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Hybrid Water Cycle Moth Flame Optimization Algorithm to Resolve the Harmonic Distortion

Akshay Kumar[1], Dr. M. K. Bhaskar[2]
[1]Research Scholar, [2]Professor, M.B.M. University, Jodhpur

***Abstract:** A novel hybrid optimization approach that combines the Hybrid Water Cycle Optimization Algorithm (HWCOA) and the Moth Flame Optimization Algorithm (MFOA) to address the challenge of harmonic distortion in electrical systems is represented in this research paper. Harmonic distortion can lead to significant inefficiencies and damage in power systems, necessitating effective mitigation strategies. The proposed hybrid algorithm leverages the strengths of both optimization techniques: HWCOA's robust search capabilities in continuous spaces and MFOA's efficient exploration of complex landscapes. Experimental results highlight significant improvements in reducing Total Harmonic Distortion (THD), showcasing the hybrid approach's potential for real- world applications in power quality enhancement.*
***Keywords:** THD, Optimization Algorithm, Power Quality, Power Converters*

I. INTRODUCTION

The study of power system converters and harmonics reduction techniques is of paramount importance in the realm of modern power systems. Understanding the inherent characteristics, diverse applications, and operational intricacies of power converters is fundamental for optimizing power system performance. Concurrently, the study delves into the adverse effects of harmonics, originating from nonlinear loads and electronic devices, on power quality and system reliability. In the context of an evolving energy landscape, where renewable integration and technological advancements are reshaping the power sector, addressing harmonics becomes imperative.

This research is trying to find a better way to reduce unwanted noise in special machines called multilevel inverters (MLIs). These machines are used to change electricity from one form to another, but sometimes they make annoying sounds called harmonics. The researchers want to get rid of some specific sounds, like the 5th, 7th, and 11th ones, because they can be bothersome. To do this, they're using a special method called the Hybrid Water Cycle Moth-Flame Optimization (Hybrid WCMFO) algorithm. With the changing energy landscape, power system performance optimization requires a deep comprehension of the intrinsic properties, wide range of applications, and operational nuances of power converters.

Furthermore, the research explores the detrimental effects of harmonics, which originate from nonlinear loads and electronic devices, on the overall power quality and dependability of the system. Given the increasing prevalence of nonlinearities in contemporary power systems, it is critical to understand the relationship b/w power converters and harmonics. To maintain the electrical grid's resilience and efficiency, harmonic mitigation becomes essential.

II. HARMONICS OPTIMIZATION METHODS

To solve the issue of harmonic distortion, the proposed algorithm combines the Hybrid Water Cycle Optimisation Algorithm (HWCOA) with the Moth Flame Optimisation Algorithm (MFOA). Water Cycle Algorithm: The natural water cycle and the downward movement of rivers and streams toward the sea serve as its foundations. In a natural water cycle, condensation creates clouds from the evaporation of water. After that, water comes down to earth through the process of rain. This water then takes the form of rivers and streams and is evaporated again, and this whole cycle is repeated. In WCA, solutions are termed as 'raindrops'. Initially, the raining process is assumed.

The raindrops that give the best and good fitness values are designated as 'sea' and 'rivers', respectively. The other solutions are designated as 'streams'. The magnitude of flow, streams are absorbed by the rivers which eventually fall into the sea (the global best). The flowchart of WCA is illustrated by Fig. 1. Moth-Flame Optimization Algorithm: As a group of insects, moths and butterflies are extremely similar. The distinctive way that moths navigate is among their most fascinating behaviours. They fly at a fixed angle to the moon in order to cover large distances in a straight line.

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We refer to this successful strategy as transverse orientation. The distance of the light source has a significant impact on how effective the transverse orientation is. For instance, the moth begins to fly in a spiral pattern around the light when it is near the light source. The moth eventually converges on the light along this spiral flight path.

The algorithm, called Moth-Flame Optimization. As we know, the WCA excels at examining the problem's solution space. The positions of streams and rivers in the WCA are updated in relation to the sea, which helps search agents adjust their locations in relation to the optimal solution. However, challenges are faced by the WCA due to a lack of a competent operator for effective exploitation.

