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Static Synchronous Series Compensator and Fuzzy Logic based Power Flow Control and Stability Improvement in Photovoltaic Power Plant Infinite-Bus System

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***Abstract*: This paper presents the stability improvement and power-flow control results of photovoltaic Power Plant using a static synchronous series compensator (SSSC). Photovoltaic System (PV system) intended for the supply of trade power into the electricity grid. They are discerned from most building-mounted and other decentralized solar power applications because they supply power at the utility level, rather than to a local user or users. An Oscillation Damping Controller (ODC) of the proposed SSSC for using stability control. A frequency-domain approach based on a linearized system using eigen value analysis is accomplished. A time-domain scheme based on a nonlinear system model subject to a disturbance is also performed.**
***Keywords*: SSSC, PV System, ODC, Linearized System**

I. INTRODUCTION

The design, modelling and control design of a 48-step inverter based static synchronous series compensator (SSSC) is presented and a magnetic circuit is chosen which contains eighteen single-phase three winding transformers and six single-phase two winding transformers to add the output voltages of eight three-phase inverters. An equivalent circuit model of the SSSC is derived and based on this model a proportional-plus-integral controller is proposed. The controller gains are chosen through eigen value analysis of the IEEE first benchmark model for subsynchronous resonance (SSR) analysis. The SSSC model, its control and the results of the eigen value analysis are then legalised through PSCAD/EMTDC simulation. It is shown that for certain controller gains torque amplification of the shaft modes can occur [1].

A review with a concise report and analysis of the fundamentals, characteristics, analytical details, merits, and problems associated with existing methods in frequency and time domain for harmonic analysis in practical power networks. The explanation and analysis are centred on methods industrialized in the harmonic domain, hybrid frequency-time domain, and time domain, respectively [16]. A bridged dynamic equivalent model of WFs based on the spanning tree (ST) is proposed. First, the clustering method grounded on the growing ST is first applied to the dynamic equivalent of WFs. Second, according to the mathematical model of doubly fed induction generator (DFIG)and the Permanent Magnetic Synchronous Generator (PMSG), clustering variables of DFIG and PMSG are classified into internal variables and external variables, reflecting the dynamic characteristics of WTs [8].

The various characteristics of unified power flow controller (UPFC) control modes and settings and evaluates their impacts on the power system reliability. UPFC is the most versatile flexible ac transmission system device ever applied to recover the power system operation and delivery. It can control various power system parameters, such as bus voltages and line flows. The impression of UPFC control modes and settings on the power system reliability has not been addressed sufficiently yet. A power injection model is cast off to represent UPFC and a inclusive method is proposed to select the optimal UPFC control mode and settings [5].

A new control method for a unified power flow controller (UPFC) for power system oscillation damping. This control is simple to gadget, yet is valid over a wide range of operating conditions. It is also effective in the presence of multiple modes of oscillation. The proposed control is implemented in some test systems and is compared against a traditional PI control [4].The philosophy and the modelling technique of a flexible alternating current transmission systems (FACTS) device, namely, static synchronous series compensator (SSSC) using an Electromagnetic Transient Program (EMTP) simulation package. The SSSC, a solid-state voltage source inverter attached with a transformer, is connected in series with a transmission line. An SSSC injects an almost sinusoidal voltage, of variable magnitude, in series with a transmission line. This injected voltage is almost in quadrature with the line current, thereby emulating an inductive or a capacitive reactance in series with the transmission line. The emulated variable reactance, inserted by the injected voltage source, inspirations the electric power flow in the transmission line [19].

II. METHODOLOGY

A. PV system using SSSC

In the Existing system presents the stability improvement and power-flow control results of a DFIG-based offshore wind farm (OWF) connected to a one-machine infinite-bus (OMIB) system using a static synchronous series compensator (SSSC). An oscillation damping controller (ODC) of the proposed SSSC is designed by using modal control theory to render proper damping to the dominant mode of the studied synchronous generator (SG). A frequency-domain approach based on a linearized system model using eigen value analysis is accomplished. A time-domain scheme based on a nonlinear system model subject to a disturbance is also performed. It can be concluded from the simulation results that the proposed SSSC joined with the designed ODC can effectively improve the stability of the studied OMIB system with an OWF under various disturbances. The inherent low-frequency oscillations of the OMIB system can also be effectively suppressed by the proposed control scheme.

