricted. For ducted indoor areas the permissible ventilation work lengths and fittings must be kept to a base. Ducted indoor areas ought to be set close to the zones they serve

C. Central Air-Conditioning System

Central Air conditioners can be both of immediate or roundabout compose. In the immediate system, the air from the space to be ventilated is circled over the coil (of refrigerant plant) in which the low weight refrigerant is running. The inactive heat of vaporization for the fluid refrigerant is taken from the air being flowed over the coil. So this is known as immediate extension system. HVAC chillers- A chiller is a machine that expels heat from a fluid through a vapor-pressure or refrigeration cycle. These machines can actualize an assortment of refrigerants. chillers use water as the refrigerant. The parts of water cooled chillers and air cooled chillers are fundamentally the same as. Every item contains an evaporator, condenser, Compressor, and an expansion valve. The essential contrast is whether air or water is utilized to give the condenser cooling. The characterization depends on the sort of cooling strategy utilized for condenser cooling.

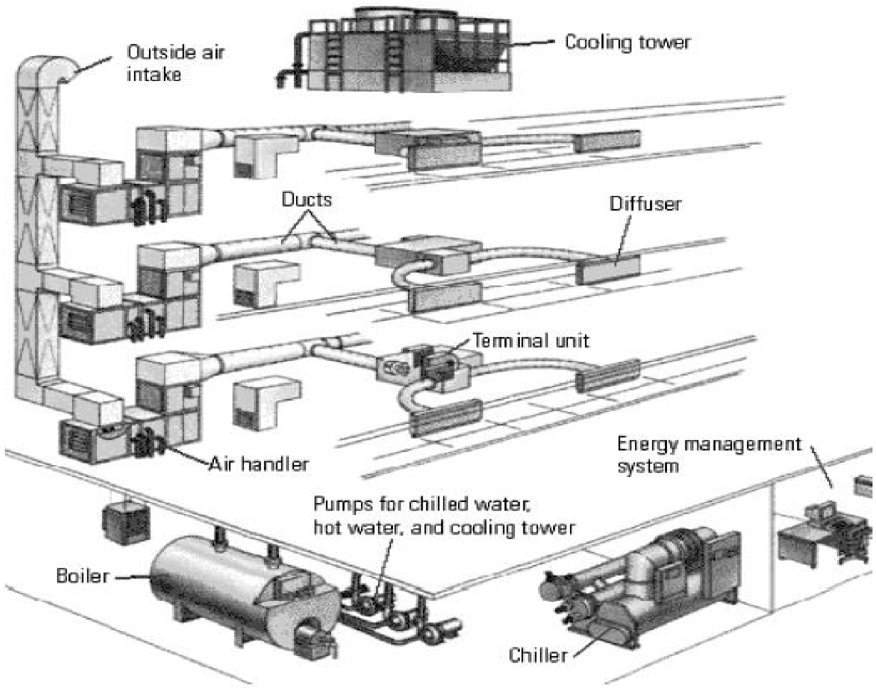

Figure-3 A Typical Central Chilled Water Air Conditioning System

V. HVAC SYSTEM DESIGN

A. Description of Building

The building considered in this Project is a Five story building located in Vijayawada, Andhra Pradesh in the south of India. The floor area of the building is 13,000 sq ft and its floor to floor height is 15 ft. with total floor area of above 65,000 sq ft. Each Floor has specific use. The walls of the building consist mainly of brick and plaster without any insulation. The roof consists of 125mm concrete block and without insulation. The windows are dotted plane with a shading coefficient of 1.0 is considered. The HVAC systems used in the building is VRF system one for each zones on each floor.

Table-1 Description Of Proposed Building

Characteristics	Description of the Base Case
Location	Vijayawada, Andhra Pradesh
Orientation	Front Elevation facing East
Plan Shape	Rectangle
Number of floors	B+G+4
Floor to Floor Height	12 FT
Floor Area	5300 sqft
Type of Glass	Plane dotted glass 4mm
Solar Absorbance (for Exterior Surfaces)	0.6
Exterior Walls	9” thick Brick walls
Roof	6” mm Concrete slab
Floors	5
Lighting Power Density	Working Area 1.5 w/sft
Infiltration	0.5 ACH
System Type	VRF System or Chilled water system
Thermostat Setting	75 degree F
Weather File	ISHRAE Vijaawada

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VI. COOLING LOADS CALCULATIONS

Cooling Loads Classified by Source Cooling loads fall into the accompanying classifications, in view of their sources:

A. Heat exchange (increase) through the building skin by conduction, because of the outside indoor temperature difference.
B. Solar heat gain (radiation) through glass or other straightforward materials.
C. Heat gain from ventilation air as well as penetration of outside air.
D. Internal heat picks up produced by inhabitants, lights, apparatuses, and hardware.
1) *Heat Load Calculations:* The space cooling load is the rate at which heat should be expelled from the space to keep up a steady air temperature. To figure a space cooling load, gritty outline parameters are required.

