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Effective Performance Improvement of SPM using Adjustable Capacitor and Multilevel Inverter

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Abstract:** A method to achieve good performances of a SPIM in specific speed range is introduced on the basis of using an adjustable capacitor. Effect of capacitor change on the most important performance factors of the motor is investigated. As different capacitances are required in different situations, an adjustable capacitor is introduced that achieves this requirement. But single phase induction motor cannot produce required starting torque. So implementing an auxiliary winding that in contribution with the main winding produces a rotating field in the air gap. In high power and high starting torque applications, a series connected capacitor with auxiliary winding is used to gain better performances. The total harmonic distortion of the input supply of single phase induction motor is reduced by using multilevel inverter. By this proposed method, the performance parameters of single phase induction motor like electromagnetic torque, speed and rotor current can be improved and THD is reduced.

***Keywords:** Adjustable capacitor, Auxiliary winding, Main winding, Single phase induction motor (SPIM), Total harmonic distortion (THD)*

I. INTRODUCTION

The increasing demand for energy has led to demand for efficient and good quality of power in motor and motor systems. Single phase induction motor is the most commonly used driving systems in domestic, commercial, agricultural, industrial and other low power applications. These motors are available in different ratings from fractional horsepower to hundreds of horsepower. Due to the rugged design, low maintenance, reliable operation and cheaper cost, single phase induction motor are most familiar over all other electric motors. Most of the domestic appliance like fans, washing machines, refrigerators etc uses this motor for their functioning which is mostly rated in the fractional horsepower. The single-phase induction motor (SIM) is preferred in the applications that do not require a variable speed drive, regarding the low efficiency, due to its low cost

and rugged construction. Due to the large number of existing motors in use, researches were done to improve the motor's performances by keeping low price and minimizing potential equipment failure.

In spite of popularity, this type of motor cannot produce required starting torque. To overcome this problem, known techniques are used as implementing an auxiliary winding that in contribution with the main winding produces a rotating field in the air gap. In high power and high starting torque applications, a series connected capacitor with auxiliary winding is used to gain better performances. The main drawback of this combination is different capacitors that are

required for optimum performances in different speeds especially at start and rated speed. Essentially, starting capacitor is larger than running one. Power electronic devices can help to convert a fixed value capacitor to an adjustable one. Moreover, rotating fields theory helps us to evaluate the machine characteristics and determine the required capacitor for optimum performances in different operating conditions.

One way to produce starting torque in the SIM is equipping it with the auxiliary winding physically perpendicular to the main winding. Proper phase shift in currents flow through these windings is required which can be reached by using a capacitor in series with the auxiliary winding. If a fixed capacitor is to be utilized, usually, maximum starting torque determines its value. When the motor reaches 70-80% of its rated speed, the capacitor is bypassed, because a large capacitor in the auxiliary circuit decreases the motor performances. "Fig.1." shows the schematic view of the windings and the capacitor of the SIM.

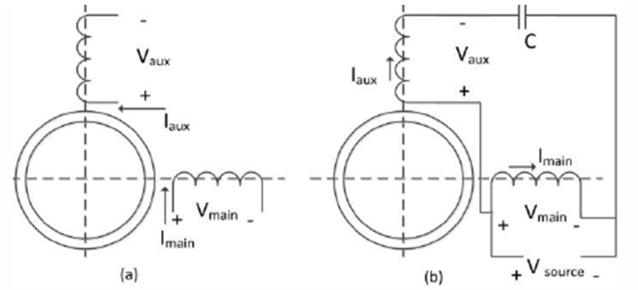

Fig.1. SIM with main and auxiliary windings
a: without capacitor , b: with capacitor

Where Rmain, Llmain, Raux, Llaux, Nmain and Naux are stator main and auxiliary winding resistances, leakage inductances and number of turns. Each winding has forward and backward rotating MMFs and the physical rotation of 90 degree is between two windings. As a result, positive and negative torque components each have an individual equivalent circuit.