This paper has proposed the stability-improvement and power-flow control results of PV System using a static series compensator (SSSC). The proposed SSSC has been properly connected in series with one of the two parallel lines to supply adequate reactive power. A PI-type ODC has been designed for the proposed SSSC by using a unified approach based on modal control theory to assign the mechanical mode of the studied SSSC system on the desired locations of the complex plane. Root-loci plots under various operating conditions and time-domain simulations of the studied SSSC system subject to a three-phase short-circuit fault at the infinite bus have been systematically performed to demonstrate the effectiveness of the proposed SSSC joined with the designed PI ODC on damping inherent low-frequency oscillations of the studied SSSC system and improving system stability under different operating conditions. It can be concluded from the simulation results that the proposed SSSC joined with the designed PV has the ability to improve the performance of the studied SSSC plus the PV system under different operating conditions as shown in Figure 1. The designed ODC of the proposed SSSC can also effectively stabilize the studied system under an unstable scenario.

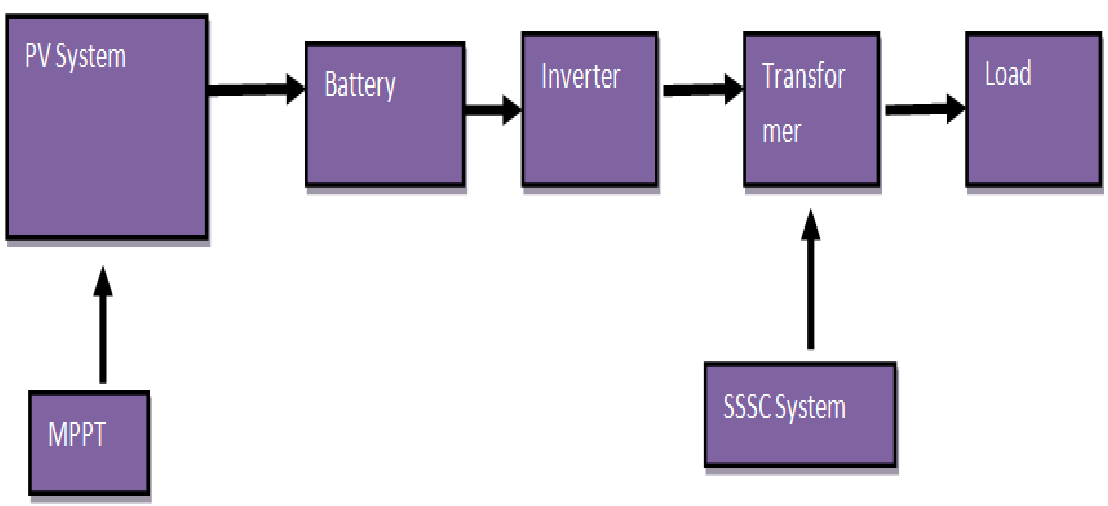

Figure 1 Block Diagram of the PV system using of SSSC

B. System Configuration and Models

The figure 2 shows the configuration of the studied system in this paper. The Solar Panel with capacity of 4 555 MVA is connected to an infinite bus through a 24/230-kV step-up transformer and two parallel transmission lines (Line 34-1 and Line 34-2). The Line 34-2 contains the proposed SSSC located near Bus #3 and the local load is connected to Bus #3. The aggregated 200-MW containing 40 5-MW is connected to Bus #3 through a 33/150-kV step-up transformer, a 150-kV HVAC line, and a 150/230-kV step-up transformer. The aggregated 200-MW is represented by a 200-MW connected to the low-voltage side of the 33/150-kV transformer through an equivalent 0.69/33-kV step-up transformer and a 33-kV infield cable.

The employed capacity of the proposed SSSC is 134 MVA, and it is calculated by taking 3 times (three-phase power) the multiplication of the maximum current through Line 34-2 and the maximum voltage injected by the SSSC. The employed mathematical models of the studied system are described as below.

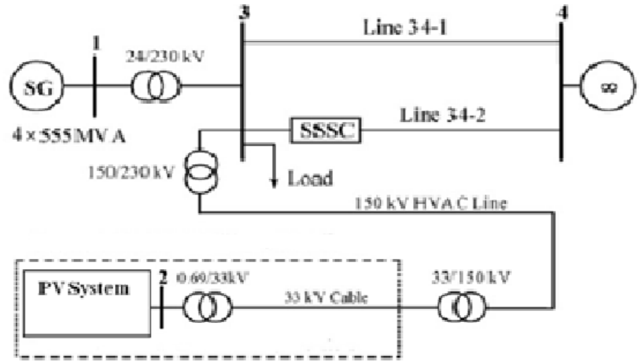

Figure 2 One-line diagram of the studied system.