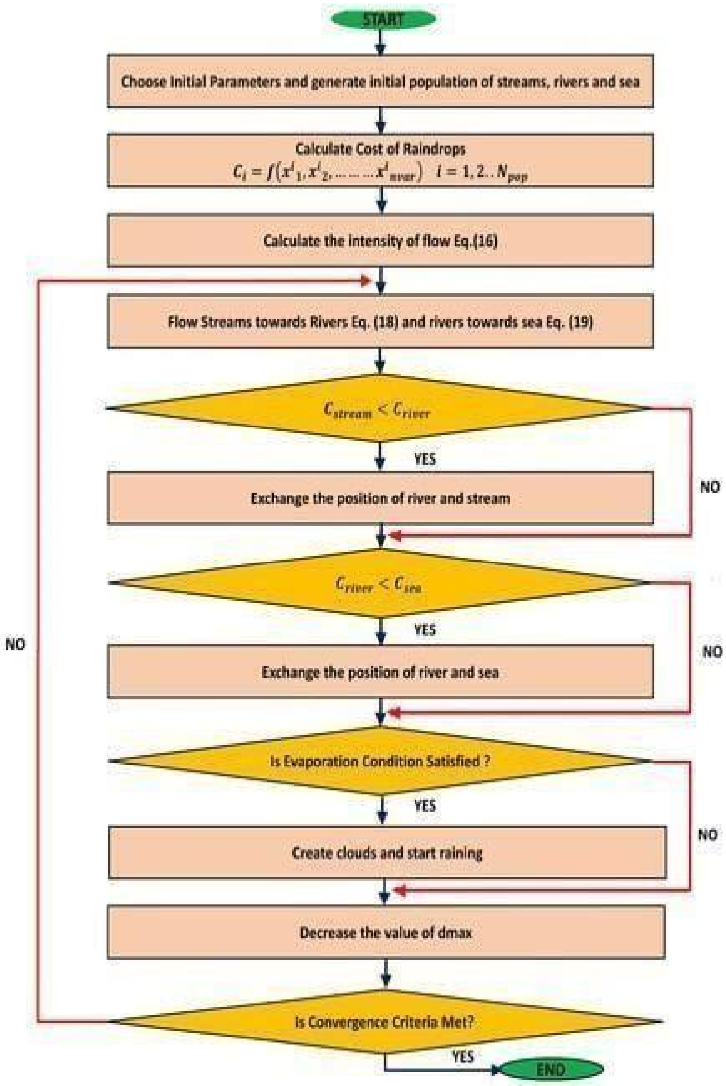

Fig. 1 Flowchart illustrating working of water cycle algorithm.

Conversely, MFO exhibits excellent exploitation performance when utilizing its spiral movement capability, but it is unable to effectively explore the solution space. This is so that every moth adjusts its position in relation to the corresponding flame. As a result, none of the search agents knows about the best solution that the MFO has found thus far.

The proposed WCMFO algorithm considers the WCA as its foundational algorithm. The first enhancement to the WCA involves using the spiral movement of the moths to update the positions of the streams and rivers. In the basic WCA updating procedure, the position of a stream is determined by the distance between the stream and a river. In other words, the next location of the stream is placed in the area separating it from the corresponding river. The MFO algorithm allows the moths to update their positions around their corresponding flame. By enabling rivers and streams to adopt the moths' spiral movement for position updates, the hybrid WCMFO significantly enhances its exploitation potential.

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III.SIMULATION & RESULT

The inverter is modelled using four H-bridge cells connected in series. Each H-bridge is powered by an independent DC source. Figure 2 shows 9-level inverter MATLAB simulation model.

