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Design of STATCOM for Power System Stability Improvement

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Abstract--* This paper presents the model of a STATCOM which is controlled externally by a newly designed Power Oscillation Controller (POC) for the improvements of power system stability and damping effect of an on line power system. The proposed POC consists of two controllers (PID & POD). PID parameters has been optimized by Ziegler Neches close loop tuning method. Both single phase and three phase faults has been considered in the research. In this paper, a power system network is considered which is simulated in the phase simulation method & the network is simulated in three steps; without STATCOM, With STATCOM but no externally controlled, STATCOM with Power Oscillation Controller (POC). Simulation result shows that without STATCOM, the system parameters becomes unstable during faults. It is the era of Digital World and this is possible only by the extensive use of electronic and power electronic devices. At the present time maximum electrical loads are nonlinear in nature. So they are very good for the use of human being but harmful to the "Power Quality". Power should be in the prescribed limitation (International Standards) but because of nonlinear loads power is not bound in limitations and distorted. So Harmonics are Present and need to be mitigating to improve the performance of the loads. Both voltage and current harmonics are distorted but current harmonics are very common and give adverse effect on economical utilities of customers so that to mitigate shunt active power filter is used.

Keywords: STATCOM, voltage regulator, power system controller, PID, POD, power oscillation, Controller (POC), PI Controller, MATLAB Simulink.

I. INTRODUCTION

The large scale use of Power electronics and electronics devices in electrical drives, traction system, converters and inverters Etc. [1]. These devices Provide smooth and controlled power supply to the load but draw harmonics and reactive power unbalance from the AC mains. Harmonics are like pollutants in the electrical supply system. In the 3 phase system it will draw large neutral current because of unbalancing. This will Result Poor power quality, reactive power burden and large neutral current. Extensive Survey happened to appraise the problems associated with the nonlinear loads [2]. Traditionally, fixed or mechanically switched shunt and series capacitors, reactors and synchronous generators were being used to enhance same types of stability augmentation [3]. An STATCOM can be controlled externally by using properly designed different types of controllers which can improve voltage stability of a large scale power system. In previous study Authors has designed a PID controller which has tuned by Triple Integral Differential (TID) tuning method [4]. However, in this study, With a view to get better performance, a new Power Oscillation Controller (POC) has been designed & proposed for STATCOM to inject Vqref externally for the improvement of power system stability. Therefore, thermistor based STATCOM with POC controllers has been used to improve the performance of power system [5].

II. CONTROL CONCEPT OF STATCOM

A static synchronous compensator (STATCOM), also known as a "static synchronous condenser" ("STATCON"), is a regulating device used on alternating current electricity transmission networks. It is based on a power electronics voltage-source converter and can act as either a source or sink of reactive AC power to an electricity network. If connected to a source of power it can also provide active AC power. It is a member of the FACTS family of devices. Usually a STATCOM is installed to support electricity networks that have a poor power factor and often poor voltage regulation. A STATCOM is a voltage source converter (VSC)-based device, with the voltage source behind a reactor. The voltage source is created from a DC capacitor and therefore a STATCOM has very little active power capability. However, its active power capability can be increased if a suitable energy storage device is connected across the DC capacitor. The reactive power at the terminals of the STATCOM depends on the amplitude of the voltage source.

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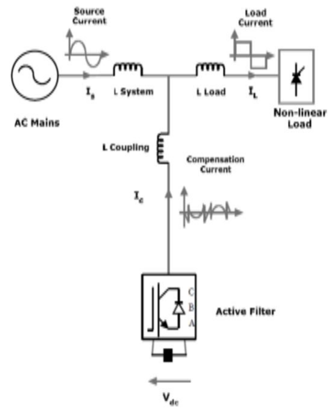

Fig 1 Shunt Active Power filter

A. Need of DC Link Capacitor

When load is changing rapidly the real Power flowing in the circuit is distorted and need to be settle down. The DC link voltage maintains the balance of active power flow through the system when active power balancing is equal to the internal losses of the Filter. So that DC link voltage maintain constant at a desired value.