III. SIMULATION RESULTS

The details of the test system are given in appendix-1. It is a three area four bus system. Two parallel lines are connected between the two areas with 200 and 280km in length. The SSSC is connected in the second line of 280km in length. The line is divided into two parts of 100km and 180km. SSSC is connected between bus 1 and bus 2 in the 100 km length line. The simulation carried out is as follows: Initially, power flow control of the line is tested. Hence, the real power reference is varied and the results are discussed. Qref is kept constant. SSSC is connected at 0.01sec. Before the insertion of SSSC, the real power flow through the line is 8.85 pu. In case (a) the Pref is set to 8.5 pu and at 0.25 sec, Pref is increased to 10 pu. Figure 3.18 shows the corresponding waveforms for power flow through transmission line 2. It is clear from the figure that the commanded power references are achieved. In case (b) the Pref is increased to a higher value of 13 pu. But the final power flow achieved is 12.8 pu which is shown in Figure 3.

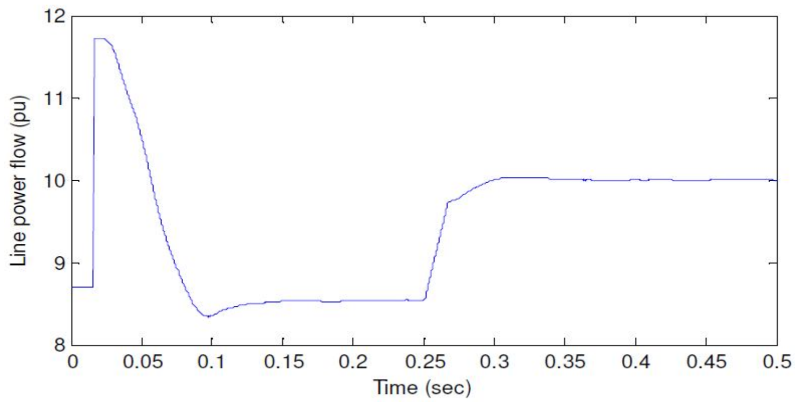

Figure 3 Real power flow through line 2 for case (a)

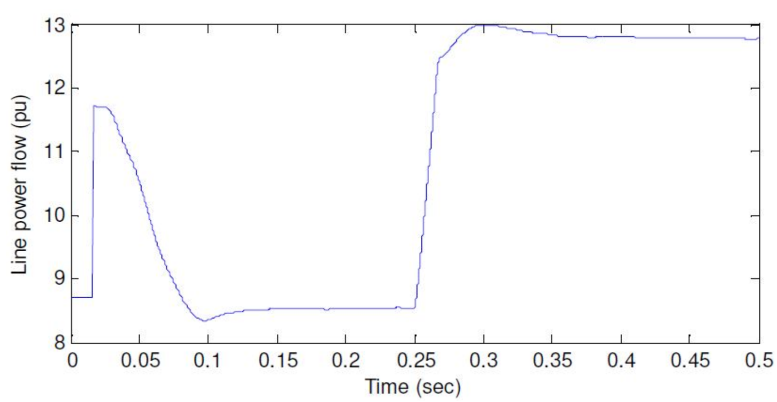

Figure 4 Real power flow through line 2 for case (b)

The next command is given to Qref. Pref is fixed to a value of 11pu. Before the insertion of SSSC, the reactive power flow is -0.62 pu. Qref is initially commanded to -0.5 pu and at 0.25 sec it is changed to -0.8 pu. The figure 4 shows the corresponding waveform for set values are obtained finally.

Figure 5 shows the quadrature relationship between the line current and the injected voltage. To have a clear waveform, the magnitude of the line current is reduced to 0.25 of the original value.

