iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 **Issue:** V **Month of publication:** May 2023

DOI: https://doi.org/10.22214/ijraset.2023.52032

www.ijraset.com

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue V May 2023- Available at www.ijraset.com

Design of Transmission Tower for a Sub Station of 132 KV

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Abstract: ***In order to properly plan and design a structure, it is necessary to have not only imagination and conceptual thinking, but also a solid understanding of the science of structural engineering, as well as practical knowledge of recent design codes and regulations, all supported by ample experience, intuition, and judgment, with the goal of ensuring safety while maintaining a careful balance between economy and safety. One type of steel structure that has seen significant progress in recent years is the transmission tower, which must be constructed with great care and maintenance in order to ensure the safety and comfort of surrounding beings. While traditional methods of designing and analyzing transmission towers can be time-consuming, software such as "Spadaro V8i" can be used to expedite the process. In this research manual calculation is done by traditional method and after that modelling is done with software.***
Keywords: Transmission tower, ASCR Conductor (aluminum conductor steel reinforced), Earth wire, Lattice Tower.

I. INTRODUCTION

Transmission Tower

Towers are tall structures with a height greater than their width, allowing for various functions to be achieved. They come in many types, including clock towers, castles, bridges, transmission towers, lighthouses, and signal towers. Transmission towers, specifically, are tall structures designed to support overhead power lines, transmitting electricity from generation stations to sub-stations in high voltage AC and DC systems. They come in a wide variety of shapes and sizes, with typical heights ranging from 15 to 55 meters (49 to 189ft), and are also known as power towers, cellular phone towers, or electric towers depending on their purpose. ISA sections, with dimensions according to steel tables, are commonly used to construct transmission towers, with K bracings, X bracings, and KX bracings used to reduce the total weight of the tower. When designing a transmission tower, several considerations must be taken into account, such as the minimum ground clearance of the lowest conductor point, the length of the insulator string, the minimum clearance to be maintained between conductors and the tower, and the location of the ground wire with respect to the outermost conductors. Additionally, transmission lines must be carefully designed to withstand natural disasters and meet requirements from both structural and electrical perspectives, with insulation and safe clearances of power carrying conductors from the ground being of utmost importance. The design of transmission towers is typically based on minimum weight, and they are often modeled as jointed space trusses using steel angle sections of different grade

II. LITERATURE REVIEW

Transmission line towers constitute about 28 to 42 percent of the cost of the transmission line. The transmission towers are constructed for transmitting the electricity from generation station to substations. The function of transmission tower is to support the conductor wires and ground wires at suitable distance and safe height from ground. Therefore, transmission line towers should be designed considering both structural and electrical requirements for a safe and economical design. In this study an attempt is made to model, analyze and design a 220kV double circuit transmission line towers. STAAD Pro program is going to be used for analysis and design of the members of 220kV double circuit tower. The transmission tower has a height of 32m and base width of 8m. [1,2] Transmission towers are essential for the purpose of supplying electricity to various regions of the nation. That's why power stations are increased & provided at different corners where it's needed. Interconnections between systems are also increasing to improve accuracy and economy. If Transmission line is not designed carefully, they can fail due to any natural disaster. That's why it should be stable and carefully designed so that they do not fail during natural disaster. [3,4] The structural planning and design process includes not only creativity and logic, but also a solid understanding of structural engineering science, as well as practical knowledge of modern design codes and bye laws, as well as a wealth of experience, intuition, and judgement. [5,6] e categories: lattice, pole and guyed. The supports of EHV transmission lines are normally steel lattice towers.

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The cost of towers constitutes about quarter to half of the cost of transmission line and hence optimum tower design will bring in substantial savings. The selection of an optimum outline together with right type of bracing system contributes to a large extent in developing an economical design of transmission line tower. The height of tower is fixed by the user and the structural designer has the task of designing the general configuration and member and joint details. [7,8]

III. METHODOLOGY

Methodology consists of collection of data, material used, study of research paper, calculation of various load acting on the tower and design of tower in software. Then analysis of tower in software, result and conclusion.