II. BLOCK DIAGRAM OF PROPOSED SYSTEM

In this proposed system the dc supply is given to the multilevel inverter, here nine level cascaded H bridge multilevel inverter is used. It consists of four semiconductor switches in two sub-systems and PWM control strategy is used in the multilevel inverter for giving the pulse signals to the semiconductor switches and get waveform of nine level including zero and reduces the total harmonic distortion of the system . The output of multilevel inverter is given to the input of single phase induction motor in which adjustable capacitor placed in series with the auxiliary winding. Power electronic devices can help to convert a fixed value capacitor to an adjustable one. The adjustable capacitor switch can be turn on by giving the triggering pulses from pulse generator. By using this method, thus obtained the improved performances of SPIM such as electromagnetic torque, speed and rotor current and the THD is reduced.

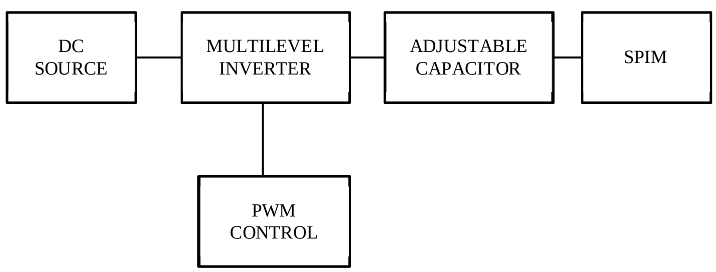

Fig.2 Block diagram of SPM using adjustable capacitor

III. EFFECT OF THE CAPACITANCE VARIATION ON THE SIM PERFORMANCES

In this section, using the sample data for a S[M, output variables and performances of the motor are analyzed over the reasonable range of the series capacitor value (1-51),uF.

"Fig. 2" shows the slip of the SIM versus electromagnetic and pulsating torque.

As shown, increasing the capacitor's value improves the starting and peak electromagnetic torque, but for low slips, large capacitors unstable the motor (negative electromagnetic torque is produced).

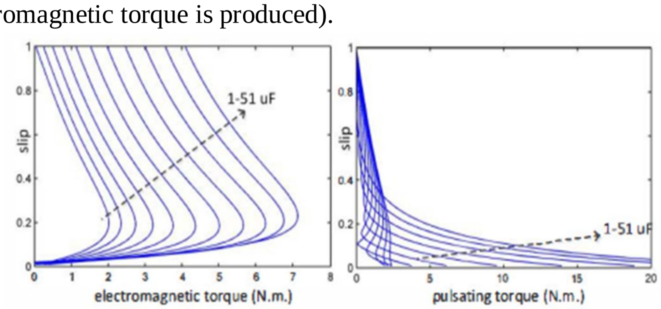

Fig.3 slip versus electromagnetic and pulsating torque

"Fig. 4" shows the motor slip versus efficiency which clears that near the rated speed, different capacitances are required to ensure maximum efficiency.

