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Power Quality Improvement in Distribution Network using D-STATCOM with Battery Energy Storage System

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Abstract: End-user equipment fails or malfunctions because to power quality issues. Outages and service interruptions affect utility distribution networks, sensitive industrial loads, and important commercial operations, resulting in considerable financial losses for everybody involved. With the restructuring of power networks and the transition towards distributed and scattered generation, the issue of power quality will take on new dimensions. Take positive efforts in this area in developing countries like India, where the volatility in power frequency and many other variables of power quality are serious concerns. As a result of this study, measures that can improve the quality of power are advised. Three-stage control transmission framework with wide compensation range was proposed for Hybrid Static Synchronous Compensator (half and half D-STATCOM) by this technology. Due to these distinct properties, the cost of the framework can be drastically reduced. The circuit design of mixed D-STATCOM is provided first in this proposal. Its V–I trademark is then dissected, studied, and compared to D-STATCOM, which is more common. Finally, a parameter configuration for framework is provided, taking into account the range in which the compensating power is available and avoiding the potential reverberation issue. As a result of this, a control methodology is proposed for half-and-half D-STATCOM to allow operation under diverse voltage and current situations, such as unequal current flow, a voltage plunge, and a voltage shortfall As a final step, a reenactment and test results are provided to verify the planned half breed D-large STATCOM's pay range and high level of performance.

Keywords: D-STATCOM, Power Quality

I. INTRODUCTION

As Per IEEE [7], D-STATCOM may be an AC voltage-independent static synchronous generator acting as a Static Var Compensator (SVC) connected in parallel to the output current (capacitive or inductive).In recent years, non-linear loads have become more prevalent in distribution and transmission networks, producing power quality concerns (power pollution).The polluted power will effect on the performance and lifetime of the system in most cases PQ means the standard of voltage that's being address within the system. Power quality concerns faced by both the purchasers and utilities are poor power factor and voltage variations (voltage sag and swell).There is a low power factor and voltage volatility, which affects customers and utilities alike (voltage sag and swell). Voltage sag is described as a reduction in RMS voltage (AC voltage) from 0.9pu to 0.1pu at power frequencies during 0.5 cycles to 1min, as per the specification. In distribution and transmission networks, voltage sag accounts for 80 percent of the power quality concerns. Various conventional methods (capacitor bank parallel feeder, UPS) are applied to mitigate the voltage sags, but these methods aren't ready to solve the PQ problems completely. Among the varied custom power devices, the D-STATCOM may be a promising device to mitigate power quality problems like voltage sag, swell, current harmonics, and reactive power control within the distribution and transmission. Electrical power systems have developed over nearly 150 years in to large networks predominantly powered by a couple of high-capacity generators. The networks as an entire are clearly separated in to distinct subsystems: generation, transmission and distribution. within the past, generation has mostly been sourced from large, centralized power stations using fossil or nuclear fuels. the facility has been fed into the transmission which successively feeds the distribution system. Consequently, most of the system control functions are performed either in large power stations or at substations connected to the transmission.

A number of networks haven't been modernized in a substantial way in the last few years. These factors, as well as the growing environmental concerns and deregulation in many parts of the world, have led to the necessity for reform. UK and the other EU nations have set a 2020 goal of producing 20 terawatt hours of power from renewable sources. From renewable sources, the United Kingdom produces around V-J Day at the moment. The next generation “Smart Grid” is predicted to contains an outsized number of semi-autonomous networks with their own energy producing capabilities connected together and dealing cooperatively. Effectively, the importance of the distribution networks increases, while the transmission becomes smaller.

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The Institute of Engineering and Technology has predicted that within the uk the number of generators providing grid control functionality could increase from10–15 at the present (all on the transmission system) to as many as 600,000 (connected to both transmission and distribution systems), and voltage regulating devices could increase from about 10,000 devices to almost a million. A simplified illustration showing a number of the changes which will occur in power systems is shown in Fig. 1.

The following are some of the key developments projected in the coming decades:
Distributed energy resources (DERs), such as renewable generating and energy storage, are increasingly being connected to the grid.
Power system voltage and frequency are increasingly being controlled by an increasing number of devices.
Island formation (separated sections of the network that continue to operate using local generation) is on the rise.

1) *Aim:* To achieve the power quality of supply using D-STATCOM.
2) *Objectives*
   a) To minimized the voltage sag or swell of the system.
   b) To improve the power quality of distribution system.
   c) Design of hybrid controller.
   d) Design of fuzzy logic controller.
   e) Compare the hybrid controller with fuzzy logic controller for control of D-STATCOM.