A. Transmission Tower Configuration

Below specified values are taken with reference to actual site condition and location as per IS 802:1995 (Part1/sec10)**,** IS 875 part 3, IS 800:2007. In this study special importance is given to actual condition of concern area atmosphere, wind velocity, extreme climatic condition.

Table 1 Configuration of transmission tower

Parameters	Values
Reliability level	2
Wind zone	2
Terrain category	2
Wind speed, V_b	44m/s
Design wind pressure, P_d	1.5 KN/m^2
Ground clearance, h_1	7.00m
Maximum sag of the lower most conductor wires, h_2	6.7m
Vertical distance between conductor wires, h_3	4m
Vertical distance between top conductor and ground wire, h_4	3.125m
Base width of the tower, b	5.5m
Length of each cross arms	6 m
Maximum sag of lower most conductor	6.734m
Temperature T1	5 °C
Temperature T2	60°C

B. Properties of Conductor Wire

The capacity of conductor for transferring current over a large distant place is entirely depend upon the strands used in the conductor wire.so, the designer must ensure minimum specified limit as per concern Indian is code.

Table 2 Details of transmission tower conductor wire

Type of conductor	ASCR conductors
Voltage	130 KV
Conductor size	6.54/30mm + 7/30mm
Area of the conductor (for all strands)	475.379mm^2 or 4.7537cm^2
Weight of the conductor(w)	16.70 n/m
Ultimate tensile strength	13316kg or 130.30kN
Coefficient of linear expansion(α)	$19.3X10^{-6}$ per ^oc
Modulus of Elasticity (E)	$0842X10^5$ N/M^2
Diameter of the ASCR wire	30MM

C. Properties of Earth Wire

Earth wire are the part of transmission tower which is place at the top of the tower, which acts as a insulator during the extreme rainfall. Probability of lighting fall on the tower is more, this wire act as earthing during storm.

Table 3 Details of transmission tower earth wire

Type of earth wire	Galvanized steel
Size of the earth wire	7/3.15mm
Configuration	One continuously to run horizontally on the top of the towers and conductors
Overall diameter	10MM
Weight of conductor	6N/M
Ultimate tensile strength	58.4kN or 5955.14 kg
Area of cross- section	545.5mm^2
Coefficient of linear expansion	11.5X10^6/^{o}c
Modulus of elasticity	1.933X10^{6}kgf/cm^2

IV. TOWER GEOMETRY

Dimension of tower is determined as per Indian standard specification. Height of tower is fixed according to seismic zones, Climatic condition, Soil Bearing capacity. Selection of Indian standard angles are chosen from the previous research done. If this angles fails, selection of another greater dimension angle is to be considered. Calculation of maximum sag of conductor wire, Dimension of cross arm, Ground clearance is calculated.

Isolated footing for each four corners of transmission tower is constructed and analysis of such fixed condition is done in software. Soil present and their bearing capacity is tested by the plate bearing test before as per records of the previously constructed tower of double circuit.