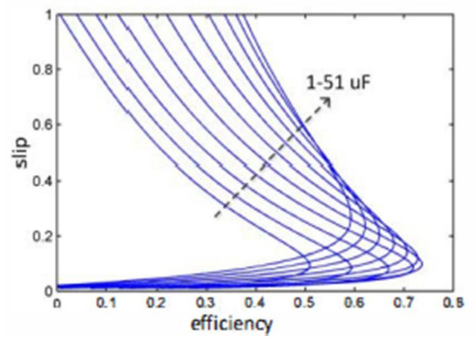

Fig.4 slip versus efliciency

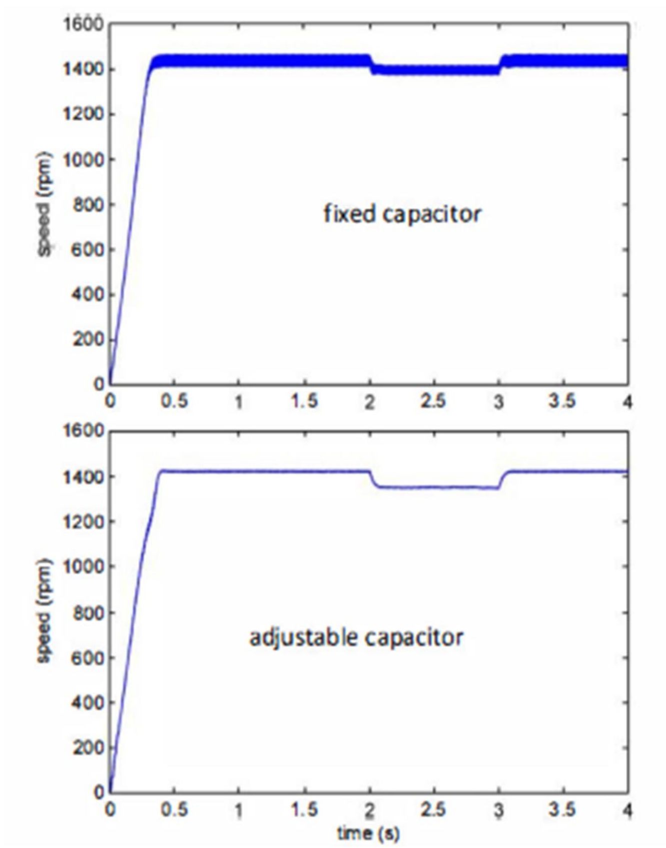

Fig.5. motor speed

IV. ADJUSTABLE CAPACITOR

Consider the circuit shown in "Fig. 5" that is consisted of a fixed capacitor and a parallel bidirectional switch.

Let the period and conducting time of the switch to be T, t_{on}" respectively. Then, the effective capacitance seen from AB is C =C_o [1/(1-D)]

Where D is the duty ratio and is defined as:

D = t_{on} /D

D is in the range of (0-1), thus this structure converts a fixed value capacitor C_o (μF) to a variable one that it can change from C_o (μF) to infinity (theoretical).

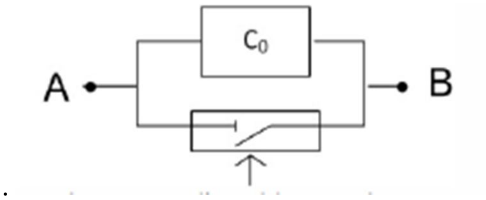

Fig.6 Adjustable capacitor

Note that to reduce switching losses, the switching is done at zero-crossing time of the capacitor voltage.

V. SIMULATIONS

A SIM with the parameters given in table.1 including an adjustable capacitor is simulated in MATLAB/Simulink asshown in "Fig. 6". As the aim of this paper is improving the
efficiency of a SIM equipped with an adjustable capacitor, for
each speed, slip is calculated, the capacitance value for maximum efficiency is selected from "Fig. 5", D is calculated
and finally, at zero-crossing time of the capacitor
voltage, the switch is closed for the time of ton'.

The input supply of the single phase induction motor is given through multilevel inverter. The DC supply is given to the multilevel inverter. The multilevel inverter is represented by two sub-systems which consist of cascaded two H- Bridge inverter. The first H-bridge and second H bridge is connected to each other as shown in figure 6.1 and each subsystem consists of four semiconductor switches, here MOSFET is used as semiconductor switches. By giving PWM control strategy to the multilevel inverter, i.e. triggering signals given to the semiconductor switches. Pulse generator 1 and pulse generator 2 is used for giving the triggering pulses for subsystem1 and subsystem 2 respectively, and produce nine-level inverter output. By this topology the total harmonic distortion is reduced to 18.28% which is displayed in the simulation model diagram.

