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Modelling & Simulation of Numerical MHO Relay for Distance Protection

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Abstract: The proposed work is about designing of numerical mho relay in MATLAB / SIMULINK to be used for distance protection schemes of long distance transmission lines with better result and characteristics. The required mho relay algorithm is evaluated by using MATLAB to model the power system under different fault condition and simulate it by using phasor based method available in MATLAB simulation. Comparison of numerical mho relay is done with model of Impedance relay in terms of performance, time required for clearing. Modelling of the numerical relay is important as it allows the users to test the internal performance of relays during normal as well as abnormal condition. Thus the modelling and simulation of numerical mho relay gives the improved result and greatly enhance the performance of mho relay.
Keywords: Distance protection, Mho characteristic, Impedance relays, Numerical relays,Matlab/Simulink

I. INTRODUCTION

Electric power systems are made up of facilities and equipment that generate, transmit and distribute electrical energy with the purpose to provide energy for human in a secure, reliable and economic manner. To maintain sustainability of power systems against faults that normally occur in the power systems, an additional protection system that is able to take corrective actions against such faults have to be applied. This system consists of transformer, relays and circuit breakers. The purpose of the protection system is to disconnect the faulted element in the power system and re-establish its services.

Distance protection system is used in most countries of the world for the protection of high voltage transmission line due to their simple operating principal and capability to work independently under most circumstances. Transmission lines are typically protected by distance protection .the use of distance relays has found to be the most feasible and effective as compared to other type of protection. Distance relays are considered of the high speed class and can provide protection.

Numerical relay models can be divided into two categories. First, the "Phasor-based models", in which only the fundamental frequency component of voltages and currents are used and were the first to be widely used by industry and academics to design relays and check their performance. The second category models, "Transient relay model", take into consideration the high frequency and decaying DC component of voltages and currents, in addition to the fundamental frequency components; this type is rarely used as it needs sophisticated filters in order to remove the DC and high frequency components.

The proposed work presents the phasor based approach to design the numerical mho relay for distance protection. The relay is modelled by using MATLAB to model the power system and simulates it for different fault conditions or incidents. Impedance relay is also modelled by using MATLAB for different fault conditions. Sample results of these studies give the comparison between the relays in detection and tripping time

II. LITERATURE SURVEY

Authors suggested the new positive sequence direction element to use in numerical distance relay, which is based on the incremental positive sequence signals, has been implemented on a numerical distance relay. They performed the experiment of numerical distance relay with positive sequence direction element on Manitoba hydro network and get the successful result on numerical relay[1].

The research work shows the use of relay in past time and in coming time, on that basis to developed software model of relay various models required data is checked which helps to develop such model of relay. The software model performance is checked against the performance of actual relay. Software model can be used iff required assumptions are made [2].Authors suggest the protection scheme based on wavelet transform. This detects the descrete frequency band which contains transient fault current wave. This detected signal is being checked by the mother wavelet and check if the fault is internal or external. This approach gives good selectivity and sensitivity. It is reliable and feasible to the time[3].

The diverse units used in any discipline of protective relaying determine whether the system is normal or abnormal. A comparator will give the relay system an output when the conditions for operation are satisfied. Since phasors are expressed in magnitude and phase, there are two types of comparators: phase and magnitude[4].

Here Author suggested a new technique of impedance's trajectory after faults represents numerical output of the impedance calculation. The output results show the behavior of the developed model under various fault locations and at different arc resistances. The simulation study presented shows assist in demonstrating the importance of and need for accurate dynamic modeling of distance protection relays[5,6].

The authors describe comparison of two different methods for phasor estimation of numerical relaying. The protective relays based on different protection principals require that the phasor of current and voltage can be extracted .Here authors take Wavelet Transform and Fourier Transform methods for comparison [7].

The operating characteristics of distance relays can be obtained by either amplitude comparison or phase comparison of the sets of vectors derived from the current and voltage signals of the protected line. Phase comparison is more widely implemented in modern relays[8].Here authors' presents a simulink model is designed for the distance zone protection scheme. Logic circuit for relay operation is developed from the observed impedance waveforms. From this model it is concluded that the zone at which the fault occurs can be identified[9].