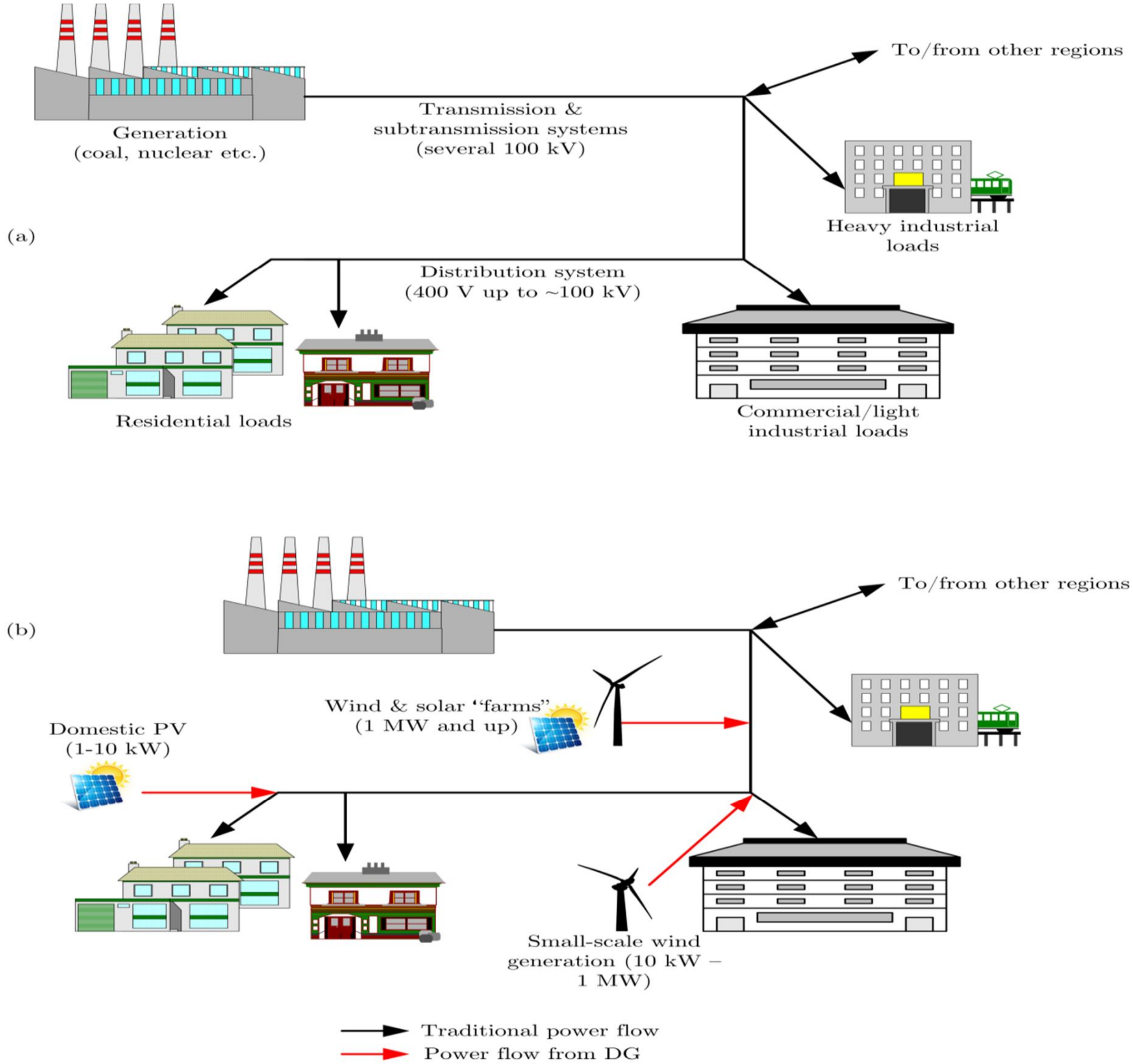

Fig. 1 An illustration of (a) a traditional power system, and (b) the same power system with distributed generation at various levels