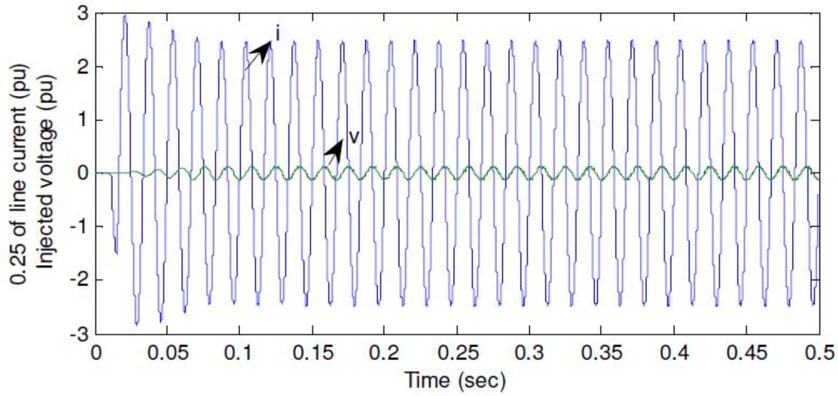

Figure 5 Wave forms for 0.25 of line current and injected voltage

For analyzing transient stability, a three phase to ground fault is simulated at 0.2 sec in line 2. The fault is cleared at 0.3 sec. The reference real and reactive power values set are 11 pu and -0.67 pu respectively and the results are analyzed. The figure 6 and 7 show the real and reactive power flow through transmission line 2.

