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Comparative Structural Analysis and Design of Transmission Tower and Monopole by using STAAD.Pro Software

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Abstract: ***In this research, the comparison of Analysis and Design of Monopole and Transmission Tower with the manual calculation and by using STAAD.Pro V8i software for analysis is done. The monopole of 18m height and transmission tower of 20m height are designed by manually calculated terms and the analysis is done by using structural analysis software. For the point of design, a 4-legged transmission tower of double circuited structure with 132KV power and a 16 sided polygonal-shaped of double circuited structure of monopole with 132KV power are considered. The structural and power fields are considered while designing towers for transmission line and monopole for its safe and economic aspects. The design of both monopole and Transmission tower are done manually using LSM (Limit State Method). The acting Loads on the monopole and transmission tower are dead load of the configured structure, braking load of the conductor, earthquake load and wind load are considered as per relevant IS code. The design are based on IS Codes which includes IS 800, IS 875, IS 802, IS 5613, etc. The wind forces are much effective on the transmission line tower and monopole, on their components like conductors and insulators, beside its self weight, hence wind analysis is done by using standard IS code 800-2007 and software. Also, the Earthquake analysis is done out using IS code for earthquake and software. In this research firstly the design of monopole and transmission tower are done with manual calculation and then analysis is carried out in analysis software, finally results are compared. The analysis with compressive stress, tensile stress, bending moment, lateral displacement and resultant displacement respect to three loading condition namely Normal, Vertical and Broken wire condition is compared for the results.***
Keywords: Transmission Line Tower, Monopole, STAAD.Pro, Loads, Conditions.

I. INTRODUCTION

In past studies, there is huge work is done on the design and analysis of Monopole and Transmission Line Tower. The monopoles and transmission line towers are measured as one of the essential salvation structures for transmitting electrical power energy. The Electric transmission generally carried out using high steel structures called transmission line tower and Monopoles. The Transmission line tower and monopole should be precisely designed so that may not cause failure all through its entire span and should be followed countrywide as well as globally. The transmission line tower is huge in shape and size because of it requires a large ground area for its proper installation, but it will be inconvenient or problematic at the places where sufficient area of ground is not vacant. A new structure for transmission is being preferred to overcome this kind of problem, which is ultimately known as Monopole (Single Pole). About 25% to 50% of the total budget cost of transmission line system is contributed by the transmission tower and hence very precise design and analysis is required while designing the transmission line tower, to make it cost-effective which ultimately leads to saving of funds. There are a lot of different sizes and shapes of transmission line tower which are constructed and designed with different type of materials. In the point of view of safety from conducting line system, the conductors are placed at particular clearance or height above the open ground areas, surface roads, rail tracks and other nearest power line cables along the path of the transmission line towers and monopoles. Hence the function of transmission line tower is to segregate the transmission line from its surrounding which includes tower structure itself and other nearer power line conductors. A large amount of electricity is produced at power plants and then it is transported at a huge distance for utility by customers with the help of transmission line towers. Transmission Tower structural basic calculations contain application loads like wind load, dead load, seismic load. Wind forces are more effectual on the transmission tower because of its huge height and large shape according to the Indian Standard code IS 802 on insulators and conductors, besides its self-weight. The cross-segment area of conductors, the spacing between all conductors, and the area of earth wires with regarding to the conductors is deciding factor while designing the towers and its foundations. As view point of non-availability of land area, monopole tower is innovative concept effective as an substitute to the transmission line tower. The monopole supports very less voltage conductors for the electric transmission to industrial consumers and substations.