The inverter output is given to the input of single phase induction motor in which adjustable capacitor is placed in series with it. The adjustable capacitor is nothing but a capacitor and a power switch placed across it and this can be turn on by giving the triggering pulses from the pulse generator. By this technique, the performances of SPIM such as speed, electromagnetic torque and rotor current were obtained and which are improved and total harmonic distortion is reduced to 18.28%.

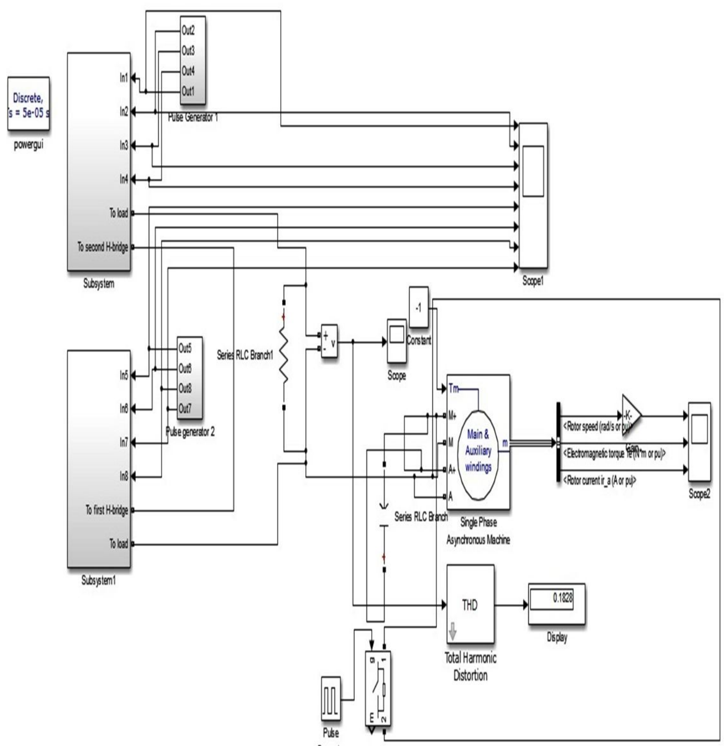

Fig.7 Simulation diagram of proposed system

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VI. SIMULATION WAVEFORM

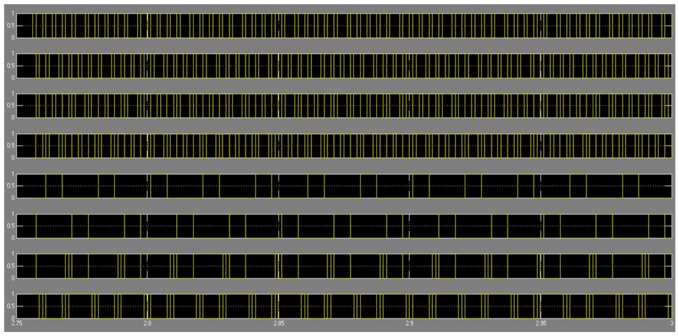

Fig.8 Pulse Generating Signals

The above Fig.8 shows the pulse generating signals that is given to the multilevel inverter semiconductor switches. The x-axis represents the time offset and y-axis represents the logic value of signals i.e either 1 or 0.This signals are given to the eight semiconductor MOSFETS switches in the multilevel inverter, in-order to turn on the semiconductor switches and produce nine level output waveform in the multilevel inverter.