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II. PROPOSED APPROACH

A. Main Block Diagram

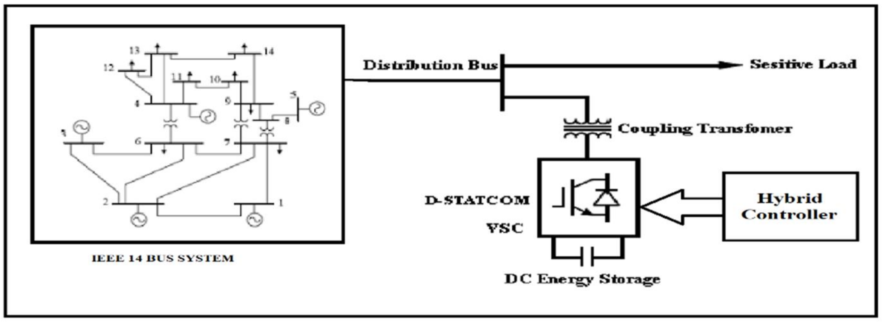

Fig.2 Connection Diagram of System

B. Controller Subsystem Model

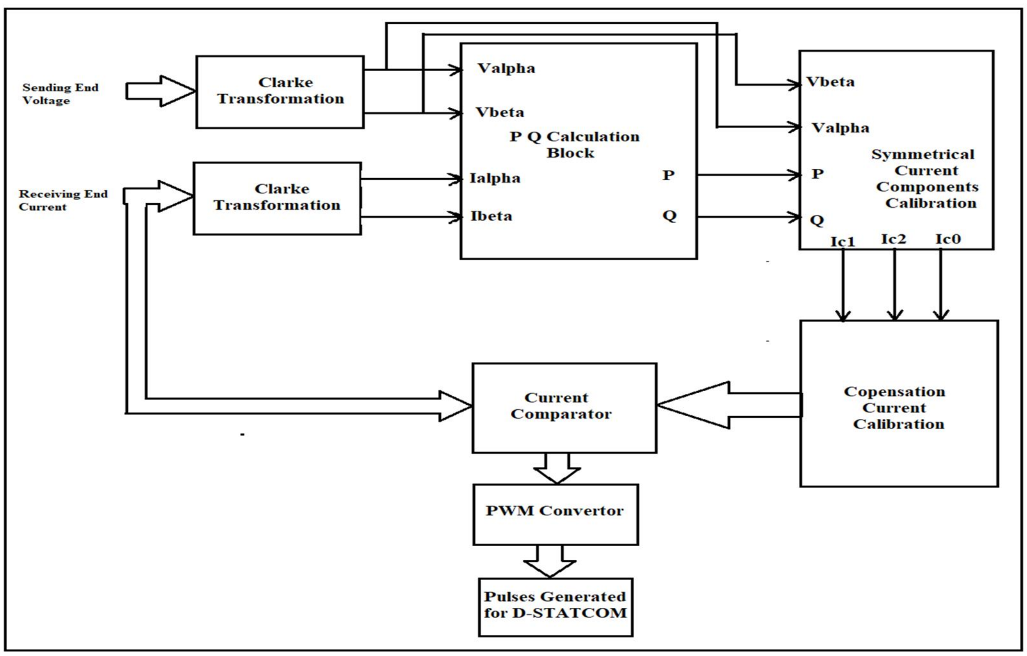

Fig. 3 Detail block diagram of controller subsystem

C. Instantaneous Power Theory for D-STATCOM Controller

P-Q theory or instantaneous power theory is the basis for the proposed instantaneous real-power (p) theory, which uses simplealgebraic computations. Operating in steady-state or transient conditions, it can also be used to regulate active power filters in real-time for various voltage and current power systems. In order to make source current sinusoidal, an active filter must supply

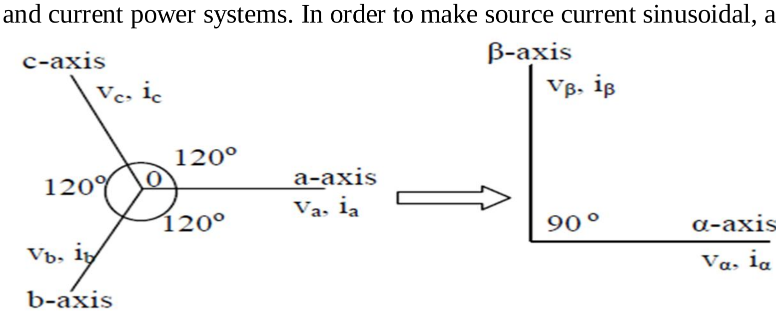

Fig.4 α-β coordinates transformation

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The oscillating fraction of the instantaneous active current of the load In the p-q theory, stationary coordinates a,b,c are transformed into orthogonal coordinates by Clarke transformation. Fig.4 shows that axes in a-b-c coordinates are fixed on the same plane, separated by 120°. voltage and current instantaneous vectors Va,ia are set on the a-axis; Vb and ib are placed on the b-axis; and Vc,ic are set on the caxis. They can be simply converted into -coordinates by converting them to space vectors. With Clarke transformation v, v is converted from the instantaneous source voltage vsa to the vsb/vc coordinate's voltage.:

Electricity voltage and current, v,i, are orthogonal to one another. Current and voltage - and -axes should be used to compute instantaneous actual power. According to the standard definition of real-power, they are as follows:

To eliminate higher order components, this instantaneous real power is filtered through a 50 Hz Butterworth-based first-order low pass filter (LPF). The fundamental component is allowed to pass through. Pac is the abbreviation for the ac components of the real-power losses. Comparing the dc-bus capacitor voltage of the cascaded inverter with the intended reference voltage, one can determine the DC power loss. The dynamic response and settling time of the dc-bus capacitor voltage are determined by the proportional and integral gains (PI-Controller) of the controller. As a result of the DC component power losses,the instantaneous real-power (p) is calculated from the AC component of the real-power loss pac and the DC power loss $P_{DC(Loss))}$

There are two types of instantaneous current components in the instantaneous current on the ic and ic coordinates: actual power losses and reactive power losses. This suggested controller computes just the real power losses. Since only instantaneous real power (p) is taken into account, the ic,ic coordinate currents are derived from v,v voltages, with the reactive power (q) assumed to be zero. This method minimizes the number of calculations and provides higher performance than standard methods.The AC and DC component of the instantaneous power $p(t)$ is related to the harmonic's currents. The instantaneous real power generates the reference currents required to compensate the distorted line current harmonics and reactive power.