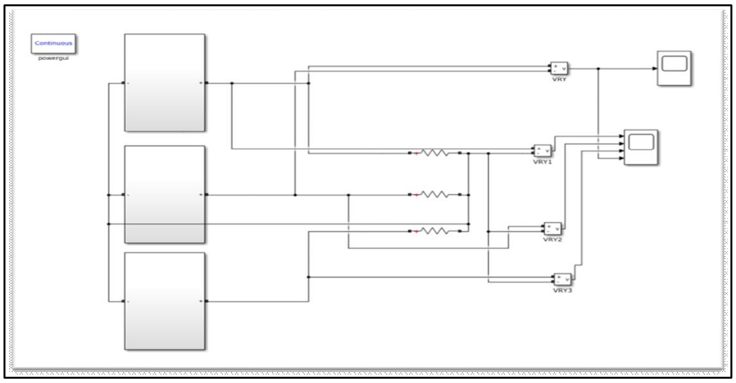

Fig. 2 Nine-Level Inverter Simulation Model

These DC Sources provide the i/p voltage for each H-bridge. The o/p levels of the inverter depend on the voltage levels of these sources. The H-bridges are controlled by switching devices such as IGBTs or MOSFETs. The switching pattern is determined by the modulation technique used. Nine-Level Inverter Sub-System Simulation Model is shown figure 3.

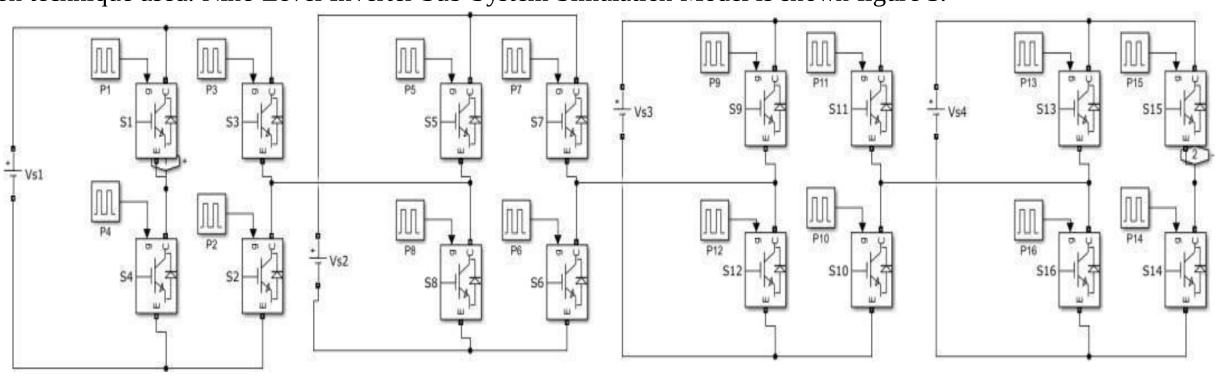

Fig. 3 Nine-Level Inverter Sub-System Simulation Model

Sinusoidal Pulse Width Modulation (SPWM) Techniques: This technique may be used in the simulation to control the switching of the H-bridges. To generate the necessary switching pulses, the reference sine wave is compared with several carrier signals and Selective Harmonic Elimination (SHE) Techniques: Alternatively, SHE could be implemented to optimize the switching angles, minimizing specific harmonics in the o/p are used in this research. Figure 4 shows DC source for simulation. Figure 5 and figure 6 depicts inverter & pulse specification for simulation. The simulation begins with initializing the parameters, such as the DC source voltages, switching frequencies, and modulation index and then the inverter's switching devices are triggered based on the selected modulation technique and then the o/p voltage waveform is generated as the sum of the voltages from the individual H-bridge cells and finally during the simulation, key data such as the o/p voltage waveform, THD, and harmonic spectrum are recorded for analysis.