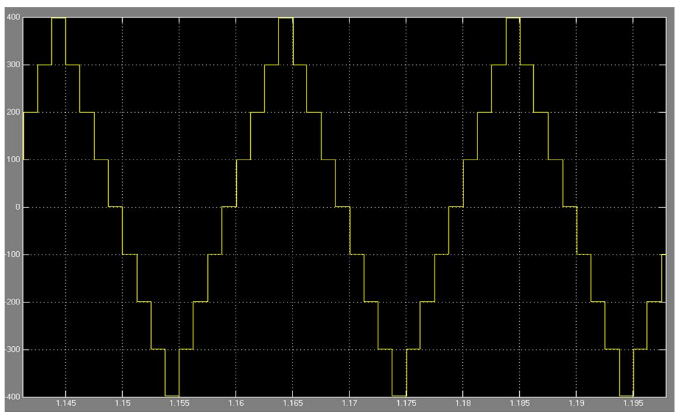

Fig.9Multilevel Inverter Waveform

The Fig.9 shows output waveform of multilevel inverter. The waveform x-axis represents the time offset and y-axis represents the voltage. It is nine-level waveform including zero. The total harmonic distortion is reduced. This nine level inverter output is given to the input of SPIM in which adjustable capacitor placed in series with it and thus THD can be reduced to 18.28% by this multilevel inverter topology.

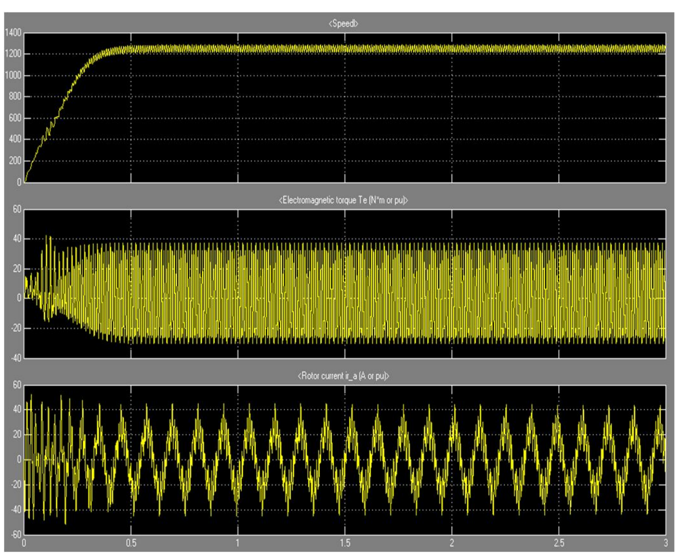

Fig.10 Output Waveform of Proposed System

The above Fig.10 shows the output waveform of the proposed system. The x-axis of the output waveform of simulation represents the time offset and y-axis represents motor performances such as speed, electromagnetic torque and rotor current respectively. Thus the proposed system improves the motor performances by reducing the harmonics level.

VII. RESULTS AND DISCUSSION

Thus compared with the simulation results of existing system and proposed system, the total harmonic distortion of the existing system is 45% and it is reduced to 18.28% in proposed system. And the time taken to reach steady state rotor speed and electromagnetic torque is 0.5sec in existing system and in proposed system it is about 0.3sec. The input supply to the single phase induction motor is given through AC supply in
existing system and in case of proposed system it is through by multilevel inverter, so the THD reduced as compared to the existing system.

Table.1 Complexity comparison of convolution and lifting DWT

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PARAMETERS	EXISTING SYSTEM	PROPOSED SYSTEM
THD	45%	18.28%
Time taken to reach steady state Electromagnetic torque	0.5sec	0.3sec
Time taken to reach steady state Rotor speed	0.5sec	0.3sec
Input supply to the SPIM	AC supply	Multilevel inverter output

VIII. CONCLUSION

A method to achieve good performances of a SIM in specific speed range is introduced in this paper which is on the
basis of using an adjustable capacitor. Effect of capacitor change on the most important performance factors of the motor is investigated. Although the focus of the simulation results was on the maximum efficiency strategy of the motor, the same method can be used to improve other performance factors of the motor.

Thus compared with the simulation results of existing system and proposed system, the total harmonic distortion of the existing system is 45% and it is reduced to 18.28% in proposed system. And the time taken to reach steady state rotor speed and electromagnetic torque is 0.5sec in existing system and in proposed system it is about 0.3sec. The input supply to the single phase induction motor is given through AC supply in existing system and in case of proposed system it is through by multilevel inverter, so the THD reduced as compared to the existing system.