DC side capacitor serves for two purposes in the shunt active power filter:

It maintains a DC voltage with small ripple in steady state.

It is working as an energy storage element to supply real power demand of the source plus a small power to compensate the losses inside the filter.

III. SIMULATION RESULTS

The load flow solution of the above system is calculated and the simulation results are shown below. Two types of faults: A. single line to ground fault & B. Three phase fault have been considered.

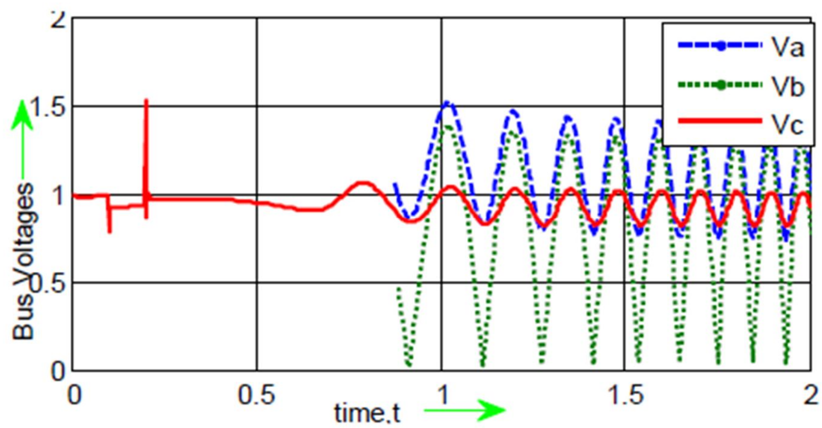

Fig .2 Bus Voltage For 1-Phase Fault (Without STATCOM)

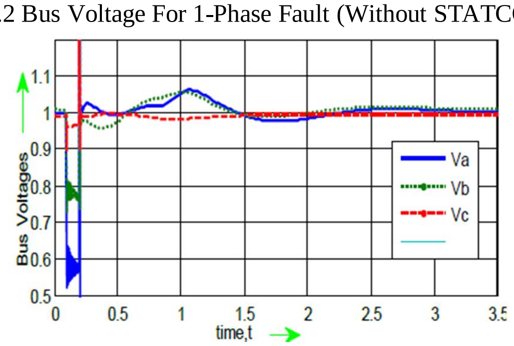

Fig.3 Bus Voltage In P.U For 1-Phase Fault(With STATCOM)

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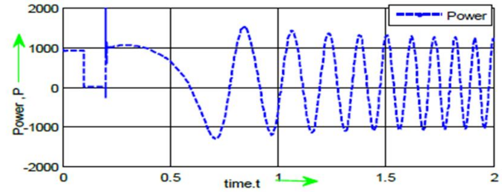

Fig.4 Bus Power In Mw During Fault(Without STATCOM)

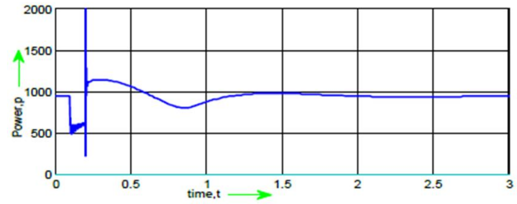

Fig.5 Bus Power(P)In Mw For Fault(With STATCOM)

A. Control Schemes

There is the review of two control strategies for reference current generation for Shunt active power filters i.e. PWM inverter named are:

Indirect current control technique with PI controller

Indirect current control technique with Fuzzy controller

PQ theory with PI controller

PQ theory with Fuzzy logic controller

IV. DESIGN OF POWER OSCILLATION CONTROLLER (POC)

The proposed Power Oscillation controller Consists of two parts, A) Proportional Integral Derivative (PID) controller which is tuned by Zieglar-Nicles method [4] & Power Oscillation Damping (POD) controller. PID Controller takes input as machines angular speed Deviation & get an error signal & POD controller takes Input as line voltage & line current & after damp out the oscillation it also gives as error signal. Finally, the proposed power oscillation controller takes input as all parameters of power system network i.e. Vabc, Iabc, dω & it gives an error signal (Vqref) which injects STATCOM for improvement of power system stability. The proposed Power Osci llation Controller consists of both two controllers (PID & POD) which injects Vqref in STATCOM further improve the power system stability.