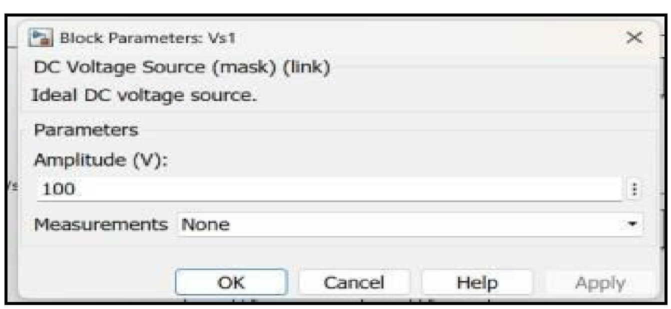

Fig 4 DC Source for Simulation

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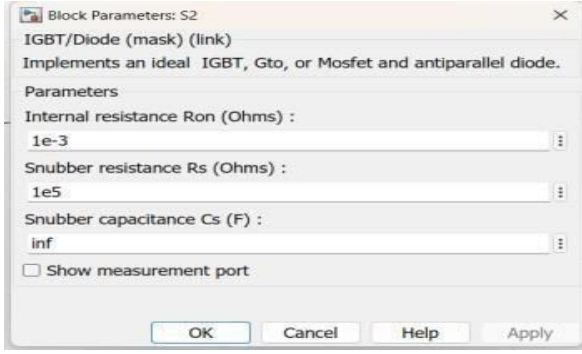