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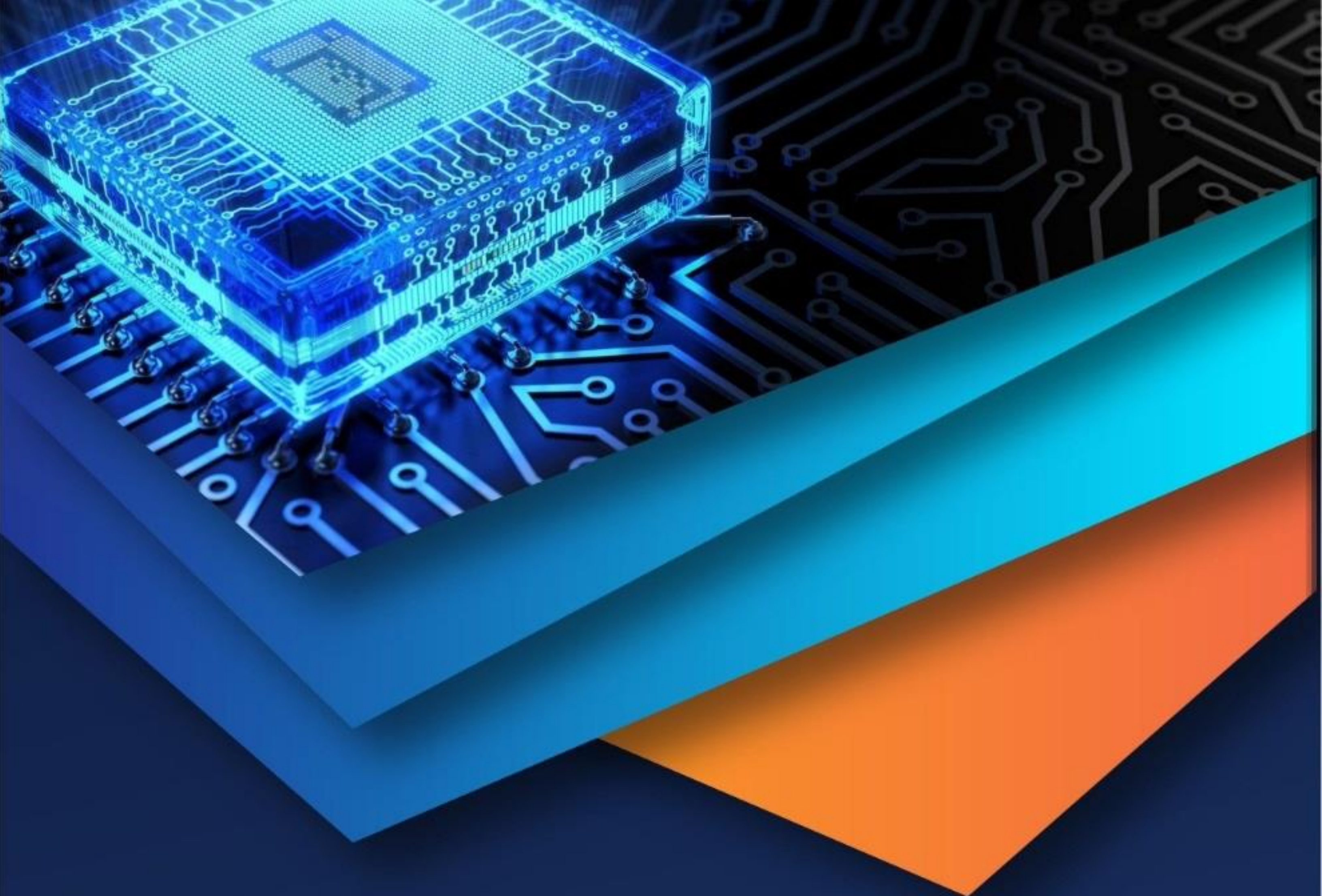

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