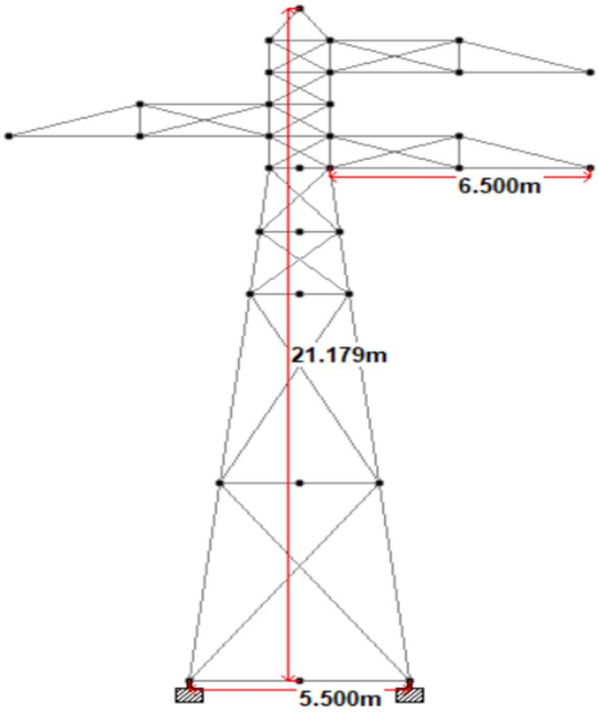


Figure 1. Geometric Dimension of Tower

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue V May 2023- Available at www.ijraset.com

V. WIND LOAD CALCULATION

Mostly in the tower case, the load considered for failure of tower during extreme condition is wind load. Calculation of wind load is one of the major portion of design of transmission tower. Various codes are used for calculating wind intensity.

A. Wind Loads On Conductor Wire

F_{WC} = Pd * Cdc * L * d * GC

Tower Located in wind zone 2

Basic wind speed (Vb) = 44m/sec

As per IS 875:2015(Part 3)

Design wind speed

Vd =K1 X K2 X Vr

K1= Risk factor =1.0 for 130kv

K2=Terrain roughness =0.85(Category 1)

VR= Vb /1.375=44/1.375=32m/sec

Design Wind Speed

$V_d = K_1XK_2XV_R$= 1.00 X 0.85 X 32 =27.2m/sec

Design wind pressure

Pd =0.6 X V_d^2

P_d=0.6 X V_d^2 =0.6^2 X27.2^2 = 443.9 m/sec^2

1) Wind load on tower (As per IS 802:1995 (Part1/sec1))

F_{wt}=P_dX C_{dt} X A_e X G_T

Pd=Design wind pressure

Cdt= Drag coefficient for tower

Ae=Total net sectional area of member(m^2)

Gt= Guss response factor for tower

=433.26 X 3.4 X 4.532 X 1.7

=11365.99 N

2) Wind load on insulator string (As per IS 802:1995 (Part1/sec1))

Fwi =Cdi X Pd X Ai X Gi

Cd1=Drag Coefficient for insulator

Ai= Area of insulator

Gi=Gust response factor for insulator

Fwi =443.9 X 1.2 X 200 X 0.035 X 1.7

= 6338.89 N

3) Wind load on Conductor and ground wire (As per IS 802:1995 (Part1/sec1))

Fwc = Pd X cdc X L X D X Gc

Cdc =Drag Co efficient for Conductor

L=Wind span =200m

d= Dia of cable = 3.5cm

Gc=Gust response factor for tower

Few =443.9 X 1.215 X 3.38 =2775 N

VI. STEEL SECTION USED FOR TOWER

ISA 130mmX130mmX10 mm – Main vertical column

ISA 80mmX80mmX6mm – Horizontal and vertical bracing

ISA 65mmX65mmX6mm – Cross Aram

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VII. MODELING OF TOWER

STAADPRO V8i is a versatile software program that allows for modeling, static and dynamic analysis, non-linear dynamic analysis, and non-linear static pushover analysis. This program is user-friendly and offers a wide range of features. Specifically, STAAD.Pro V8i is an excellent choice for seismic analysis of multistory buildings with or without floating columns. It is an all-inclusive finite element analysis and design software, which includes a user-friendly interface, visualization tools, and design codes. STAAD.Pro V8i can analyze any structure exposed to static loading, dynamic response, wind, earthquake, and moving loads. It is capable of providing FEM analysis and design for various types of projects such as towers, culverts, plants, bridges, stadiums, and marine structures.