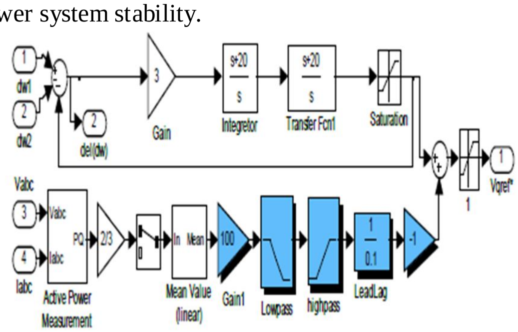

Fig.6 Internal Structure Of Power Oscillation Controller(Poc)

A. Designed Of PID Controller

The process of selecting the controller Parameters to meet given performance specifications is called PID tuning. Most PID controllers are adjusted onsite, many different types of tuning rules have been proposed in the literature [4]. Using those tuning rules, delicate & fine tuning of PID controllers can be made onsite. Also automatic tuning methods have been developed and some of the PID controllers may possess on-line automatic tuning capabilities [4]. The PID controller has three term control signal [4], (1) In Laplace Form, (2) Block diagram of PID controller parameters for selecting the proper controller parameters, Ziegler-Nichols PID Tuning [4], Second Method is described below. In the 2^{nd} method, the parameter is selected as Ti=∞, Td=0. Using the proportional controller action only increase Kip from 0 to a critical value Ker. At which the output first exhibits sustained oscillations.

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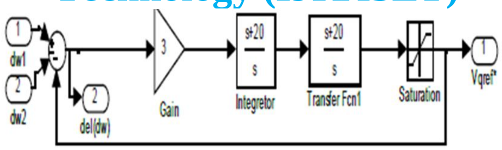

Fig.7 Internal Structure Of Pid Controller

B. Designed Of POD Controller

The Power Oscillation Damping Controller takes input as Vabc, Iabc & it convert it as power. If no faults has occurred then switch remains open. But when fault occurred then switch becomes closed & after filtering or dampout oscillation, it also gives an error signal & finally two error signal has been added & this is Vqref.

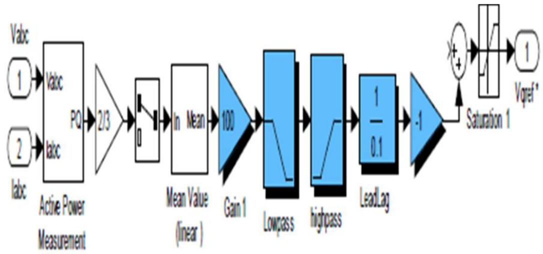

Fig.8 Internal Structure Of Pod Controller

V. INDIRECT CURRENT CONTROL TECHNIQUE WITH PI CONTROLLER

In this Technique the active power filter is implemented with a four quadrant current Controlled PWN converter in between Source and load parallel. By doing this Type of circuit arrangement converter begins to behave like SAPF without losing its characteristics as a four quadrant converter. This current controlled converter does not sense the current at the load side it is only maintain it sinusoidal. So that there is no need to sense the nonlinear load current and filter current. [4]

We are only taking source current and then calculate the Reference source current by using PI controller. The Input to the PI controller are difference of the voltage of DC link capacitor and reference voltage. After then it will generate the reference source current and then given to the hysteresis band controller. After then with the source current it will generate the Gate pulses for positive leg and negative leg of the converter so as to control and generate the compensating current to cancel out the harmonics.