This research presented a detailed phasor model for a distance relay of mho characteristics. Mho relays are inherently directional so there is no need for directional elements in the relay model. Simulation results of different faults regarding type and position show clearly the accurate performance of the developed distance relay model[10].

III.BASIC OF DISTANCE PROTECTION RELAYS

Line impedance by measuring voltages and currents can be calculated by distance relay on one single end. The relays compare the setting impedance with the measured impedance to determine if the fault is inside or outside the protected zone. They immediately release a trip signal when the impedance value is inside the zone 1 impedance circle of distance relay. For security protection consideration, the confirmation of a fault occurrence will not be made until successive trip signals are released in one zone

Table I.Apperent Impedance for Multiphase Faults

Appearent inpadances	Type of fault which is suitable
$\frac{Va-Vb}{Ia-Ib}=\frac{V1-V2}{I1-I2}=Z1\ ab$	a-b ungrounded a-b grounded 3-phase ungrounded 3-phase grounded
$\frac{Vb-Vc}{Ib-Ic}=\frac{V1-V2}{I1-I2}=Z1\ bc$	b-c ungrounded b-c grounded 3-phase ungrounded 3-phase grounded
$\frac{Vc-Va}{Ic-Ia}=\frac{V1-V2}{I1-I2}=Z1\ ca$	c-a ungrounded c-a grounded 3-phase ungrounded 3-phase grounded

Table II. Apparent Impedance for pPhase to Ground Fault

Apparent imadances	Type of fault which is suitable
$\frac{Va}{Ia+mI0} - Z1\,a$	a to ground
$\frac{Vb}{Ib+mI0} = Z1\,b$	b to ground
$\frac{Vc}{Ic+mI0} - Z1\,c$	C to ground

Fault impedance due to different types of faults can be calculate by different formulaes .The table below shows formula for different faults. Table (a) & (b) provides the set of equations or algorithm which is required to calculate the positive sequence impedance measured between distance relay location and the fault point for different fault types. Symbol (m) in Table (b)is the compensation factor , and given by, (m = $(Z0 - Z1)\,Z1/$). Z1 and Z0 are the line positive and zero sequence impedances respectively. The Ia, b, c are the phase currents, the Va, b, c are the line to neutral phase voltages, and the a, b, c are the phase designation in a 3-phase system.

A general distance relay characteristic is derived by a two-input comparator of vectors S1 and S2 given by equations (1 and 2).

$$S_1 = I_r Z_r - K_1 \; Vr \quad (1)$$

$$S_2 = K_2 V_r + K_3 \; I_r Z_r + K_4 V_{pol} \quad (2)$$

Where, S1, and S2are the relay comparator input signals; Zr is the relay reach impedance, and the K1,2,3,4 are complex constants define the relay characteristics.The parameters Vr and Ir are the appropriate loop voltages and currents resemble those given in Table (a) and Table (b). Examples are listed below:

Vr = Va –Vb For the A-B element; Ir = Ia –Ib For the A-B element; and/or Vr = Va For the A-Ground element; Ir = Ia +m I_0 For the A-Ground element;

The angular displacement of vectors S1 and S2 is considered positive if S1 leads S2. The phase comparator operates if the following condition is satisfied :-

$$-90^0 \leq \angle S_1 - \angle S_2 \leq 90^0 \quad (3)$$

$$|\angle S_1 - \angle S_2| \leq 90^0 \quad (4)$$

By using such approach the distance mho relay characteristics can be developed which is shown in figure below.In numerical reays we can design operating characteristics of almost any shape by changing the values of the 'K' parameters in the comparator inputs..