VIII. RESULTS AND DISCUSSIONS

As per the stud and modelling, analysis of tower in STAAD.PRO software, the angle section used in the tower for vertical, horizontal and in inclined member is passed against the load acting on the tower. According to result, used of such angle in actual tower is satisfactory or is the ideal design for specified location for which these research is carried out.

A. Axial Forces Acting In The Tower

Axial forces are the forces which is acting through the members longitudinal axis. For the determination of such forces various method is used. Below given are the axial forces acting in the various member of tower calculated in STAADPRO software

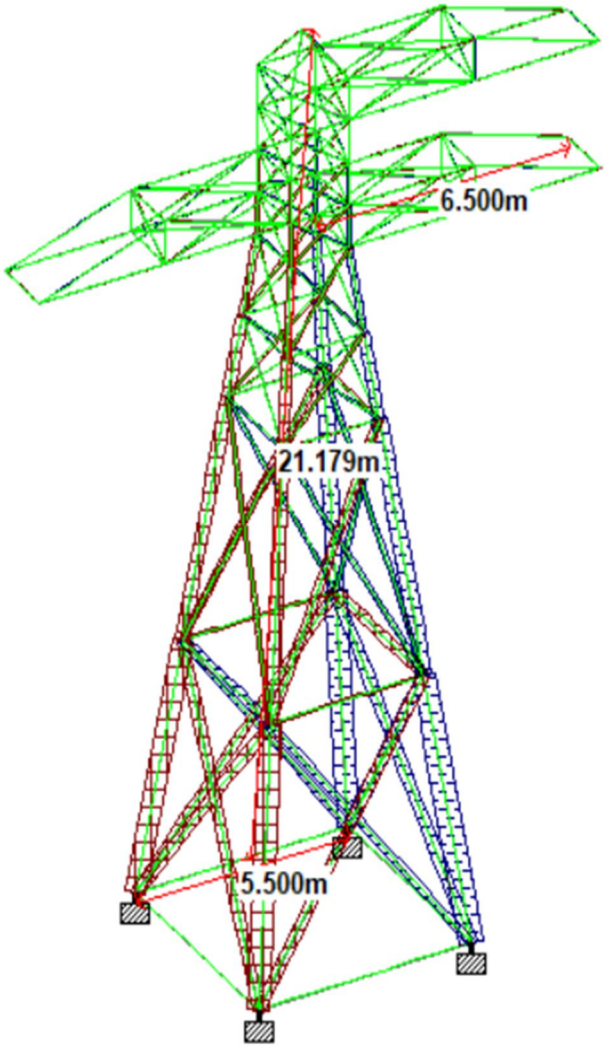


Fig 2.1: Axial Forces

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Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kip-in	My kip-in	Mz kip-in
1	1 DL	1	0.000	0.167	0.000	0.000	0.000	1.304
		75	0.000	0.029	0.000	0.000	0.000	0.374
	2 WIRE LOA	1	0.000	0.000	0.000	0.000	0.000	0.000
		75	0.000	0.000	0.000	0.000	0.000	0.000
	3 W1	1	0.000	0.000	0.000	0.000	0.000	0.000
		75	0.000	0.000	0.000	0.000	0.000	0.000
	4 W2	1	0.000	0.000	0.000	0.000	0.000	0.000
		75	0.000	0.000	0.000	0.000	0.000	0.000
	5 W3	1	0.000	0.000	0.000	0.000	0.000	0.000
		75	0.000	0.000	0.000	0.000	0.000	0.000
	6 V4	1	0.000	0.000	0.000	0.000	0.000	0.000
		75	0.000	0.000	0.000	0.000	0.000	0.000
	7 GENERATE	1	0.000	0.284	0.000	0.000	0.000	2.217
		75	0.000	0.050	0.000	0.000	0.000	0.636
2	1 DL	2	0.000	0.247	0.000	0.000	0.000	2.005
		3	0.000	0.247	0.000	0.000	0.000	-2.005
	2 WIRE LOA	2	0.000	0.000	0.000	0.000	0.000	0.000
		3	0.000	0.000	0.000	0.000	0.000	0.000
	3 W1	2	0.000	0.000	0.000	0.000	0.000	0.000
		3	0.000	0.000	0.000	0.000	0.000	0.000
	4 W2	2	0.000	0.000	0.000	0.000	0.000	0.000
		3	0.000	0.000	0.000	0.000	0.000	0.000
	5 W3	2	0.000	0.000	0.000	0.000	0.000	0.000
		3	0.000	0.000	0.000	0.000	0.000	0.000
	6 V4	2	0.000	0.000	0.000	0.000	0.000	0.000
		3	0.000	0.000	0.000	0.000	0.000	0.000