Fig 5 Inverter Specification for Simulation

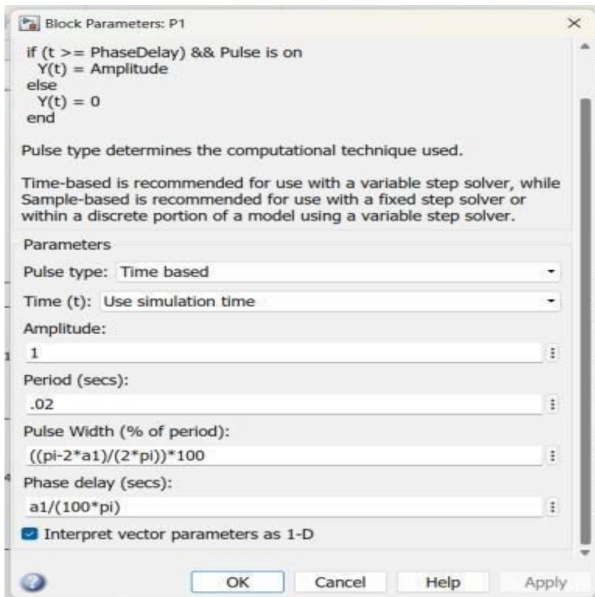

Fig 6 Pulse Specification for Simulation

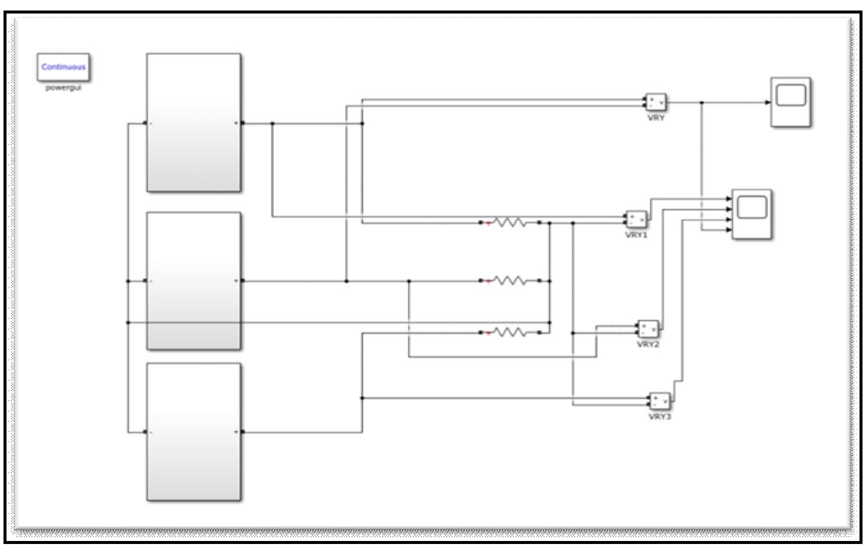

Fig 7: Proposed system diagram

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The suggested system's Simulink model is displayed in figure 7. Level 1, Level 2, and Level 3 are the three separate levels that have been designed in this. The voltage is returned and the three-phase o/p is produced by these three levels. In this case, the level stands for the inverter, or nine-level cascaded H-bridge (CHB) MLI. The MFO optimization algorithm is employed to generate the pulses supplied to the inverter. These pulses are created based on the switching angle. The 9-level CHB MLI receives these pulses and produces the o/p voltage. The system's total generated o/p voltage is obtained by combining the o/p voltages of the final three levels. The performance of this system is then analyzed further to verify that whether the generated o/p of the proposed system gives the efficient results in terms of harmonic distortion. The results of the performance analysis obtained are represented.
As stated in the above section, the new approach i.e., MFO is used in the proposed work to resolve the problem of SHE in MLIs. Now, this proposed approach is implemented in the MATLAB environment and simulation is performed in order to analyze its performance in terms of different parameters. And obtained results of the simulation are discussed in this section.

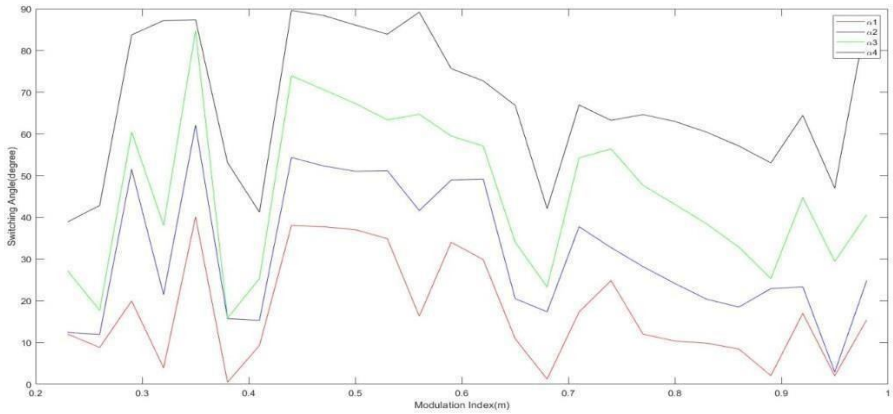

Fig. 8 Switching angles in proposed approach with respect to modulation index

The graph shown in figure 8 illustrates the calculated switching angles i.e. α1, α2, α3and α4 with respect to modulation index (m). In which, s represents number of dc sources, represents supply voltage and implies fundamental voltage. In the graph, the y-axis calibrates the value of switching angles that ranges from 0 to 90 degree, and x-axis calibrates the values of modulation index ranging from 0.2 to 1. The switching angles are calculated so as to minimize the system's total harmonic distortion.

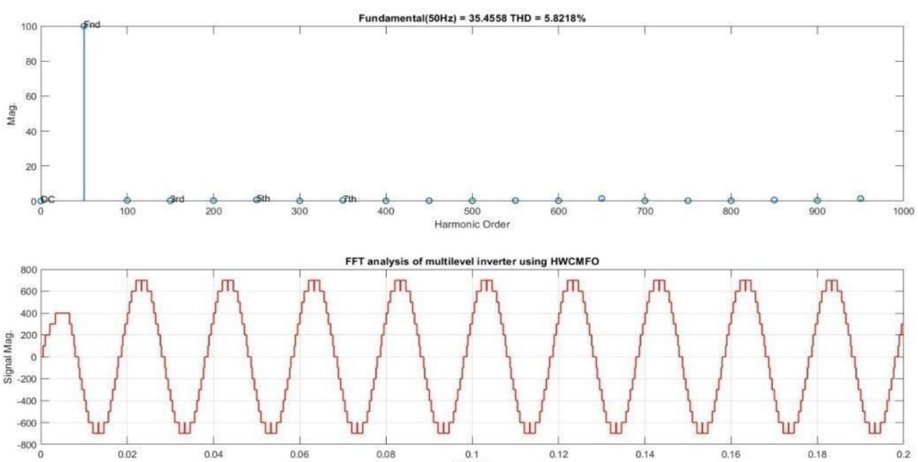

Fig 9 FFT analysis of MLI using proposed MFO

As seen in figure 9, the suggested MFO technique is used to carry out the FFT analysis of the MLI. The magnitude of the third, fifth, and seventh order harmonics as well as the THD, which is 6.7852%, are displayed in the figure . The magnitude and harmonic order values in that graph are calibrated by the y- and x-axes, respectively. Here, the harmonic order ranges from 0 to 1000, while the magnitude ranges from 0 to 100.