A. Self-Polarized MHO Relay Characteristics

The mho relay characteristics are defined as circles in the impedance plane which passes through the origin. This characteristic is obtained by setting: $K_1 = K_2 = 1$, and $K_3 = K_4 = 0$. Hence equations (1) and (2) become can be write as:

$$S_1 = Ir\, Z_r - Vr \quad (5)$$

$$S_2 = Vr \quad (6)$$

To represent the mho relay characteristics, it is necessary to implement the voltage phasors S1 and S2 in the impedance plane

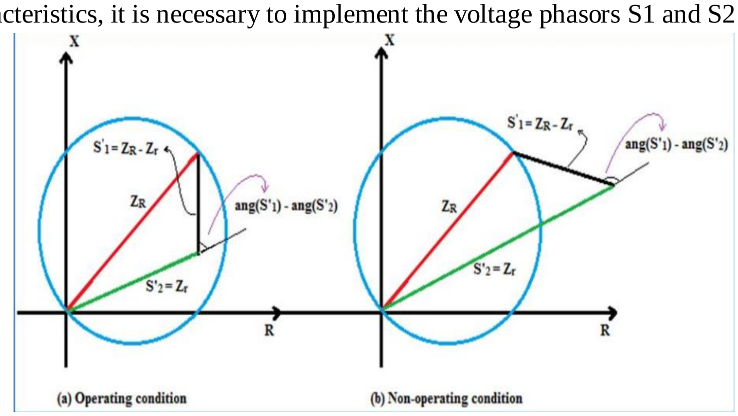

Figure. 1 Definition of Mho Characteristics Phase Ccompartor

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From above figure It can be seen that with Zr measured inside of the characteristic circle, the angular difference between S'1 and S'2 will be less than 90 degrees, which fulfils the operating condition. Figure1b demonstrates an example of the mho relay with the operating conditions not met.

IV. MODELING TRANSMISSION LINE AND DISTANCE RELAY

Here phasor based estimation algorithm is used to model the relay with the help of MATLAB simulink. The estimated phasors of voltages and currents are used in the implementation of protection algorithms in numerical relays. The ratio of appropriate voltages and currents then provide the impedance to the fault. The performance of all of these algorithms is dependent on obtaining accurate estimate of the fundamental frequency component of a signal from a few samples..

The numerical MHO relay model is based on apparent impedance equations given in above table(a) & (b) with phase comparator inputs given by equation (5) &(6) for mho characteristics.The inputs for phasor based model are fundamental frequency components.The structure of phase and ground relay model of 3-zone is developed by using. MATLAB/SIMULINK.The model of numerical mho relay made up of a)phase element model and b)ground element model.

A. Matlab Modeling & Simulation

A phasor based distance relay is designed by taking 400 kv voltge as base value. A distributed transmission line of total length 350 km as 100km+150km+100km is taken. Phasor based relay software models consist of a set of phasor equations into which phasor quantities of current or voltage are substituted to solve for the relay response.

The impedance relay model is designed shown in below figure(2) by using phasor based method, and figure (3) shows the phasor based model of numerial mho relay. The results or output of both the relays give time required comparatively to operate.