	7 GENERATE	2	0.000	0.420	0.000	0.000	0.000	3.409
		3	0.000	0.420	0.000	0.000	0.000	-3.409
3	1 DL	3	0.000	0.247	0.000	0.000	0.000	2.005
		4	0.000	0.247	0.000	0.000	0.000	-2.005
	2 WIRE LOA	3	0.000	0.000	0.000	0.000	0.000	0.000
		4	0.000	0.000	0.000	0.000	0.000	0.000
	3 W1	3	0.000	0.000	0.000	0.000	0.000	0.000
		4	0.000	0.000	0.000	0.000	0.000	0.000

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Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kip-in	My kip-in	Mz kip-in
		4	0.000	0.247	0.000	0.000	0.000	-2.005
	2 WIRE LOA	3	0.000	0.000	0.000	0.000	0.000	0.000
		4	0.000	0.000	0.000	0.000	0.000	0.000
	3 W1	3	0.000	0.000	0.000	0.000	0.000	0.000
		4	0.000	0.000	0.000	0.000	0.000	0.000
	4 W2	3	0.000	0.000	0.000	0.000	0.000	0.000
		4	0.000	0.000	0.000	0.000	0.000	0.000
	5 W3	3	0.000	0.000	0.000	0.000	0.000	0.000
		4	0.000	0.000	0.000	0.000	0.000	0.000
	6 V4	3	0.000	0.000	0.000	0.000	0.000	0.000
		4	0.000	0.000	0.000	0.000	0.000	0.000
	7 GENERATE	3	0.000	0.420	0.000	0.000	0.000	3.409
		4	0.000	0.420	0.000	0.000	0.000	-3.409
4	1 DL	4	0.000	0.247	0.000	0.000	0.000	2.005
		1	0.000	0.247	0.000	0.000	0.000	-2.005
	2 WIRE LOA	4	0.000	0.000	0.000	0.000	0.000	0.000
		1	0.000	0.000	0.000	0.000	0.000	0.000
	3 W1	4	0.000	0.000	0.000	0.000	0.000	0.000
		1	0.000	0.000	0.000	0.000	0.000	0.000
	4 W2	4	0.000	0.000	0.000	0.000	0.000	0.000
		1	0.000	0.000	0.000	0.000	0.000	0.000
	5 W3	4	0.000	0.000	0.000	0.000	0.000	0.000
		1	0.000	0.000	0.000	0.000	0.000	0.000
	6 V4	4	0.000	0.000	0.000	0.000	0.000	0.000
		1	0.000	0.000	0.000	0.000	0.000	0.000
	7 GENERATE	4	0.000	0.420	0.000	0.000	0.000	3.409
		1	0.000	0.420	0.000	0.000	0.000	-3.409
11	1 DL	11	3.100	0.040	0.003	0.000	-0.014	0.055
		82	-3.100	0.013	-0.003	-0.000	-0.005	0.036
	2 WIRE LOA	11	-0.687	-0.001	-0.001	0.000	-0.006	-0.004
		82	0.687	0.001	0.001	-0.000	0.010	-0.000
	3 W1	11	4.899	-0.012	-0.070	0.000	0.561	-0.105
		82	-4.899	0.012	0.070	-0.000	-0.094	0.025
	4 W2	11	1.686	0.012	0.069	-0.000	-0.527	0.106
		82	1.686	0.012	0.069	0.000	0.070	0.023