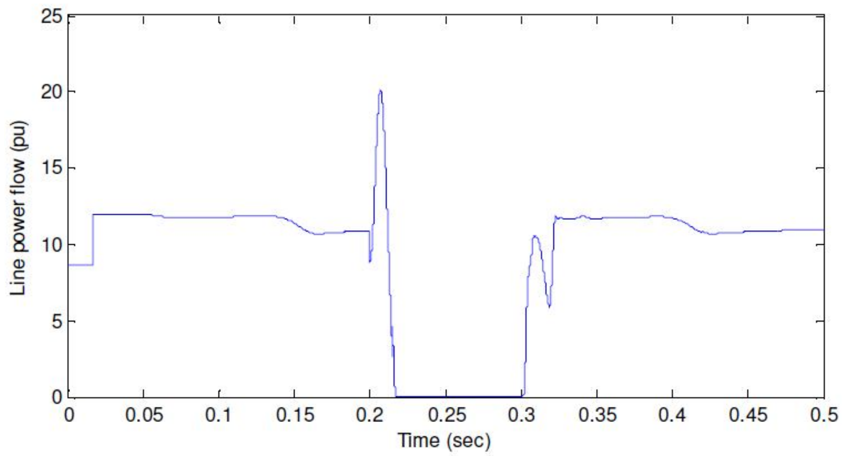

Figure 6 Real power flow through line 2

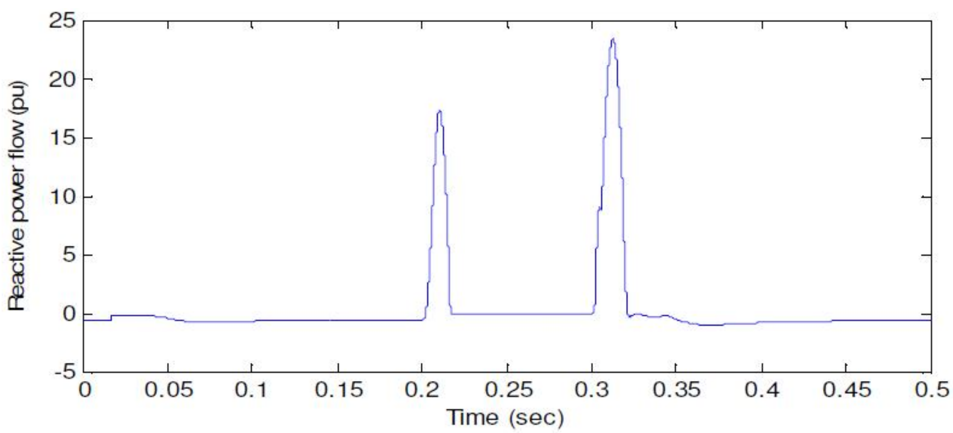

Figure 7 Reactive power flow through line 2

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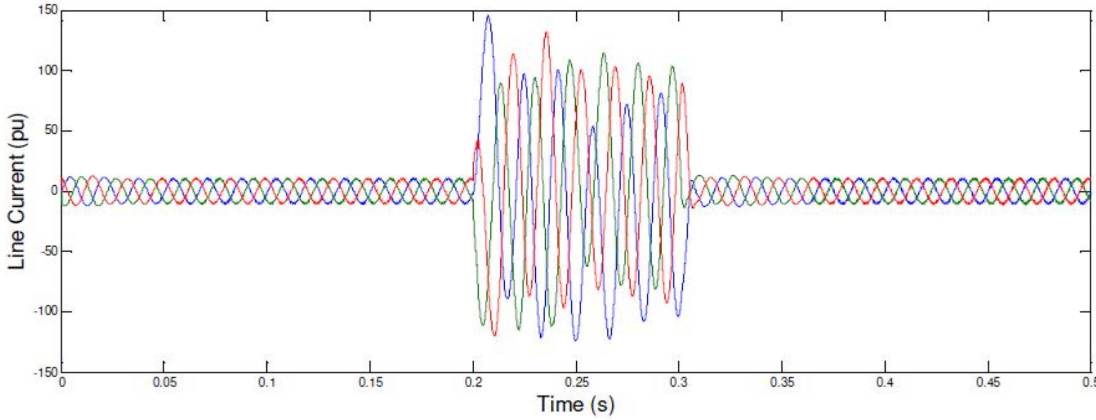

Figure 8 Current flowing through line 2

Figure 8 represents the current flow through line 2 and the value is 10 pu during normal operating condition and the peak value goes to 147 pu during fault. Figure 9 shows the injected voltage from SSSC and it is 0.06 pu during steady state condition and the oscillations are more during fault period.

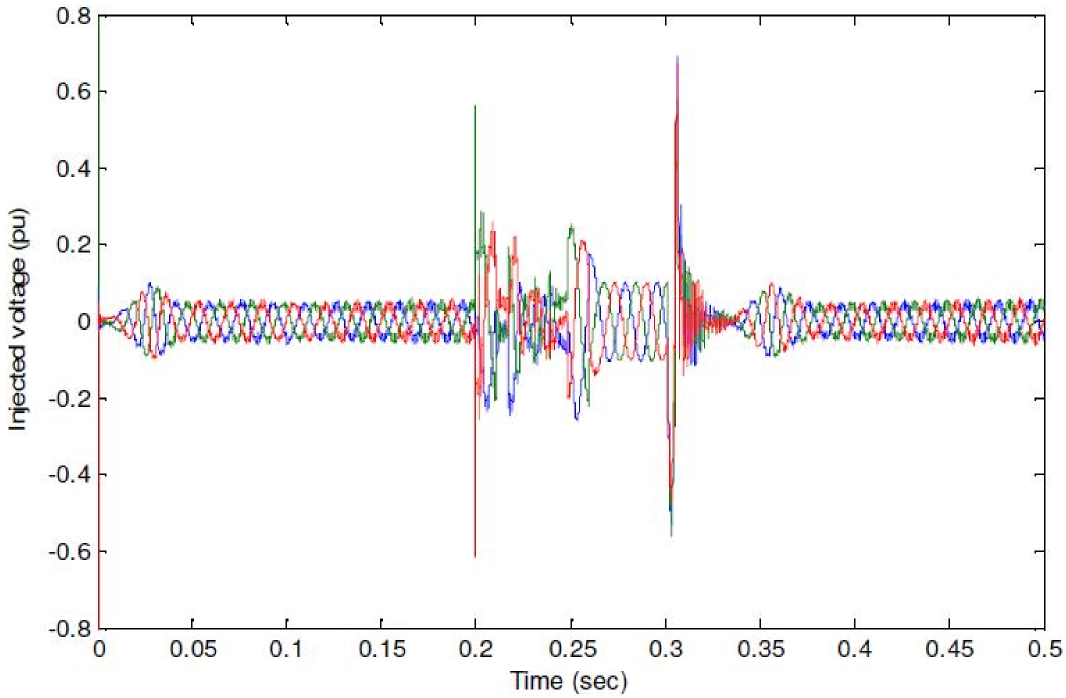

Figure 9 Injected voltage from SSSC

IV. CONCLUSIONS

This paper has presented the stability-improvement and power-flow control results of PV System using a static series compensator (SSSC). The proposed SSSC has been properly connected in series with one of the two parallel lines to supply adequate reactive power. A PI-type ODC has been designed for the proposed SSSC by using a unified approach based on modal control theory to assign the mechanical mode of the studied SSSC system on the desired locations of the complex plane. Root-loci plots under various operating conditions and time-domain simulations of the studied SSSC system subject to a three-phase short-circuit fault at the infinite bus have been systematically performed to demonstrate the effectiveness of the proposed SSSC joined with the designed PI ODC on damping inherent low-frequency oscillations of the studied SSSC system and improving system stability under different operating conditions. It can be concluded from the simulation results that the proposed SSSC joined with the designed PV has the ability to improve the performance of the studied SSSC plus the PV system under different operating conditions. The designed ODC of the proposed SSSC can also effectively stabilize the studied system under an unstable scenario.