D. Reference Current Control Strategy

The instantaneous real-power compensator must be used in the control scheme of the shunt active power filter to derive the current reference signals from each phase of the inverter Fig.5 shows the block design of the control scheme that creates the reference current required to adjust the load current harmonics and reactive power. To maintain the DC-bus voltage across the inverter's capacitor constant, the PI-controller is used. For the compensation of current, this instantaneous real-power compensator with a PI-controller is used. With the instantaneous coordinate currents, these three reference currents are determined instantaneously and without any time delay. It is possible to generate cascaded multilayer inverter switching signals by comparing reference currents (isa, isb, and isc), thanks to the suggested triangular-sampling current modulator.

This algorithm compensates for all undesired components by adjusting the basic component of reference currents. A balanced and sinusoidal power system voltage results in continuous power at the dc bus capacitor and balanced sinusoidal AC mains currents concurrently.

E. Control Loop Design Using PI controller

In order to compensate for conduction and switching losses, the voltage of the dc-bus capacitor is adjusted by modifying the little amount of power flowing into DC components. In order to eliminate the steady state error and lower the ripple voltage of the cascaded inverter, a proportional integral controller is utilized.

F. Control Loop Design using Fuzzy logic Controller

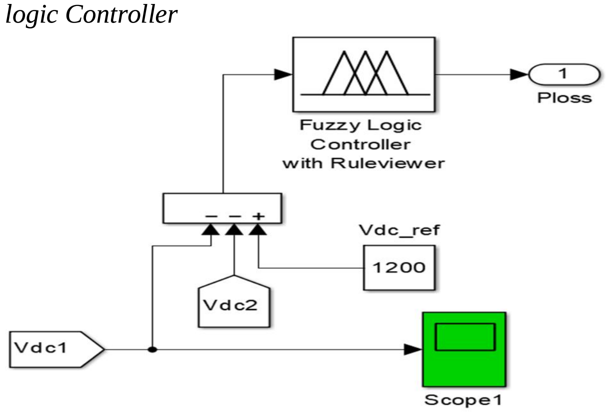

Fig.6: Fuzzy logic controller for power loss calibration

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III. MATLAB SIMULATION MODEL AND RESULTS

A. IEEE 5 Bus system

Fig.7 is a comprehensive model of the IEEE 5 bus system subsystem. Table I shows the resistance, inductance, and capacitance of the transmission line that connects each bus bar. On bus bars 1 and 2, two generators are linked, while RL loads are connected to the remaining bus. In order to optimize the voltage profile of the substation, the D-STATCOM system is connected to bus bar 4.

TABLE I
IEEE 5 Bus System MATALB Simulation Transmission Line Data

Line Number	From Bus	To Bus	Line impedance (pu)		Line charging
			Resistance (pu)	Inductance (pu)	
1	1	2	0.02	0.06	0+j0.03
2	1	3	0.08	0.24	0+j0.025
3	2	3	0.06	0.25	0+j0.02
4	2	4	0.06	0.18	0+j0.02
5	2	5	0.04	0.12	0+j0.015
6	3	4	0.01	0.03	0+j0.01
7	4	5	0.08	0.24	0+j0.025