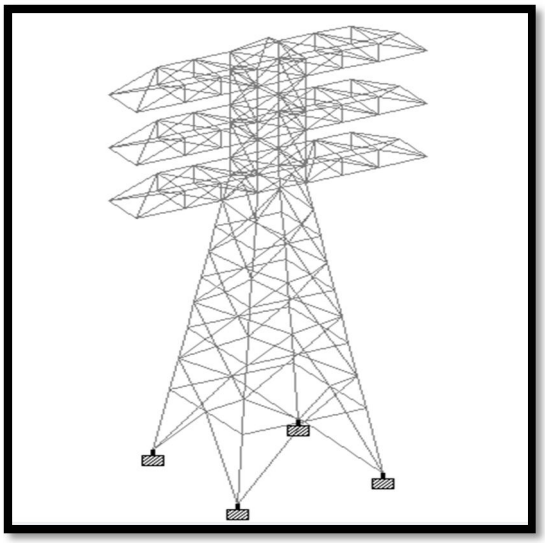

Fig.1: Transmission Tower

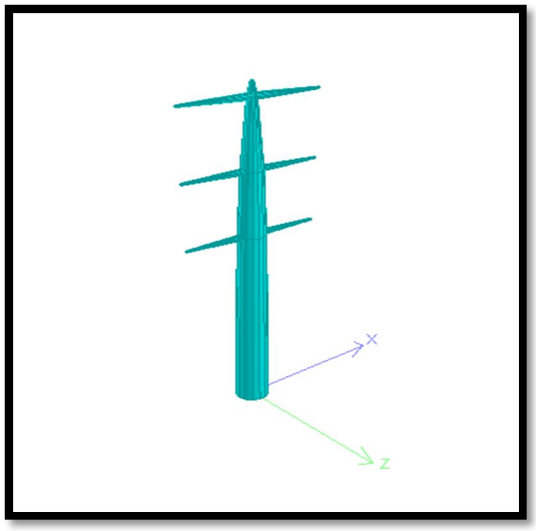

Fig.2: Monopole

II. REVIEW OF LITERATURE

A. Gopi Sudam Punase ISSN: 2249–6645, Volume. 04, Issue 01, January 2014

"Analysis and Design of Transmission Line Tower" In this work, Design and Analysis of narrow-based Transmission Line Tower (using Multi-Voltage and Multi-Circuit configuration) is done keeping in point of view to supply optimal utilization of electric energy supply with available Right Of Way and rising population in the locality of our country India. Using STAAD Pro v8i software analysis and the design of the transmission tower has been conceded out as a 3D structure (three-dimensional structure). This study concluded that the tower with X-bracing and angle section has a large decrease in weight subsequent to optimization. Total weight of transmission tower taking into account weight of anchor bolts, nut bolts and hardware etc. come out to 30 tonne to 35 tonne.

B. Jobil Varghese, Riya Joseph ISSN No. 2395-0900 Volume 01, No. 11, November 2015

"Analysis of Monopole Communication Tower" This research work presents the analysis of mobile monopole towers. The analysis is carried out by using ANSYS finite element analysis software. These have lesser plan dimensions and are possessed of only little components. These are supplementary economical bearing in mind the cost of land area. Displacements were obtained contained by the permissible limits of degree. The variation in the end result with alter in thickness was premeditated. Air stream effect was studied by analyzing the similar structure to an enlarged wind load. Towers of two dissimilar heights were taken for the purpose of this study.

C. Sai Avinash, Rajasekhar ISSN 0974-5904, Volume 09, No. 03 June 2016

"Analysis and design of transmission tower by using STAAD.Pro v8i software" This research work is inattentive on optimising the transmission line tower with assigning the K and X bracings, and by increasing the sections, using static or stationary analysis. They concluded that the transmission line tower configured with X bracing requisite a lesser steel percentage i.e. about 6% compared to K bracing. In the aspect of design, it reveals that by providing or assigning unique sectional property throughout the transmission line tower leads to too expensive design.

D. Yogesh Kaushik, Shivam Panwar ISSN 2349-4476, Volume 04, Issue 05, May 2016

"Structural Analysis and Design of Steel Transmission Tower in Wind Zones IV and II - A Comparative Study" In this work an attempt has been prepared to compare the identical transmission line towers with the equivalent bracing system at unlike wind zone viz. zone II and zone IV situated at Delhi and Panjim. The conclusion is drained on the basis of this research and the analysis is done using the Staad.Pro.V8i software. There is a huge differentiation in the bending moment on the components and there is a large change in axial force in the member of cross arms of tower.