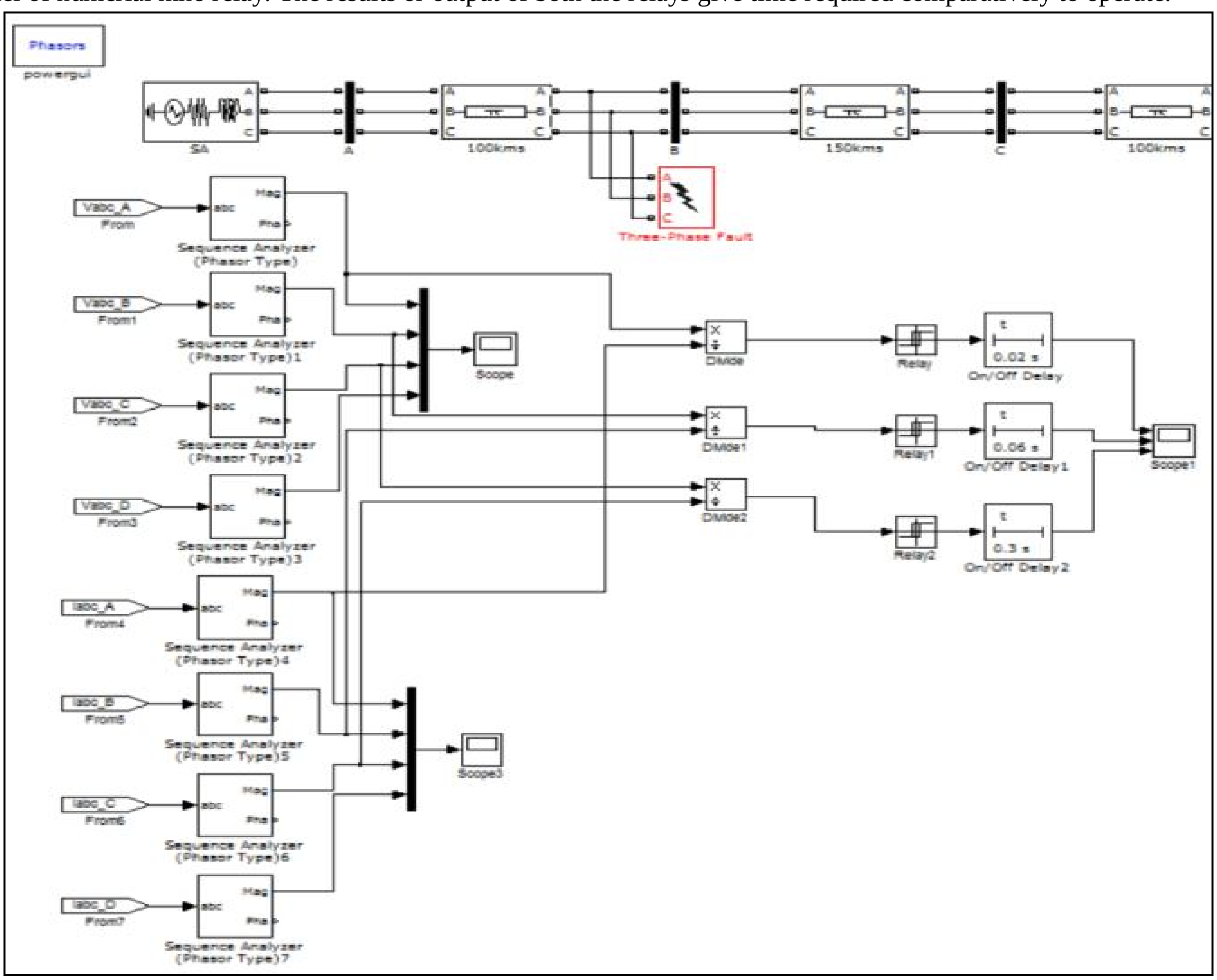

Figure.2. Phasor Based Impedance Relay

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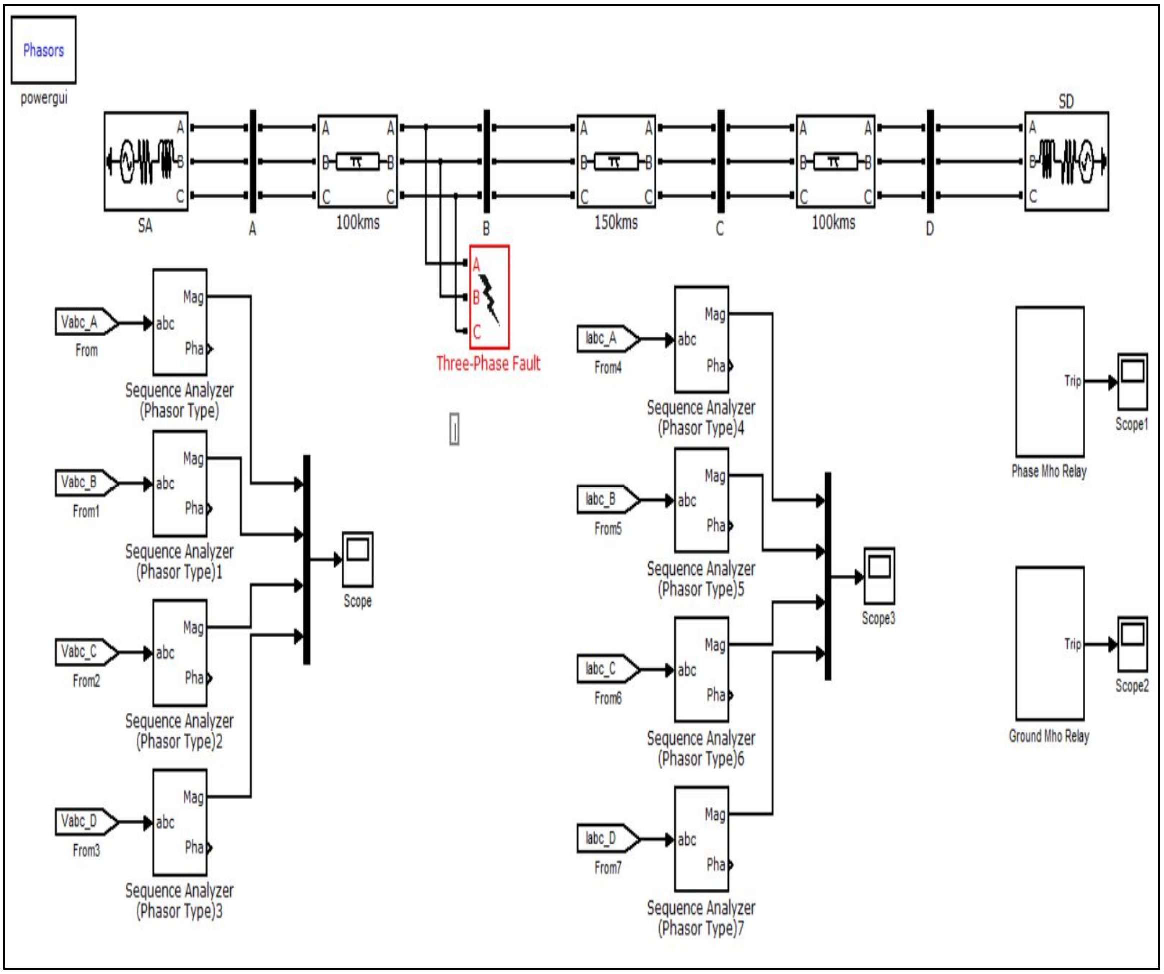

Figure.3. Phasor Base Numerical Mho Relay

B. Test System Parameters and Calculations

A four bus EHV transmission system is considered for testing the developed distance relay model. The system shown in figure 5 resembles part of a 400kV, 50Hz, 350km length transmission system. The line parameters are:

Z1=Z2=0.034+j0.315 Ω/km , Z0=0.299+j0.975 Ω/km

The source end characteristics considered here are;

SA, short circuit level = 7892 MVA, |VA| = 1.0 p.u

SD, short circuit level = 7892 MVA, |VD| = 0.97 p.u

The loading state considered is that to produce 20° load angle lead for V̅Aover V̅D.

The mho characteristic distance relay located at bus A has the following zone settings:

1) Zone1 reach =80% of line L1 Zone1 reaches = 0.8 * 100 * (0.034+j0.315) = 25.34∠83.83° Ω This zone has no intentional time delay. Practically it needs very short time for the equipment's to respond; therefore its operation is set to 2ms.
2) Zone2 reach =line L1+ 50% line L2 Zone2 reach = (0.034+j0.315) (175) = 55.445∠83.83° Ω This zone time delay is set to 0.3s.
3) Zone3 reach = (line1 + line2) * 120% Zone3 reach = (0.034+j0.315) (250) * 1.2= 95.048∠83.83° Ω this zone time delay is set to 0.6s.
4) Compensation factor = m = Z0−Z1 Z1 = 2.24∠-15.622° The number and direction of zones and the setting for the zone reach and time delay can be changed as desired.

C. Simulation Result and Comparison

With the distance relay located at bus A, several fault scenarios can be staged to get and quantify the relay model response. That is to show the model ability to detect the fault and respond according to the fault location and for the different fault types.