The plan premise regularly incorporates data on

a) Geographical site conditions (scope, longitude, wind speed, precipitation and so on.)
b) Outdoor plan conditions (temperature, mugginess and so forth)
c) Indoor plan conditions
d) Building attributes (materials, size, and shape)
e) Configuration (area, introduction and shading)
f) Operating timetables (lighting, inhabitance, and equipments)
g) Additional contemplations (sort of ventilating and cooling system, fan energy, fan area, conduit heat loss and pick up, sort and position of air return system…)

VII. RESULTS

The total heat load for the whole project was calculated and it was found to be 204 TR with the help of E-20 sheet, cooling loads are calculated using E20 sheets. Sample sheet is as shown:

Table -1 LOAD CALCULATIONS

Job Name	COMMERCIAL BUILDING					
Address	VIJAYWADA					
Estimated By	SABER					
Date	7/27/2018					
Item	Area or Quantity		Sun Gain or Temp. Diff.		Factor	Btu/Hour
ROOM SENSIBLE HEAT						
Solar Gain - Glass						
Glass - N	0	SqFt x	23	F x	0.56	0
Glass - NE	0	SqFt x	12	F x	0.56	0
Glass - E	0	SqFt x	12	F x	0.56	0
Glass - SE	0	SqFt x	12	F x	0.56	0
Glass - S	0	SqFt x	12	F x	0.56	0
Glass - SW	150	SqFt x	85	F x	0.56	7140
Glass - W	0	SqFt x	163	F x	0.56	0
Glass - NW	195	SqFt x	138	F x	0.56	15070
Skylight	0	SqFt x		F x	0.56	0
Solar & Trans. Gain - Walls & Roof						
Wall - N	0	SqFt x	19	F x	0.34	0
Wall - NE	0	SqFt x	25	F x	0.34	0
Wall - E	0	SqFt x	33	F x	0.34	0
Wall - SE	0	SqFt x	33	F x	0.34	0
Wall - S	0	SqFt x	31	F x	0.34	0
Wall - SW	301	SqFt x	29	F x	0.34	2968
Wall - W	0	SqFt x	27	F x	0.34	0
Wall - NW	391	SqFt x	21	F x	0.34	2792
Roof	0	SqFt x	50	F x	0.56	0
Trans. Gain - Except Walls & Roof						
All Glass	0	SqFt x	30	F x	1.13	0
Partition	1160	SqFt x	25	F x	0.3	8700
Ceiling	2402	SqFt x	25	F x	0.4	24020
Floor	0	SqFt x	25	F x	0.5	0
Outside Air						
Ventillation	932	Cfm x	30	F x	0.16	4530
Internal Heat						
People	19	Nos. x		245		4655
Light	2330	SqFt x	1.5	W/SqFt x	3.41	11918
Equipment	1	kW x		3410		1705
Effective Room Sensible Heat Sub Total						83497
Factor					10.0%	8350
EFFECTIVE ROOM SENSIBLE HEAT						91846
ROOM LATENT HEAT						
Ventillation	932	Cfm x	33	Gr/Lb x	0.102	3137
People	19	Nos. x		205		3895
Effective Room Latent Heat Sub Total						7032
Factor					5.0%	352
EFFECTIVE ROOM LATENT HEAT						7384
EFFECTIVE ROOM TOTAL HEAT						99230
OUTSIDE AIR HEAT						
Sensible	932	Cfm x	30	F x	0.92	0
Latent	932	Cfm x	33	Gr/Lb x	0.58	0
Grand Total Heat Sub Total						99230
Factor					5.0%	4962
GRAND TOTAL HEAT						104192