E. Saurabh S. Aher, Dr. Tushar Shende, ISSN: 2349-7841 Volume 04, Issue 08, Feb-2018

"Comparative Study for the Design and Analysis of Transmission Tower" In our country large population is living all over the large area of country. A huge amount of electricity supply and demand is desirable for this resident makes the requirement of a large transmission system and distribution system. The use of Transmission tower is preferred in consideration of confronting very high voltage current transmitting insulators and conductors to carriage in need of high altitude from the ground level. Transmission Towers comprise of around 29% to 47% of the actual cost of the Transmission Line system.

III.AIM AND OBJECTIVE

This investigation work presents the structural design and analysis of monopole and transmission tower by using software STAAD.Pro V8i. The calculations are done manually for both of monopole and transmission tower as per IS Codes.
The results are compared for a variety of parameters.

A. The chief objective of this research work is to design the transmission tower and monopole manually and analyze the transmission tower and monopole by using software.
B. To produce a 3 Dimensional frame model of monopole and transmission tower using Staad.Pro V8i analysis software to bring out modeling and analysis of structure.
C. To check the lateral displacement, resultant displacement, variations in stresses (ie. tension and compression) in members, support reaction and bending moment in the components of monopole and transmission tower for which composition gives enhanced strength.
D. To analyze the structure for wind forces and seismic forces.
E. To study the evaluation of monopole and transmission line tower (both Double circuited) for several loadings (self-weight, earthquake load and wind load) acting on it.
F. To learn the effect of wind load on monopole and transmission line tower structures as per IS code of practice, ie. IS875 (part-3): 1987 and IS802 (part-1/sec-1): 1995.
G. To determine the quantity of steel required for both monopole and transmission tower.
H. To compare both transmission tower and monopole for their use in the view of convenient, economical, safety aspects.

IV.METHODOLOGY

The monopole and transmission line tower are designed manually by LSM method and by using Indian standard codes. The analysis is carried out using STAAD.Pro V8i analysis software. The monopole and transmission tower are both considered for voltage of 132KV with double circuit configuration. The 16 sided polygonal-shape monopole and 4-legged transmission line tower are designed in this research work. The total height of the monopole is 18m and the tower is 20m which is calculated according to IS code 5613:1995 (part 2/ sec 1). In the view of design an optimized transmission line tower with increasing section IS: 802:1995 (Part 1/ Sec 1) has been followed. Calculations which are done manually are significant for the recommendations of Indian Standard codes but the justification of these results and research work for the effects of these considered loads on the tower structure is also an essential part to do. The wind analysis is carried out using IS Code. At the conclusion point, the results are compared for both monopole and transmission tower. Now based on the validation and confirmation of the results through STAAD.ProV8i software, the significant conclusions are made.

V. DESIGN

A. Transmission Line Tower

Data

1) Tower Type- Tangent Type (2˚ line deviation)
2) Transmission Voltage – 132KV
3) Circuit –Double (Three Phase)
4) Terrain type– plain
5) Terrain category – Category 2
6) Reliability level – Level 1
7) Return period - 50 yrs
8) speed of Wind – 39 m/s

a) Geometry of Transmission Tower: The total height of tower is determined keeping in point of view of the clearance requirements above ground and maximum sag of power conductor.

i) Clearance Requirements

According to IS 5613-1995 (part2/sec1)

- Vertical height of conductor above ground surface (H1) = 6.1m
- Vertical spacing among power conductor (H3) = 4m
- Height of earth wire above peak conductor (H4) = Half of Horizontal spacing among power conductor (6.25m)

(H4) = 3.12m

b) Calculation of Sag (Tension)

Tension (T) = U.T.S / F.O.S

U.T.S. – Ultimate Tensile Strength of conductor = 9130 Kg

F.O.S. - Factor of safety = 4

Sagging = $wl^2 / 8T$ = 5.28 m

Increasing 4% of sag calculated (H2) = 5.49m

Total height of Transmission Line Tower (H) = H1 + H2 + H3 + H4 = 6.1 + 5.49 + 4 + 3.12 = 18.71m