Fig.9 Indirect Current Control Technique With Pi Controller

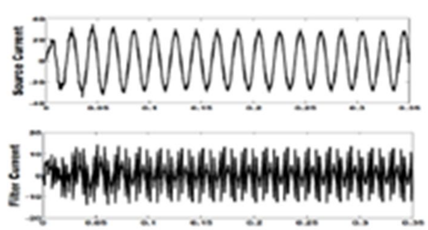

Fig.9 a) Source and Filter Current after compensation using indirect current control with PI controller

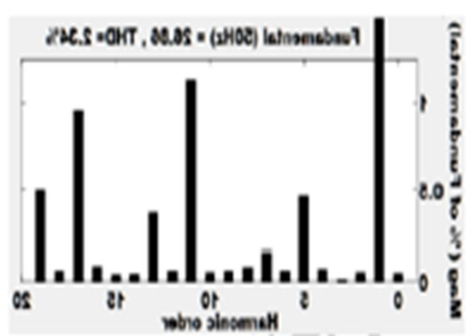

Fig.9 b) Harmonics after compensation using indirect current control with PI controller

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VI. SIMULATION RESULTS WITH POC

The network remains same just simple STATCOM is replaced by power system controlled STATCOM. During fault, machines speed deviation (dω) & Line voltage (Vabc), Line current (Iabc) are always monitored by power system controller & taking input of those oscillation, after processing as shown in it reduces damping of power system oscillation & helps STATCOM to improve stability. Two types of faults has been considered: A. Single line to ground fault and B. Three phase fault. a) Single line to ground fault during 1-phase faults, if POC is used as STATCOM controller then, the system voltage becomes stable within 0..25s with 0% damping & Power (P, Q) becomes stable within 0.25s.

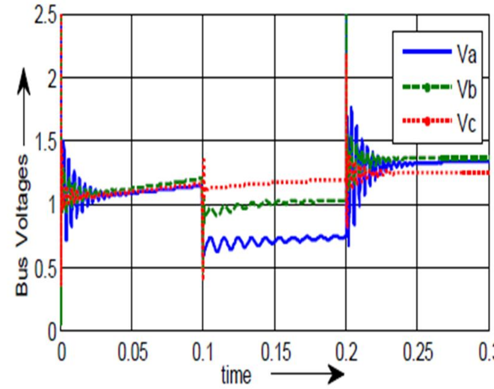

Fig.10 Bus Voltage In P.U For 1-Phase Fault(With Poc)

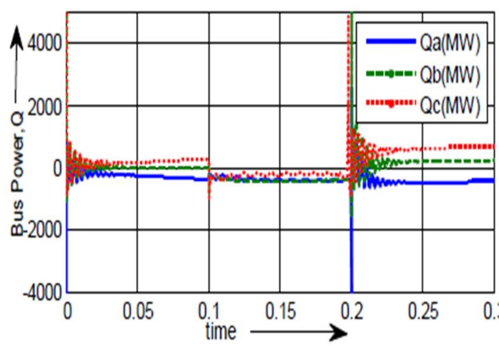

Fig.11 Bus Power Q For 1-Phase Fault,Mw(With Poc)

A. Three Phase Fault

During 3-phase faults, If POC is used as STATCOM controller then, the system voltage becomes stable within 0.25s & Both power, P becomes stable within 0.25s.

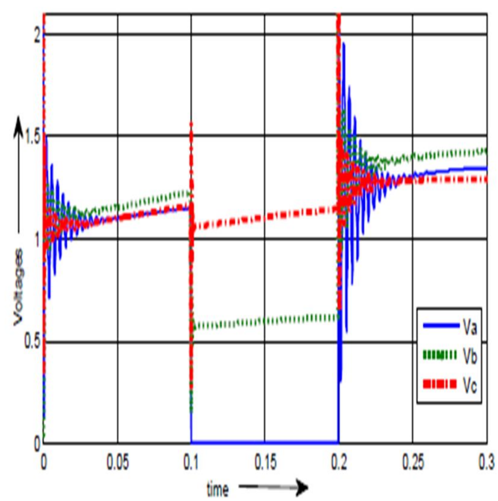

Fig.12 Bus Voltage In P.U For L-L Fault(With Poc)