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Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kip-in	My kip-in	Mz kip-in
	7 GENERATE	4	0.000	0.420	0.000	0.000	0.000	3.409
		1	0.000	0.420	0.000	0.000	0.000	-3.409
11	1 DL	11	3.100	0.040	0.003	0.000	-0.014	0.055
		82	-3.100	0.013	-0.003	-0.000	-0.005	0.036
	2 WIRE LOA	11	-0.687	-0.001	-0.001	0.000	-0.006	-0.004
		82	0.687	0.001	0.001	-0.000	0.010	-0.000
	3 W1	11	4.899	-0.012	-0.070	0.000	0.561	-0.105
		82	-4.899	0.012	0.070	-0.000	-0.094	0.025
	4 W2	11	1.686	0.012	0.069	-0.000	-0.527	0.106
		82	-1.686	-0.012	-0.069	0.000	0.070	-0.023
	5 W3	11	4.899	-0.012	-0.070	0.000	0.561	-0.105
		82	-4.899	0.012	0.070	-0.000	-0.094	0.025
	6 V4	11	1.686	0.012	0.069	-0.000	-0.527	0.106
		82	-1.686	-0.012	-0.069	0.000	0.070	-0.023
	7 GENERATE	11	6.968	0.089	0.121	-0.000	-0.929	0.266
		82	-6.968	0.002	-0.121	0.000	0.128	0.021
12	1 DL	12	-0.360	0.036	0.007	0.000	-0.062	0.079
		13	0.360	0.036	-0.007	-0.000	-0.034	-0.082
	2 WIRE LOA	12	0.465	0.001	-0.011	-0.000	0.086	0.004
		13	-0.465	-0.001	0.011	0.000	0.065	0.003
	3 W1	12	0.062	0.000	0.117	0.000	-0.782	0.003
		13	-0.062	-0.000	-0.117	-0.000	-0.768	-0.000
	4 W2	12	0.134	-0.001	-0.105	-0.000	0.689	-0.004
		13	-0.134	0.001	0.105	0.000	0.709	-0.003
	5 W3	12	0.062	0.000	0.117	0.000	-0.782	0.003
		13	-0.062	-0.000	-0.117	-0.000	-0.768	-0.000
	6 V4	12	0.134	-0.001	-0.105	-0.000	0.689	-0.004
		13	-0.134	0.001	0.105	0.000	0.709	-0.003
	7 GENERATE	12	0.406	0.061	-0.186	-0.000	1.211	0.136
		13	-0.406	0.062	0.186	0.000	1.259	-0.140
14	1 DL	11	0.099	0.042	0.002	0.000	-0.013	0.094
		14	-0.099	0.042	-0.002	-0.000	-0.013	-0.092
	2 WIRE LOA	11	-0.076	-0.000	-0.005	-0.000	0.034	-0.003
		14	0.076	0.000	0.005	0.000	0.033	0.000
	3 W1	11	1.476	0.002	0.224	0.000	1.530	0.008

IX. CONCLUSION

The growing demand for reliable and sufficient electricity supply in all sectors, driven by the increase in population, necessitates the use of transmission towers. These towers must be able to withstand dead load, live load, and wind load under normal operating conditions. The maximum nodal displacement occurs at the top node (13), with a displacement of 175.255 mm. All sections considered in the design have been found to be safe against critical load combinations. The estimated steel required for construction is 5.2 tones (51 KN). Further studies could focus on designing transmission towers with a more appealing aesthetic appearance. Dynamic loads should be applied during the tower's analysis. The quantity of steel required can be optimized by using different bracing systems. The cost of construction can be compared for different bracing systems.