Total height of Transmission Line Tower (H) ≈ 20 m

Width of Base of Transmission Line Tower

For the requirement of stability, the width of tower at base is taken as = $1/4^{th}$ × total height of tower = $1/4^{th}$ × 20 = 5m

Top width = 1/3 or 1/3.5 of base width = 1/3 or 1/3.5 x 5 ≈ 1.5m

c) Design Wind Pressure

As per IS 802:1995 (part1/sec1)

$P_d = 0.6 \times V_d$

i) To Calculate Wind Speed

As per IS 802:1995 (part1/sec1)

$V_d = V_R \times K_1 \times K_2$

V_r - Reference wind speed

K_1 - Risk coefficient for different level of reliability

K_2 - Terrain roughness coefficient for 3 categories

$V_R = V_b \times K_0$

d) Calculation of Wind Load

As per IS 802:1995 (part1 /sec1)

i) Wind load on conductor wire and ground wire

$F_{wc} = P_d \times C_{dc} \times L \times d \times G_c$

ii) Wind load on insulator string

$F_{wi} = C_{di} \times P_d \times A_i \times G_i$

A_i = 12 × diameter of conductor × insulator length

iii) Wind load on tower structure

$F_{wt} = P_d \times C_{dt} \times A_e \times G_t$

e) Vertical loads

As per IS 802:1995 (part1/sec1)

i) Line man with tools = 1.5KN

ii) Weight of conductor = 1.5 LWC

iii) Load at tip of cross arm = 3.5KN

B. Monopole

Data

1) Tower Type - Tangent Type (2˚ line deviation)
2) Transmission Voltage – 132KV
3) Circuit Type –Double (Three Phase)
4) Terrain type– plain
5) Terrain category – Category 2
6) Reliability level – Level 1
7) Return period - 50 yrs
8) speed of Wind – 39 m/s

a) Geometry of Monopole Structure: The total height of Monopole is decided keeping in point of view of the clearance requirements above ground and maximum sag of power conductor.

i) Clearance Requirements

As per IS 802:1995 (part1/sec1)

- Vertical height of conductor above ground surface (H1) = 7m
- Vertical spacing among power conductor (H3) = 4.5m
- Height of ground wire above peak conductor (H4) = Half of Horizontal spacing among power conductor (6.25m)

(H4) = 3.12m

b) Calculation of Sag Tension

Tension (T) = U.T.S / F.O.S

Sagging = $wl^2 / 8T$ = 3.06m

Increasing 4% of sag calculated (H2) = 3.18m

Total height of Monopole (H) = H1 + H2 + H3 + H4 = 7 + 3.18 + 4.5 + 3.12 = 17.8m

Total height of Monopole (H) ≈ 18 m

Width of Base of Monopole

For stability requirement the Base width of Monopole at base as kept as = $1/4^{th}$ × height of Monopole

= $1/4^{th}$ × 18 = 4.5m

Top width = 1/3 or 1/3.5 of base width = 1/3 or 1/3.5 x 4.5 ≈ 1.4m

c) Design Wind Pressure

As per IS 802:1995 (part1/sec1)

$P_d = 0.6 \times V_d$

i) To Calculate Wind Speed

As per IS 802:1995 (part1/sec1)

$V_d = V_R \times K_1 \times K_2$

V_r - reference wind speed

K_1 - Risk coefficient for different level of reliability

K_2 - Terrain roughness coefficient for 3 categories

$V_R = V_b \times K_0$

d) Calculation of Wind Load

As per IS 802:1995 (part1/sec1)

i) Wind load on conductor wire and ground wire

$F_{wc} = P_d \times C_{dc} \times L \times d \times G_c$

ii) Wind load on insulator wire

$F_{wi} = C_{di} \times P_d \times A_i \times G_i$

A_i = 12 × diameter of conductor × insulator length

iii) Wind load on tower

$F_{wt} = P_d \times C_{dt} \times A_e \times G_t$

e) Vertical loads

As per IS 802:1995 (part1/sec1)