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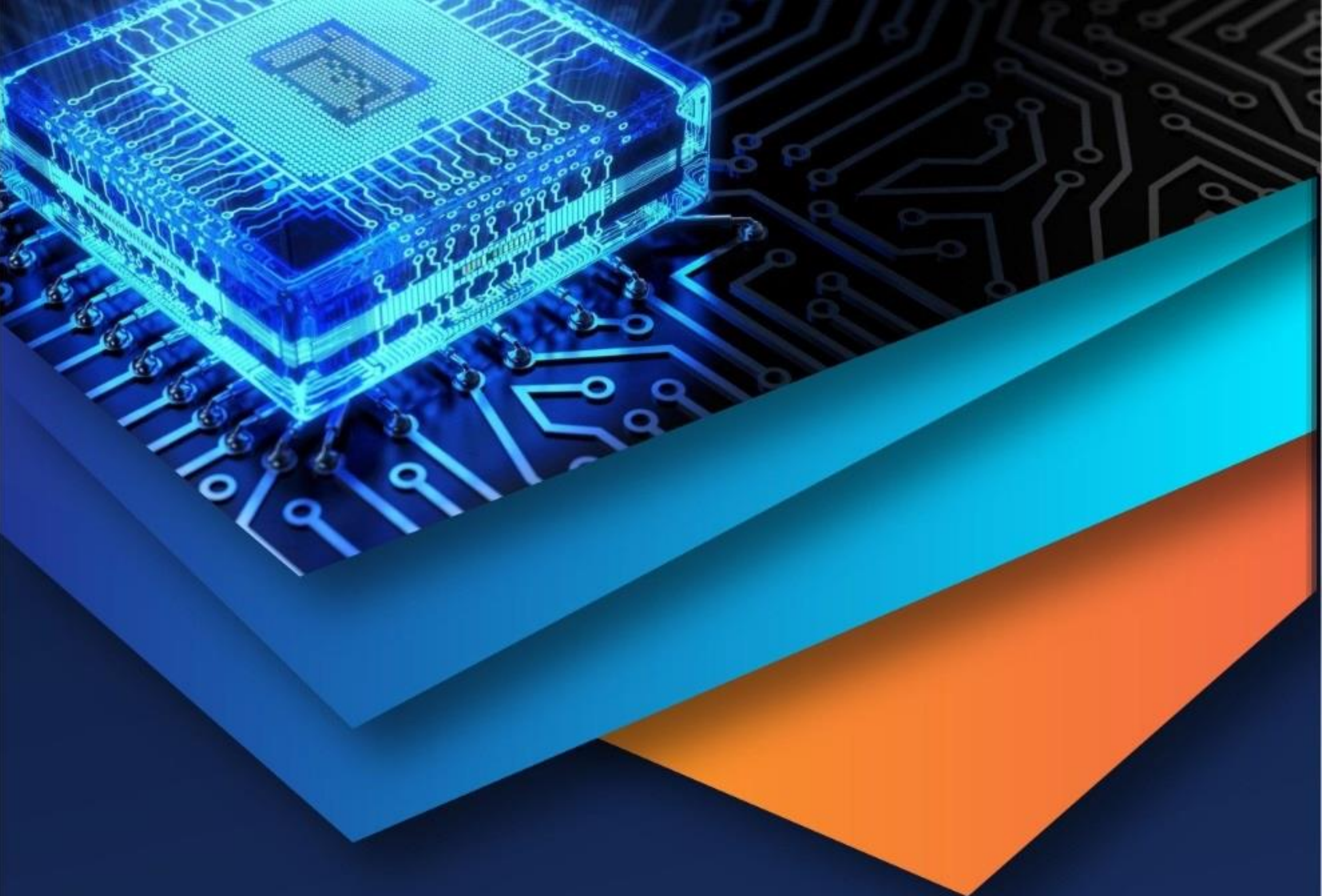

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