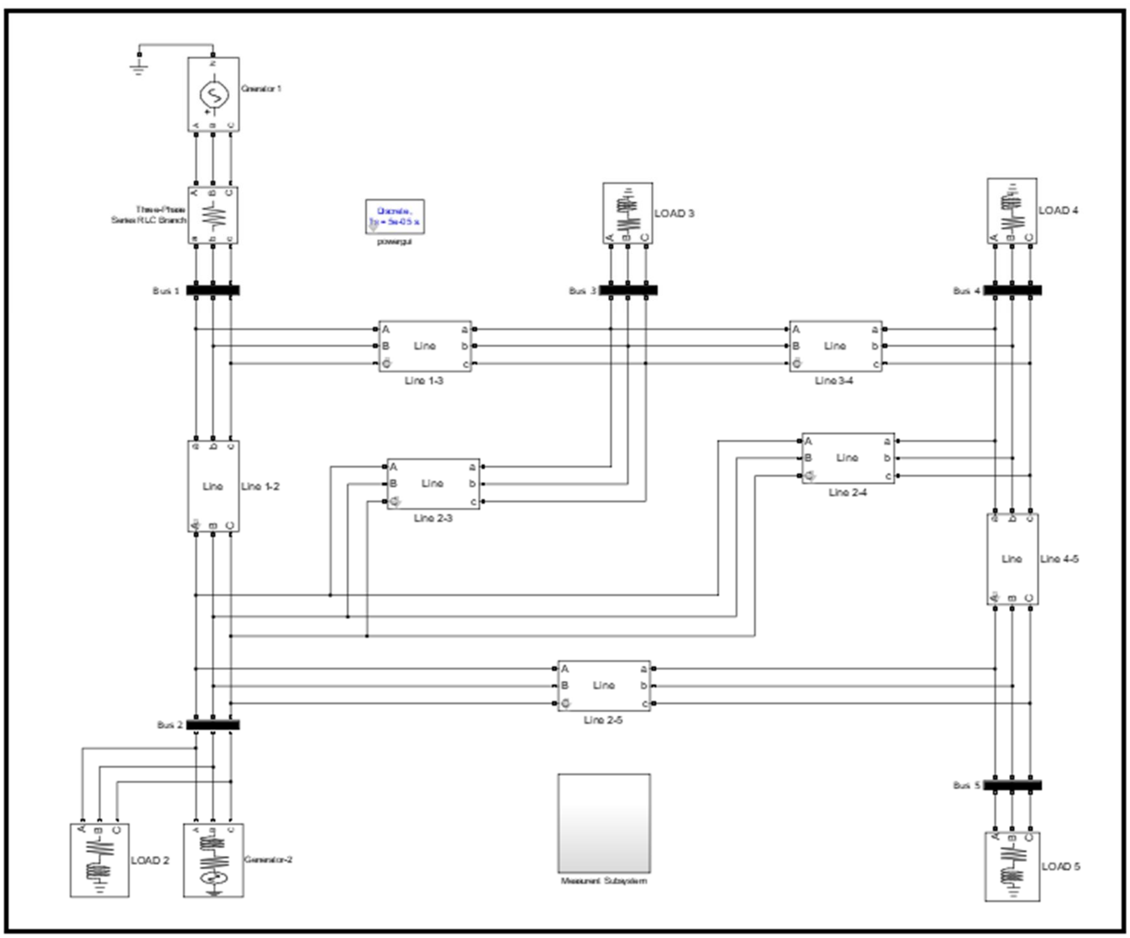

Fig.7 MATLAB simulation of IEEE 5 Bus subsystem model

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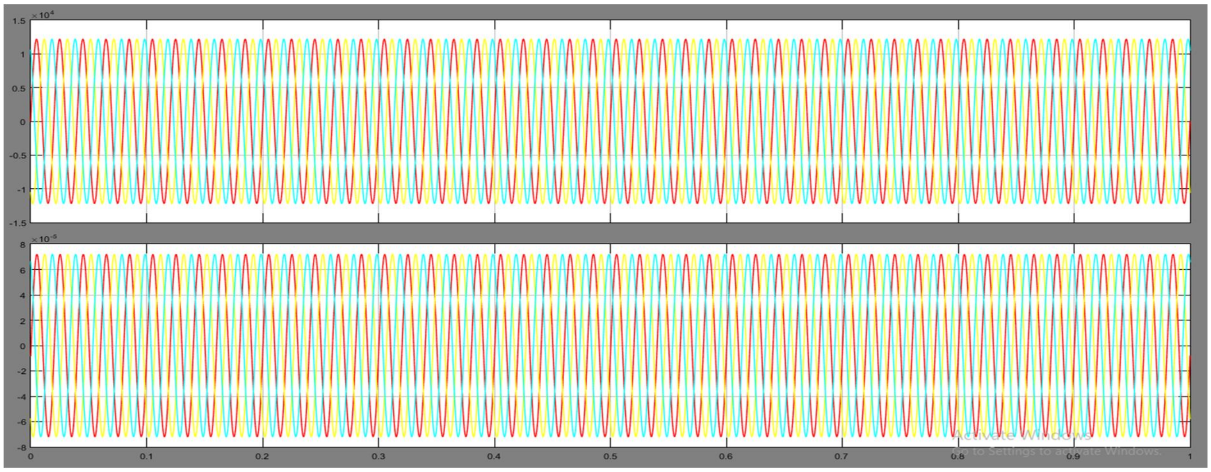