i) Line man with tools = 1.5KN

ii) Weight of conductor = 1.5 LWC

iii) Load at tip of cross arm = 3.5KN

VI. RESULT

The results are given for 132 KV Double Circuit Monopole and Transmission Tower. The results are shown in terms of Compressive Stress, Tensile Stress, Bending Moment, Resultant Displacement, Lateral Displacement and Quantity of Steel for Monopole and Transmission Line Tower. The comparison is based on three loading conditions that is NLC (Normal Load condition), VLC (Vertical Load condition) and BWC (Broken Wire Load condition).

Fig.3, 4 shows, the Compressive Stress and Tensile Stress in Tower are little for VLC and very large for BWC and NLC as compared to the Monopole. Fig.5 shows, the Bending moments in Transmission line Tower are very fewer as compared to Monopole. Fig.6 shows, the Resultant Displacement in Monopole are nearly equal of VLC and very large as compared to Transmission line Tower. Fig.7 shows, the Lateral displacement in Monopole is almost zero for VLC and very large for BWC and NLC as compared to Transmission line Tower.

Fig.8 shows, the Transmission tower requires great quantity of steel as compared to Monopole.

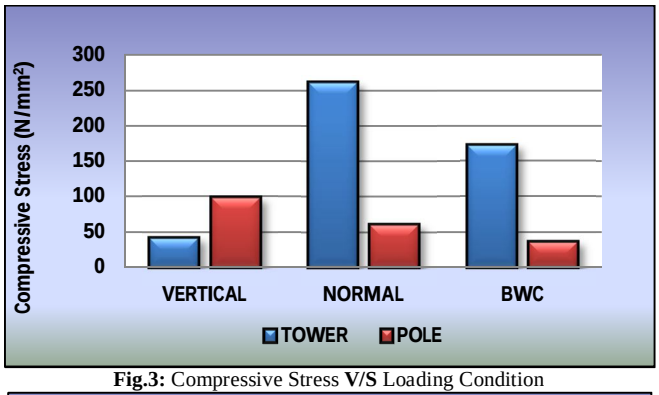

Fig.3: Compressive Stress **V/S** Loading Condition

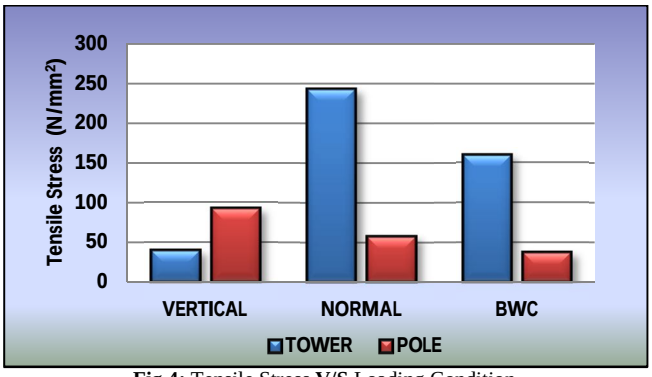

Fig.4: Tensile Stress **V/S** Loading Condition

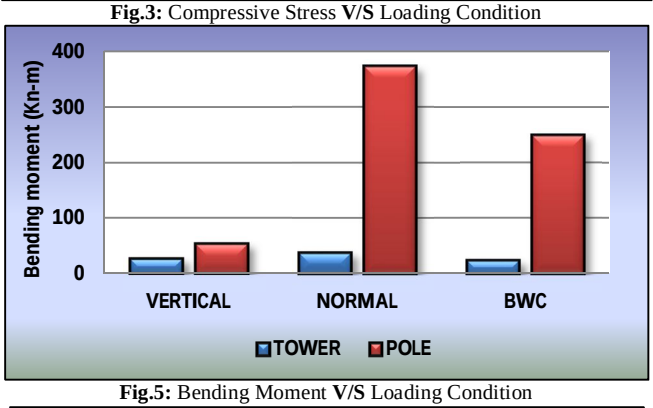

Fig.5: Bending Moment **V/S** Loading Condition

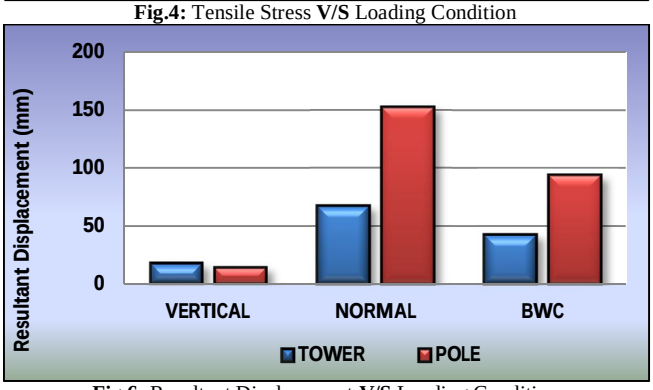

Fig.6: Resultant Displacement **V/S** Loading Condition

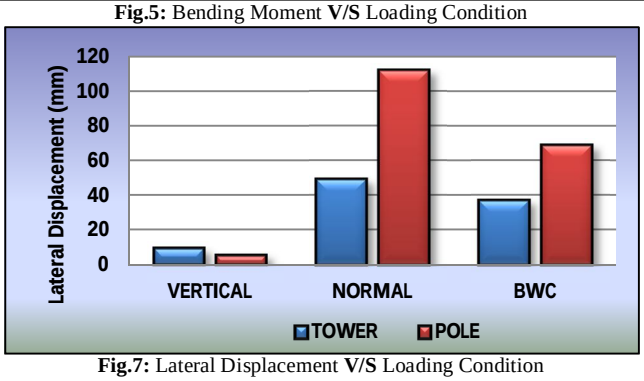