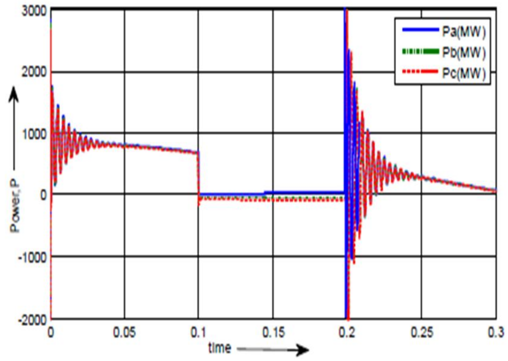

Fig.13Bus Power P In Mw For L-L Fault(With Poc)

VII. PQ THEORY WITH PI CONTROLLER

A. The PQ Theory

In the Year 1983 Akagi had proposed a new control scheme " The generalized theory of the instantaneous reactive power in the three phase circuits.[5] This theory is known as " PQ theory". It is based on the instantaneous values of the current and voltage of the power system. It is valid for Steady state as well as transient condition. The PQ theory consists of the Clark transformation of voltage and current in the a-b-c to the α-β-o coordinates.

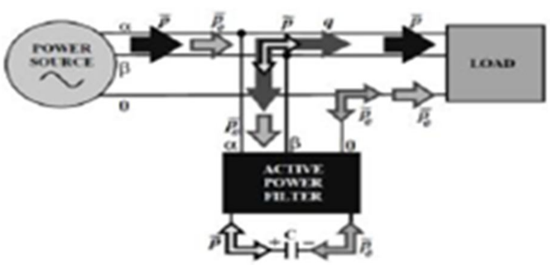

Fig.14 Basic Circuit For Sapf For Pq Theory

The Clark transformation of Voltage is,

$$\begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$

The Clark transformation of Current is,

$$\begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

This theory is applied to the shunt active power filter for the generation of reference current. Mean value of active power and zero sequence power are transferred from supply to the load and other quantity are compensated form SAPF. Even at the time of load unbalance the mean value of active power sometimes compensated. The main component is reactive power which is undesired. All the undesired power components are compensated through the SAPF. For the balanced system the source current is in phase with the source voltage. So that power supply think that load is purely resistive symmetrical. Since all the resistive power should be compensated. So the reference current generation for the zero sequence is .iq,

$$\begin{bmatrix} i_{ca} \\ i_{cb} \\ i_{cc} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1 & 0 \\ 1/\sqrt{2} & -1/2 & \sqrt{3}/2 \\ 1/\sqrt{2} & -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_{c0} \\ i_{c\alpha} \\ i_{c\beta} \end{bmatrix}$$

This is the reference current for the PWM converter.

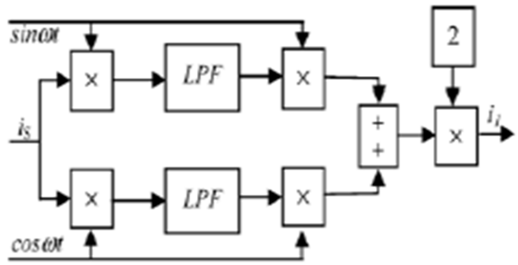

Fig.15 Calculation Of Fundamental Component

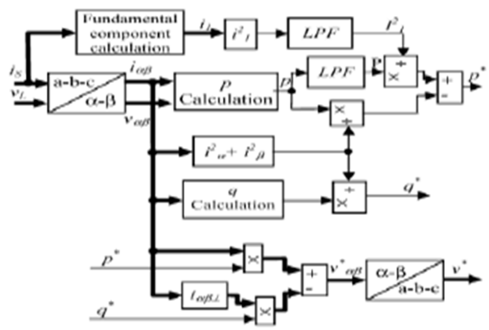

Fig.16 Control Scheme

VIII. RESULTS & CONCLUSION

The performance of the proposed Power Oscillation Controller with STATCOM has been summarized in the table-I. In table-I, α (infinite time) means the system is unstable, STATCOM rating in MVA. The network is simulated in three steps; without STATCOM, With STATCOM only, STATCOM with proposed Power Oscillation Controller (POC) & Excitation controller. This paper is very useful to understand the power quality improvement using Shunt Active Power Filter. Here we are discussed the control techniques and their implementation using their block diagram and study about the procedure and simulation results. Reactive power theory is also better than indirect control scheme because it is compensated the reactive power and as well as eliminate harmonics. So these theories bring down the THD of source current that is in compliance with IEEE 519 and IEC 61000-3 required harmonics standards.