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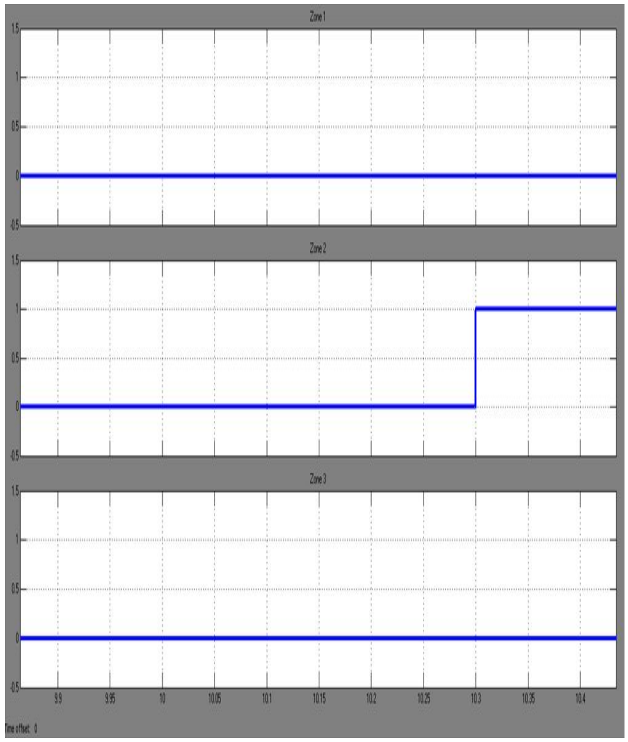

Figure4..Zone Protection of Mho Relay

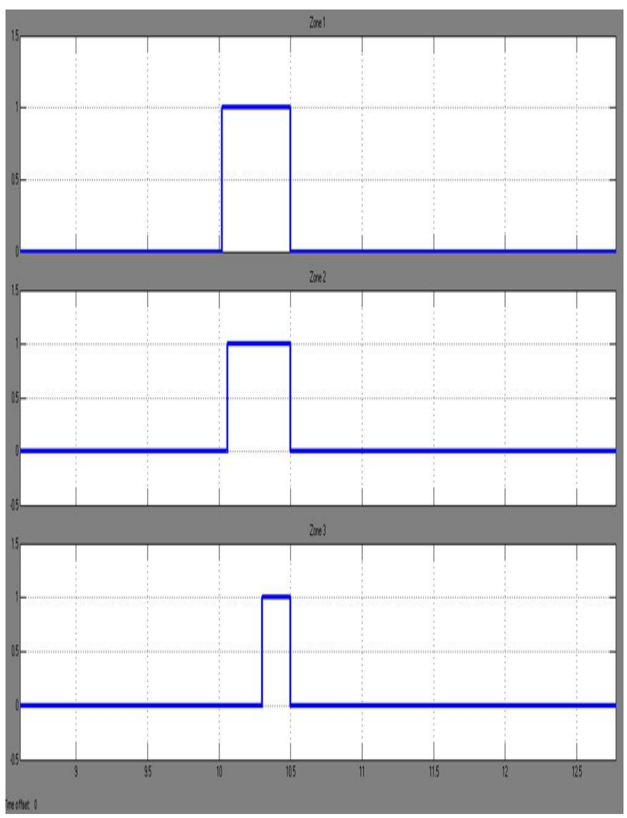

Figure.5. Zone Protection of Impedance Relay

The above figure shows the trip output of impedance relays for line to line fault.

D. Comparison between Phasor based Impedance and Numerical MHO Relay

Table III. Comparison of Results o Impedance relay &Numerical Mho Relay

Criterion	Phasor Based Impedance Relay	Phasor Based Mho Relay
Speed of Operation	Not as Fast (0.8 sec – 0.6 sec)	Very Fast
Speed with in service testing	Slower	As Fast
Suitable for Auto Reclose	Yes	Yes
Loss of Communication	Poor	Good
Current Reversal	Special Features Required	Yes possible with less computation
Length of Operation	Medium Transmission Line	Long Transmission Line

V. CONCLUSIONS

This work presents a detailed phasor model for a distance relay of mho characteristics. Mho relays are inherently directional so there is no need for directional elements in the relay model. Here the developed simulation is evaluated for line to line fault on the system, and the results found as

A. Simulation results of different faults regarding type and position show clearly the accurate performance of the developed distance relay model in figure (2, 3).