Fig.8 Three phase voltage and current measured at bus bar 1

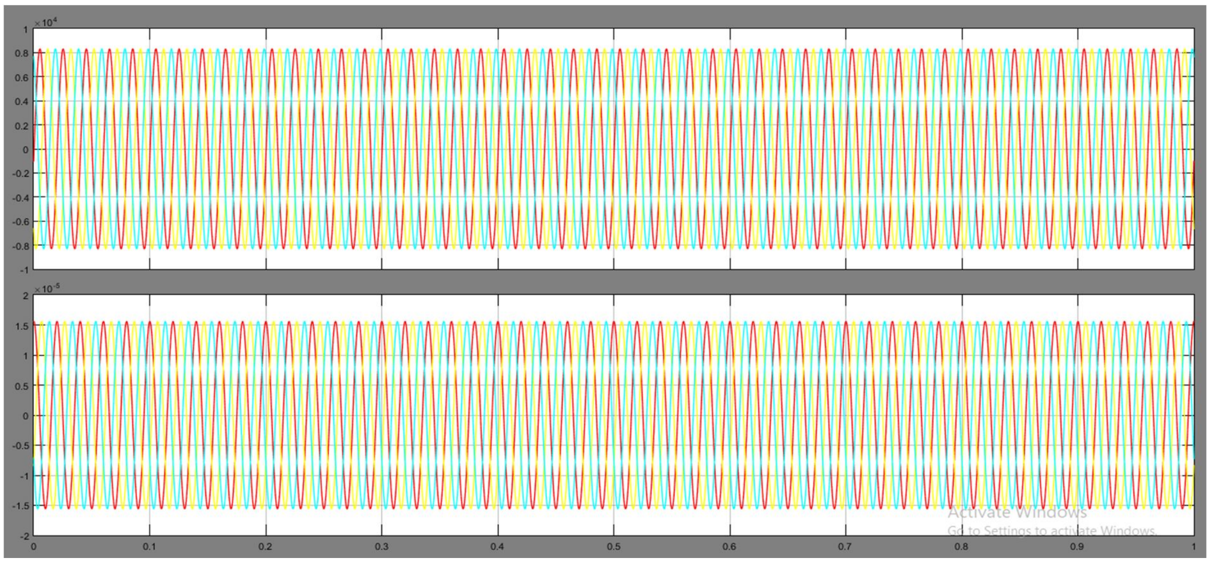

Fig.9 Three phase voltage and current measured at bus bar 2

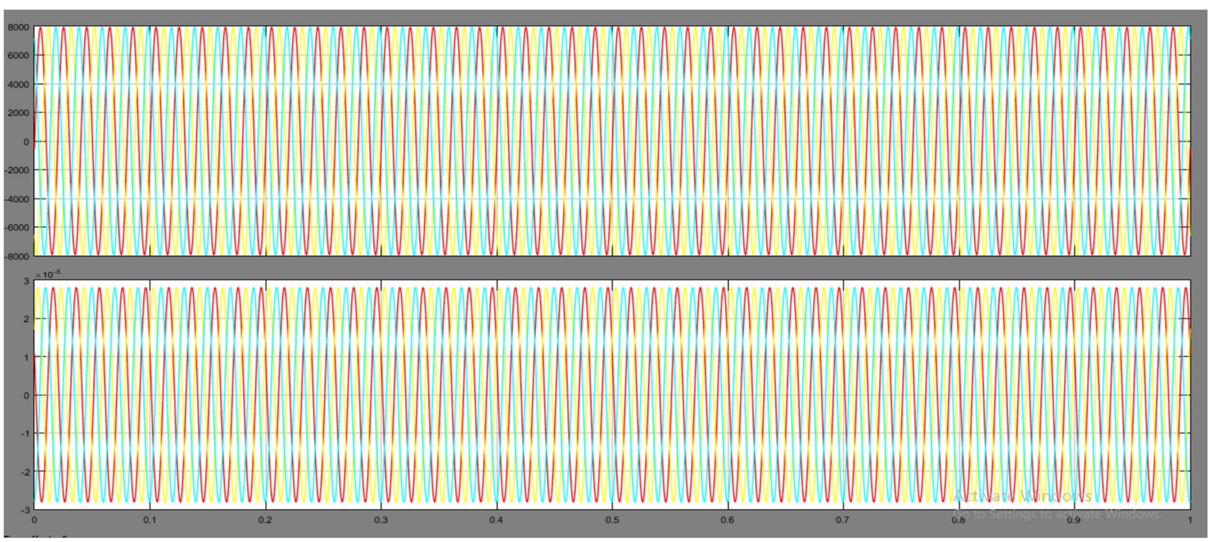

Fig.10 Three phase voltage and current measured at bus bar 3

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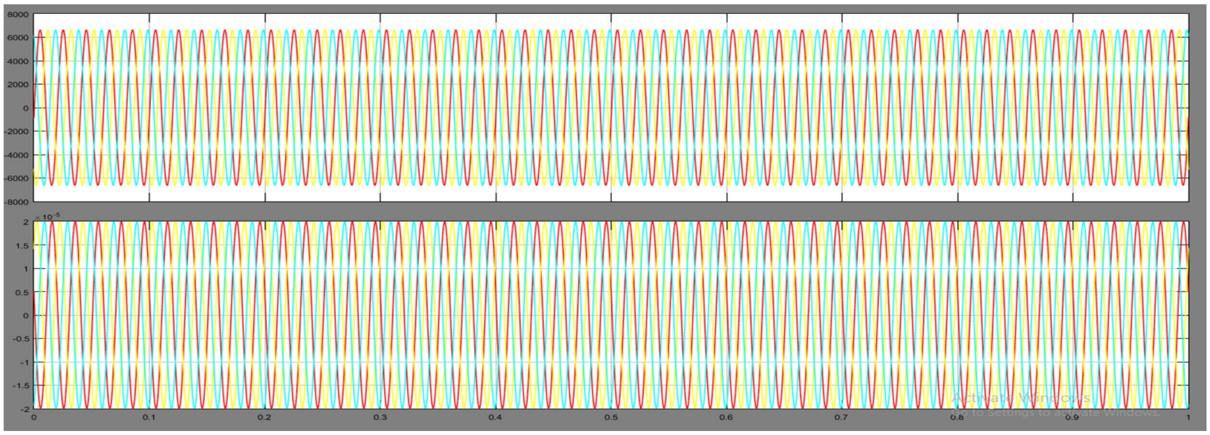