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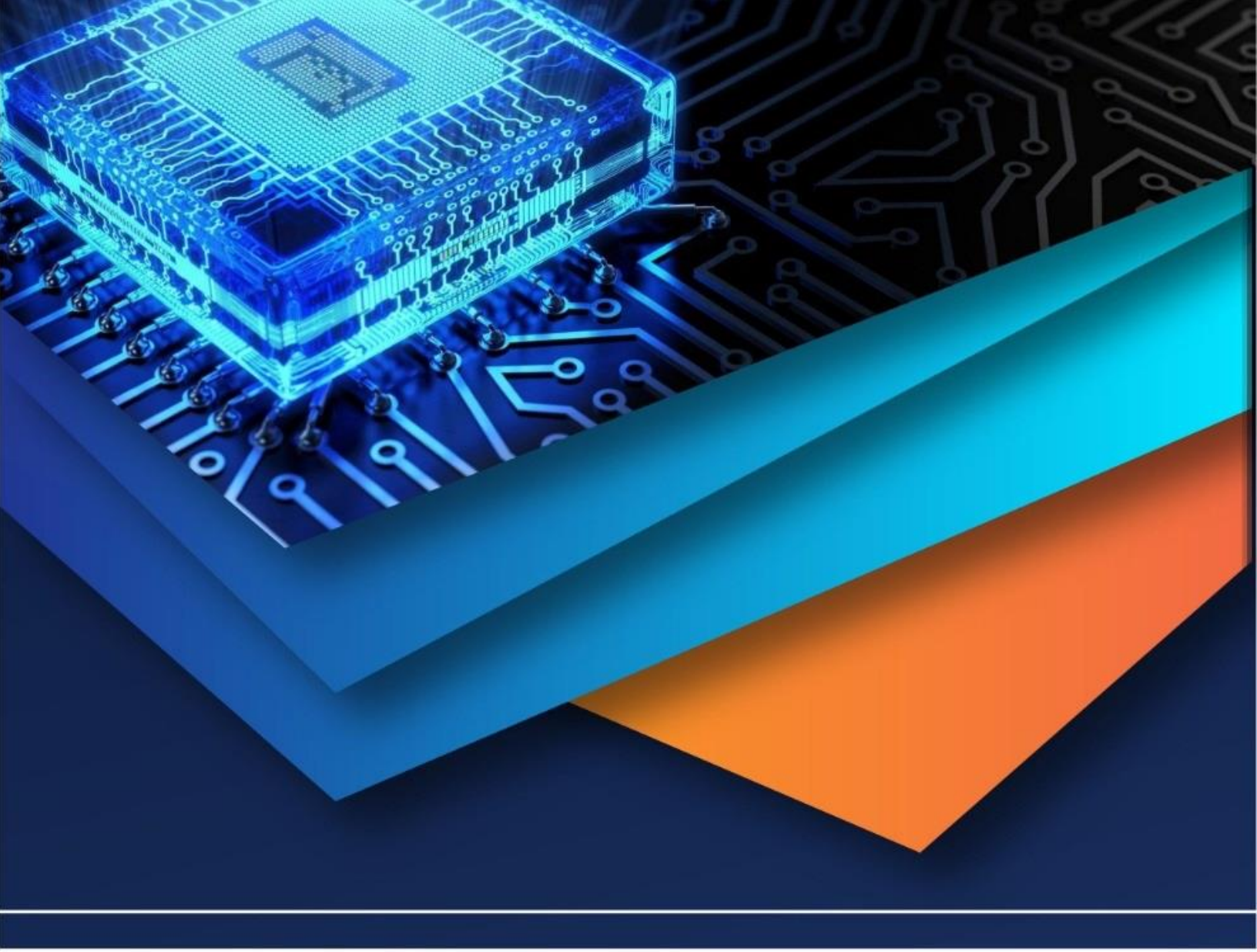
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