Space Used For	WAITING LOUNGE			
Area (SqFt)	2330			
Height (Ft)	12			
Volume (CuFt)	27960			
Estimate For				
CONDITION	DB (F)	WB (F)	RH (%)	Gr/Lb
Outside	104	78	28	100
Room	74	60	50	67
Difference	30	XXX	XXX	33
Daily Range (F)			=	20
Correction for Temp. Diff. (F)			=	27
By Pass Factor (BF)			=	0.15
Contact Factor (CF = 1 - BF)			=	0.85
Occupancy (Nos)			=	19
Lighting Load (W/SqFt)			=	1.5
Equipment Load (kW)			=	0.5
OUTSIDE AIR				
Cfm Per Person :	19	10	=	190
Air Change Per Hour :		2.0	=	932
Ventillation (Cfm)			=	932
EFF. ROOM SENS. HEAT FACTOR				
Eff. Room Sens. Heat	91846		=	0.93
Eff. Room Total Heat	99230			
APPARATUS DEW POINT (ADP)				
Indicated ADP (F)			=	51.0
Selected ADP (F)			=	54.0
DEHUMIDIFIED RISE				
(Room Temp. - ADP) x CF		17	=	17
DEHUMIDIFIED Cfm				
Room Sens. Heat	91846		=	5003
Dehum. Rise x 1.08	18			
ACTUAL T R			=	8.7
DEHUMIDIFIED CFM/SFT			=	2.1
SFT/ TR OF REFRIGN.			=	268.4
RECOMMENDED				
AS 15% SAFETY FACTOR	=	10.2		
AS PER CFM	=	12.5063		
SUGGESTED TR	=	10.2		

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A. HAP Software Energy Simulation Results

Table-2 HAP Chilled Water Plant Simulation Results

Month	Cooling Coil Load (kWh)	Plant Load (kWh)	Chiller Output (kWh)	Chiller Input (kWh)
January	44588	44588	44588	16090
February	58440	58440	58440	22138
March	91377	91377	91377	39211
April	111556	111556	111556	52046
May	134815	134815	134815	66935
June	127103	127103	127103	55717
July	109432	109432	109432	42437
August	99326	99326	99326	37393
September	95090	95090	95090	36580
October	84207	84207	84207	32200
November	59904	59904	59904	22035
December	43405	43405	43405	15576
Total	1059244	1059244	1059244	438359

Table-3 VRF System Simulation Results Ground Floor

Month	Terminal Cooling Coil Load (kWh)	Terminal Cooling Eqpt Load (kWh)	Terminal Unit Clg Input (kWh)
January	17613	17613	3334
February	19486	19486	3987
March	25341	25341	5923
April	27436	27436	7030
May	30704	30704	8449
June	27670	27670	7009
July	24063	24063	5462
August	22410	22410	4930
September	22590	22590	5024
October	23328	23328	5003
November	20723	20723	4111
December	17941	17941	3363
Total	279303	279303	63624

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Table-4 VRF System Simulation Results First Floor

	Terminal Cooling Coil Load (kWh)	Terminal Cooling Eqpt Load (kWh)	Terminal Unit Clg Input (kWh)
January	7486	7486	1857
February	10292	10292	2695
March	17232	17232	5047
April	21679	21679	6802
May	26294	26294	8791
June	25763	25763	7824
July	22376	22376	6068
August	20401	20401	5364
September	18744	18744	5041
October	15559	15559	4130
November	10289	10289	2620
December	7187	7187	1774
Total	203302	203302	58011

Table-5 VRF System Simulation Results second Floor (typical)

Month	Terminal Cooling Coil Load (kWh)	Terminal Cooling Eqpt Load (kWh)	Terminal Unit Clg Input (kWh)
January	14891	14891	3227
February	17653	17653	4076
March	25667	25667	6667
April	30213	30213	8487
May	35368	35368	10604
June	33157	33157	9099
July	29664	29664	7302
August	27588	27588	6590
September	26281	26281	6390
October	23906	23906	5697
November	18063	18063	4071
December	14463	14463	3112
Total	296914	296914	75322

VIII. CONCLUSION

HVAC System design of the commercial building is designed for VRF and Chilled water system to evaluate the energy consumption and cost evaluation. The Energy consumption of the building is evaluated using HAP 4.51 Software. It is found that the Annual net cooling energy consumption of the building for a VRF System is 347,601 kWh, and for a chilled water system is 438,359 kWh.

It is found that the net energy savings of 90,758 kWh, for a VRF system which accounts to 20.70 % of the energy consumed for cooling.