B. From results in figure (4, 5) it is seen that speed of operation of numerical mho relay is faster than impedance relay.

The model versatility, adaptability and applicability promote it for use in power system simulators. Also, it can be used as a training tool to help users understand how a distance relay works and how settings are performed.

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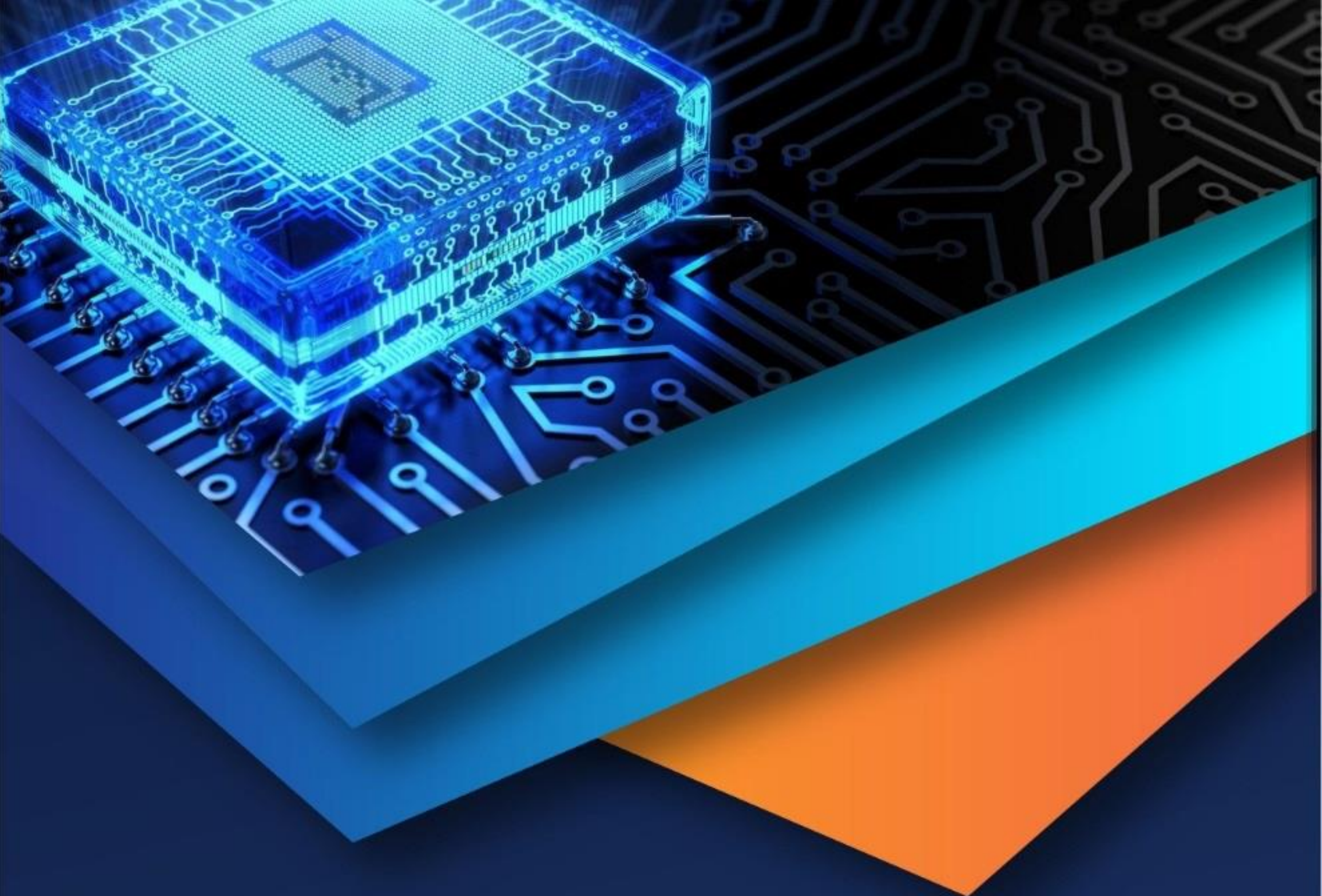

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