Fig.7: Lateral Displacement **V/S** Loading Condition

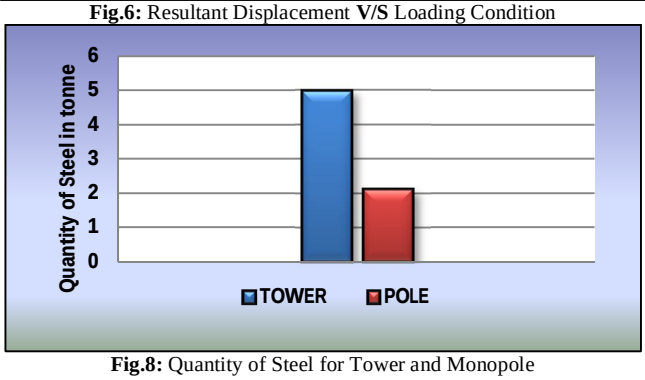

Fig.8: Quantity of Steel for Tower and Monopole

VII. CONCLUSION

A. Result shows, the compressive and tensile stresses are much additional in transmission line tower compared to the monopole; hence tower requires superior precision while designing.

B. Result shows, the bending moment for the transmission line tower is very lesser in amount of compared to monopole so tower provides superior stiffness under heavy loadings.

C. Result shows, the resultant and the lateral displacement for the transmission tower is very fewer as compared to the monopole, so the tower can carry heavy loads securely and proficiently compared to the monopole.

D. Percentage of steel material for double circuited transmission line tower is about 57% additional than the double circuited monopole, which makes the tower less cost-effective than monopole.

E. The above study shows, it is found that the construction of monopole is much easier and cost optimum. In the future, it is superior to go for construction of monopole than conservative transmission tower. Also monopole is easy for the safeguarding and safe and sound for environment. As it required least criteria for design of monopole and installation, monopole stand for superior option to the system of transmission line.

F. This study shows, the monopole can be installed in the places or locations where less quantity of legroom is available, as it required slighter foot print compared to transmission line tower, leads to wealth in the point of view of the acquirement of land.