Table-6 Energy consumption of VRF System

Floor	Energy Consumption kWh
Ground Floor	63,624
First Floor	58,011
Second Floor – Typical 3 floors	75,322
Total	347,601

The Net capital investment of chilled water system and VRF system is evaluated. The net capital expenditure of chilled water system is Rs 1, 66,82,500. And for vrf system is Rs
1,20,93,050. The net savings in the capital investment if VRF system is used is rupees 45,89,450 which accounts to 27.51 % capital savings.

REFFERENCE

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[2] Ashrae handbook, 2001 fundamentals applications.
[3] Hvac design manualby james e.brombaugh.
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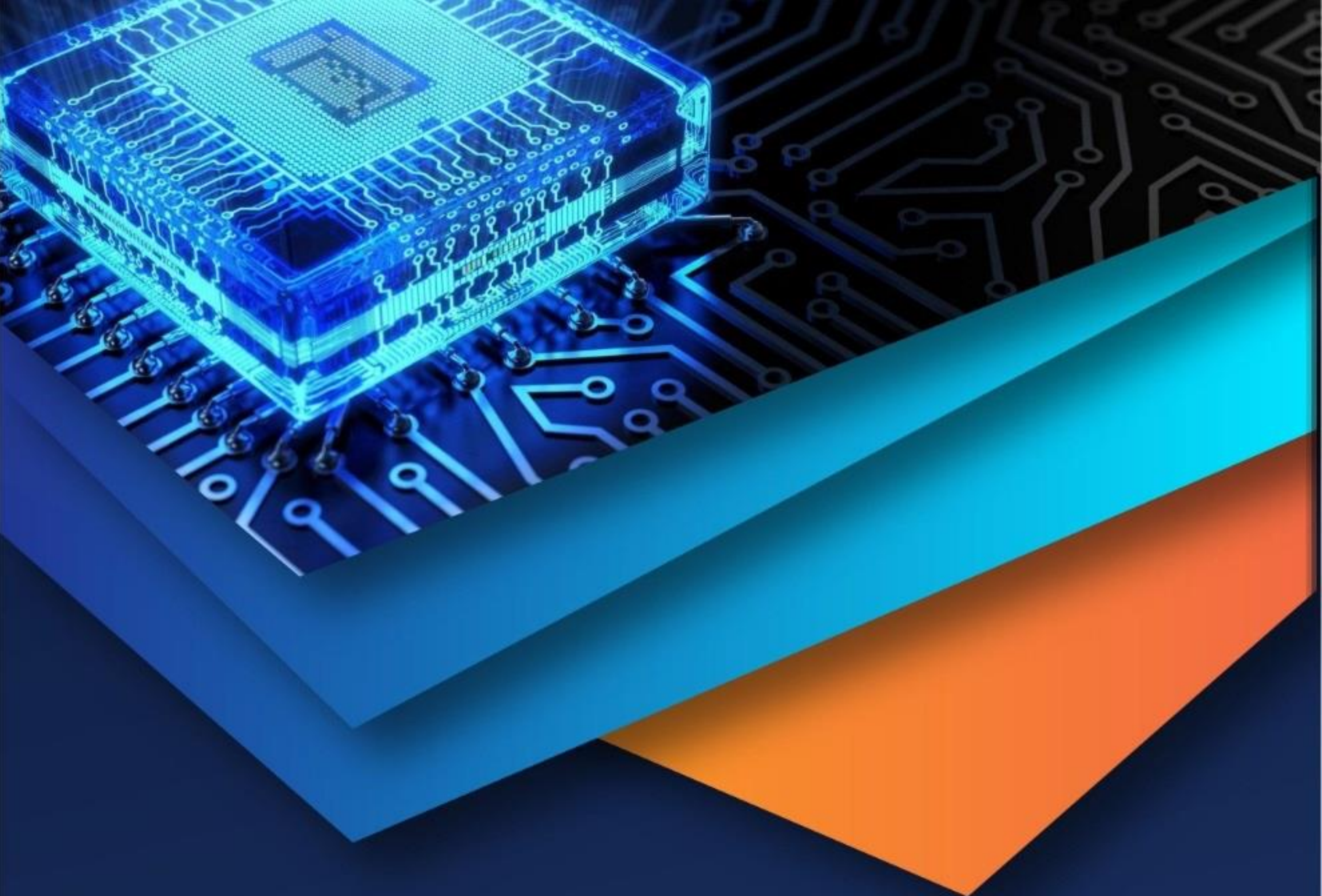

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