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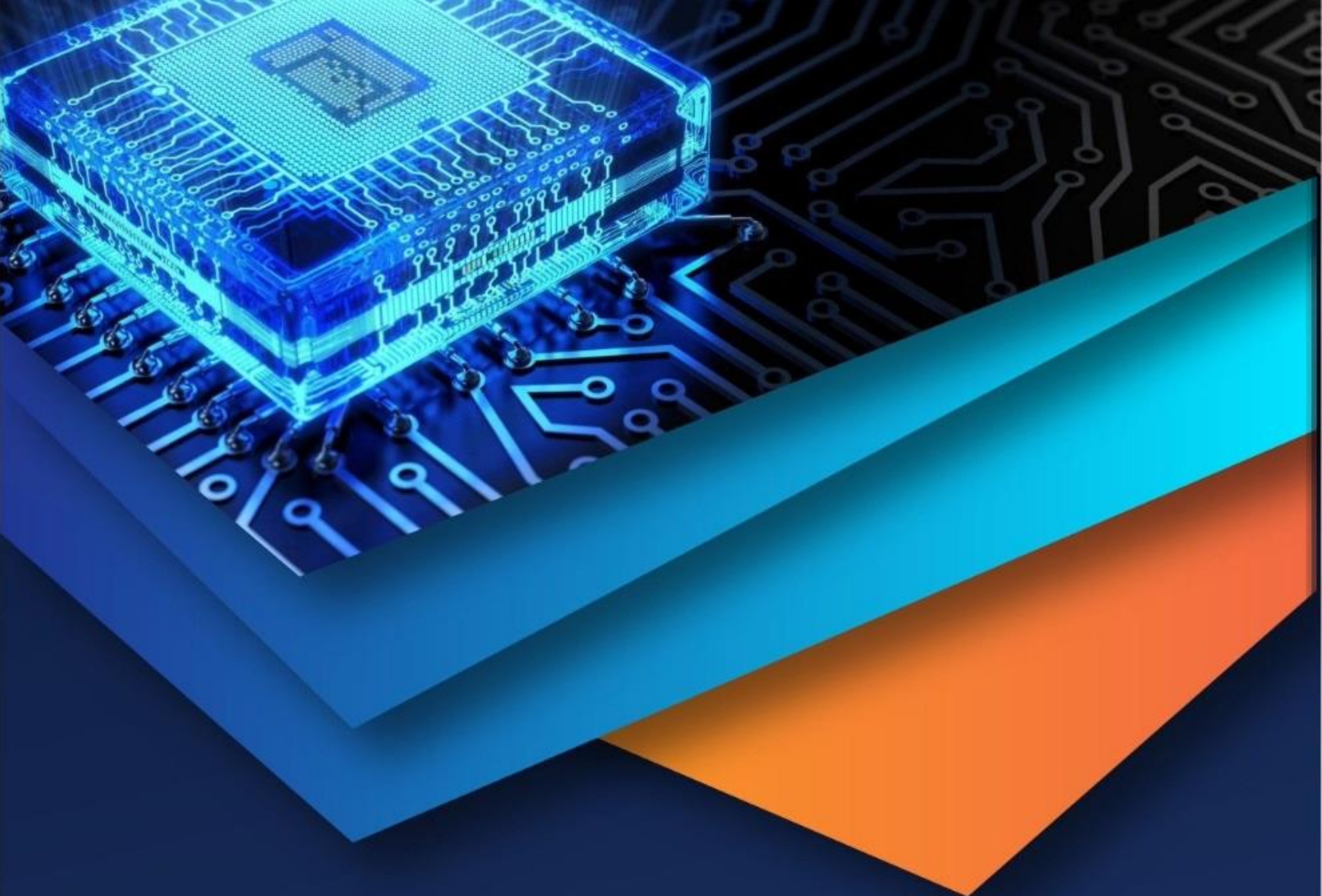

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