Additionally, the figure's below graph illustrates the MLI's FFT analysis's signal magnitude. This graph displays the MLI's signal magnitude using the suggested method in relation to changing times. The range of the signal magnitude is -1000 to 1000, and the range of the time is 0 to 0.2 seconds. The findings suggest that the suggested method effectively reduces the desired harmonics. Now, a comparison is made in terms of THD between the suggested MFO approach and the traditional approaches, NR and SCA approach. The results are shown Fig. 10.

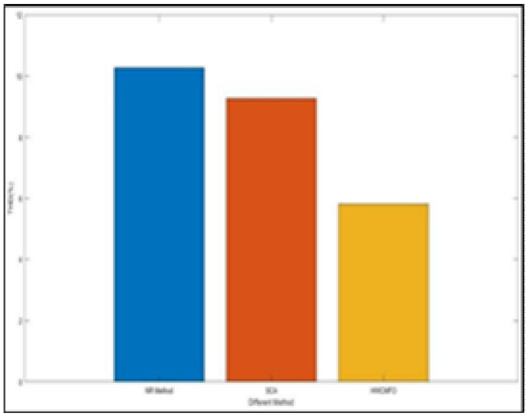

Fig 10 Comparative analysis in terms of THD

The results of a comparative analysis between the suggested MFO approach and the traditional NR and SCA approaches in terms of THD are displayed in the bar graph in figure 10. Given that NR has the highest THD value of the three approaches, it is evident from analyzing the graph that it is the least effective strategy. In contrast, SCA has lower THD values than NR, making it more efficient than NR. But the suggested MFO approach's THD value is even lower than SCA's, showing how much better the suggested approach is in terms of THD than these two traditional approaches—NR and SCA. Table I records the values of two distinct parameters, namely THD and improvement, for both the proposed and conventional approaches.

TABLE I

THD VALUES OF DIFFERENT APPROACHES

Parameter	**NR**	**SCA**	**HWCMFO**
THD%	10.27	9.28	5.82

The THD and improvement of the suggested and traditional methods are compared, and the results are shown in the table I. The presented values clearly show that NR has the highest THD value, 10.27%, followed by SCA, 9.28%. In contrast, the suggested WCMFO approach has the lowest THD value, 5.82%, making it the most effective method compared to the other two prior approaches. This proves the effectiveness of the suggested strategy.

IV. CONCLUSIONS

This work developed a method to remove harmonic distortion and remove the 5th, 7th, and 11th order harmonics in multilevel inverters (MLIs) in a selective manner. The suggested approach solves the Selective Harmonic Elimination (SHE) problem by applying the Hybrid Water Cycle Moth-Flame Optimization (Hybrid WCMFO) algorithm. Through simulations run in the MATLAB environment, the effectiveness of this approach was evaluated with consideration given to a number of different parameters, including switching angles, Total Harmonic Distortion (THD), and FFT analysis. The suggested Hybrid WCMFO-based approach was compared to traditional techniques, namely the Sine-Cosine Algorithm (SCA) and Newton-Raphson (NR) approaches. The suggested strategy outperformed the other techniques, as evidenced by the results, which showed that it had the lowest THD of 5.82%.

All things considered, the suggested Hybrid WCMFO-based method has shown to be very successful when it comes to the parameters considered, which create it a viable option for harmonic elimination in MLIs. Further research endeavors may concentrate on enhancing the fitness function and investigating hybrid optimization methods to further improve system efficiency and minimize harmonic distortions.