G. From the analysis, it is observed that the values of bending moment and maximum displacement are higher for monopole as compare to transmission line tower. This makes the monopole structure lesser effective.

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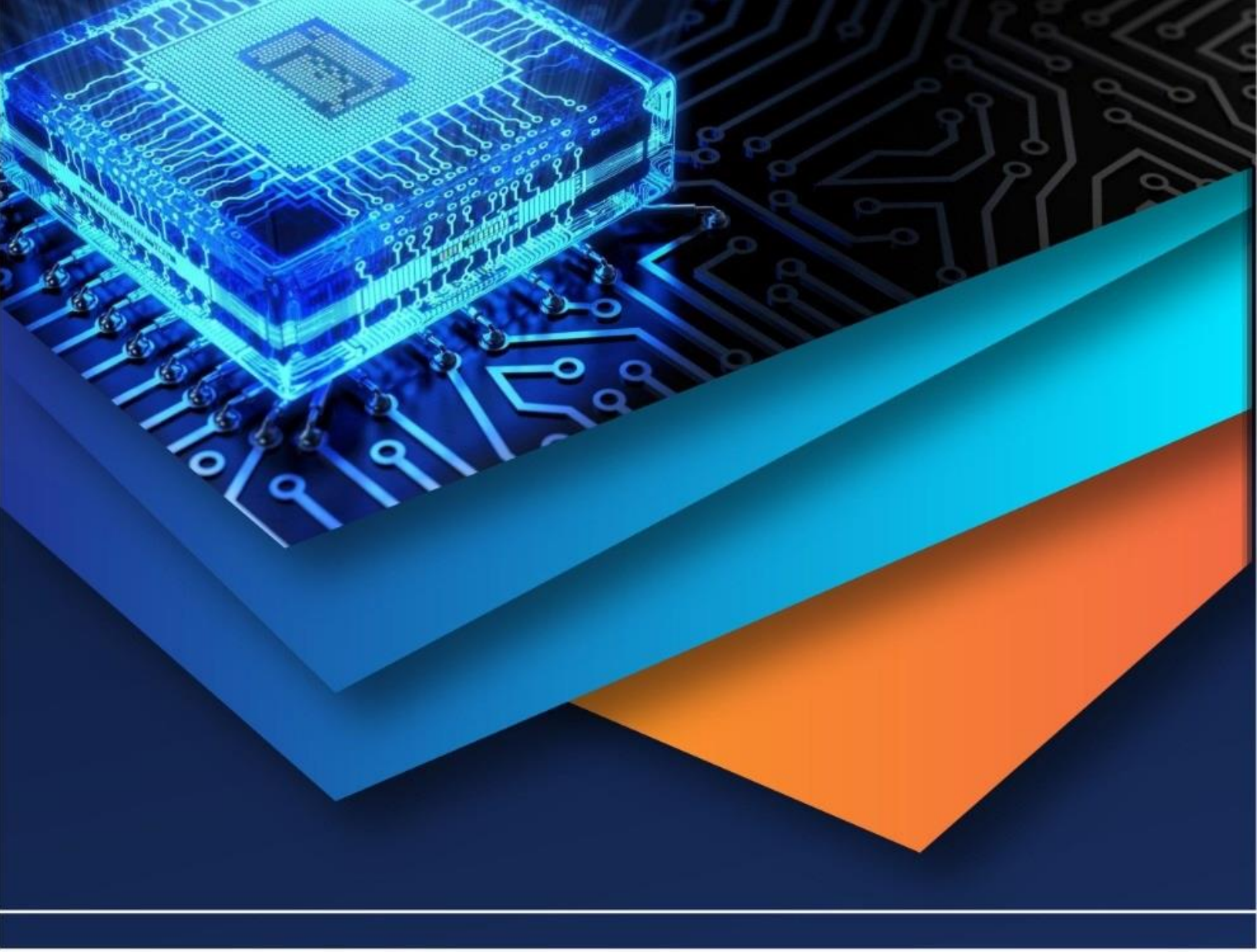

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