Fig.11 Three phase voltage and current measured at bus bar 4

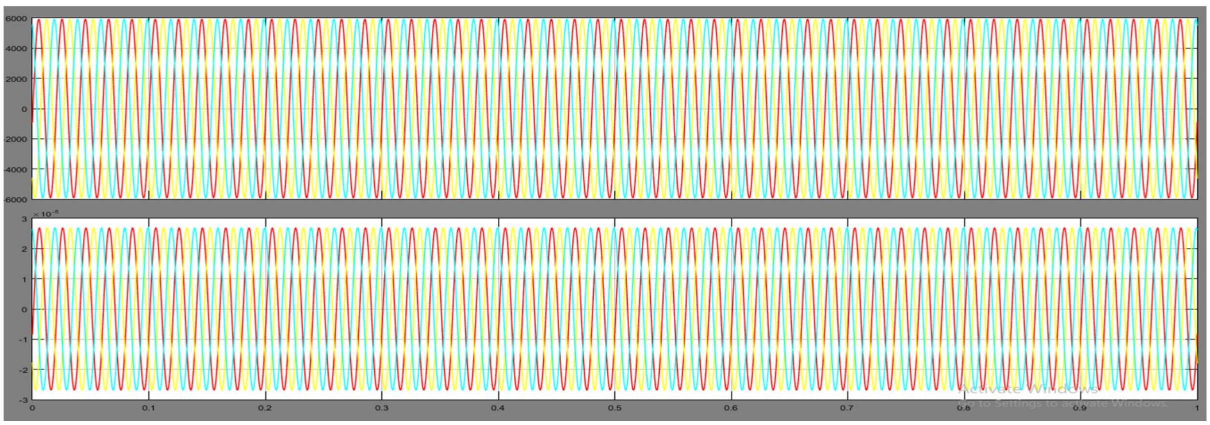

Fig.12Three phase voltage and current measured at bus bar 5

B. *Fuzzy logic controller results*

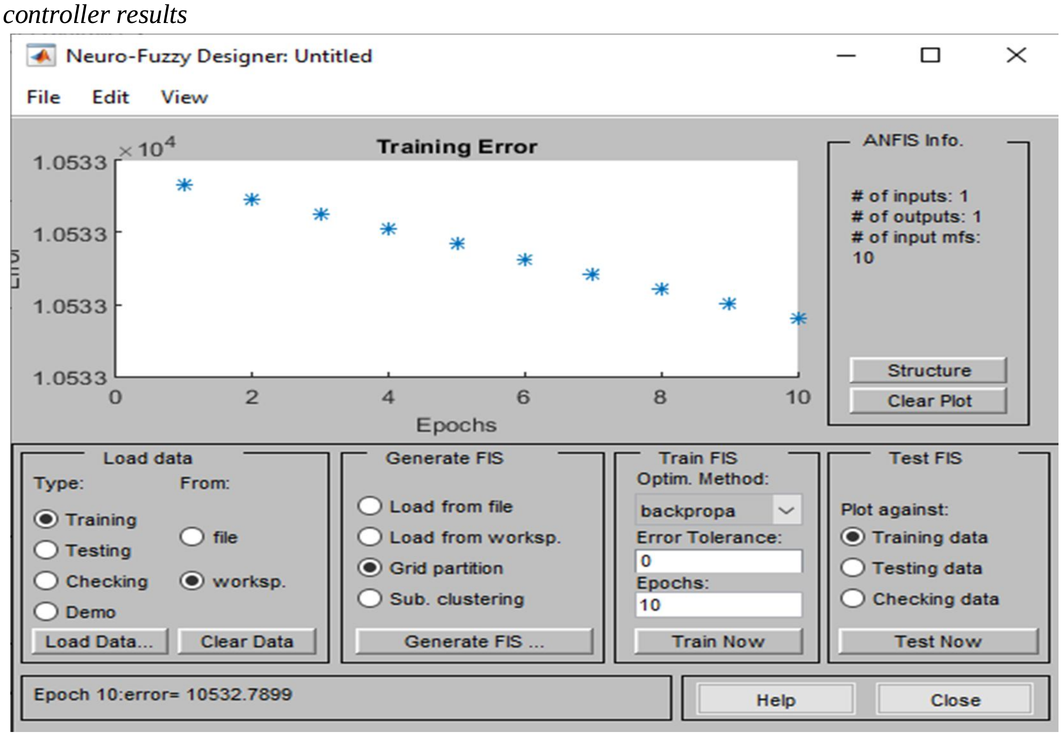