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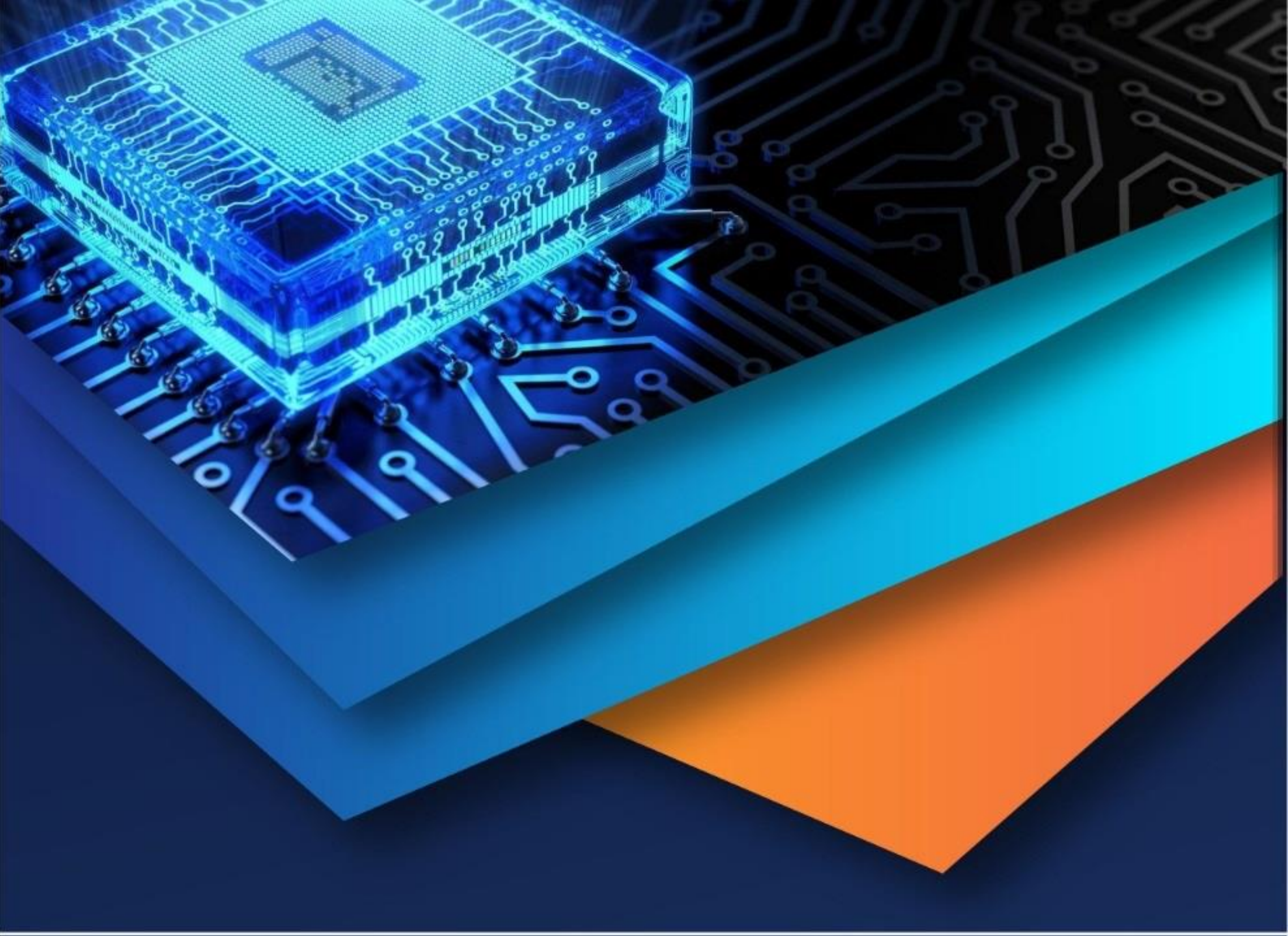

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