Fig.13 Fuzzy logic controller designer tool window

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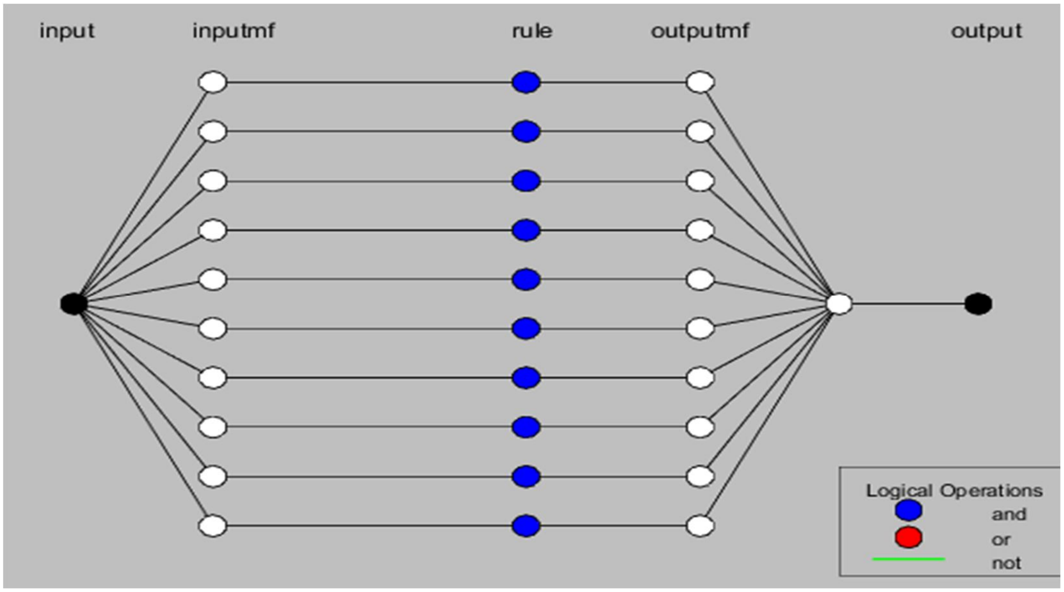

Fig.14 Fuzzy logic controller structure

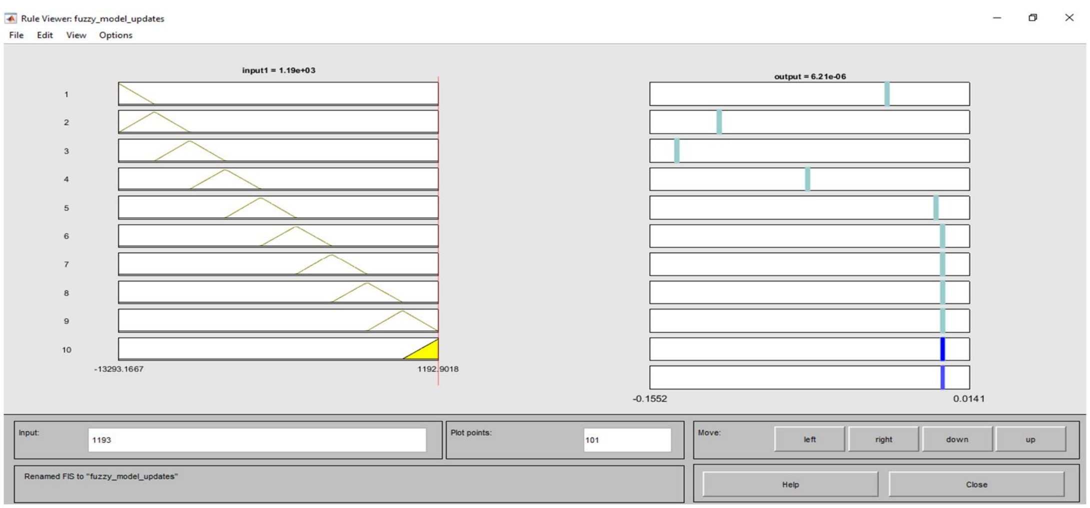

Fig.15 Fuzzy rule based all membership function

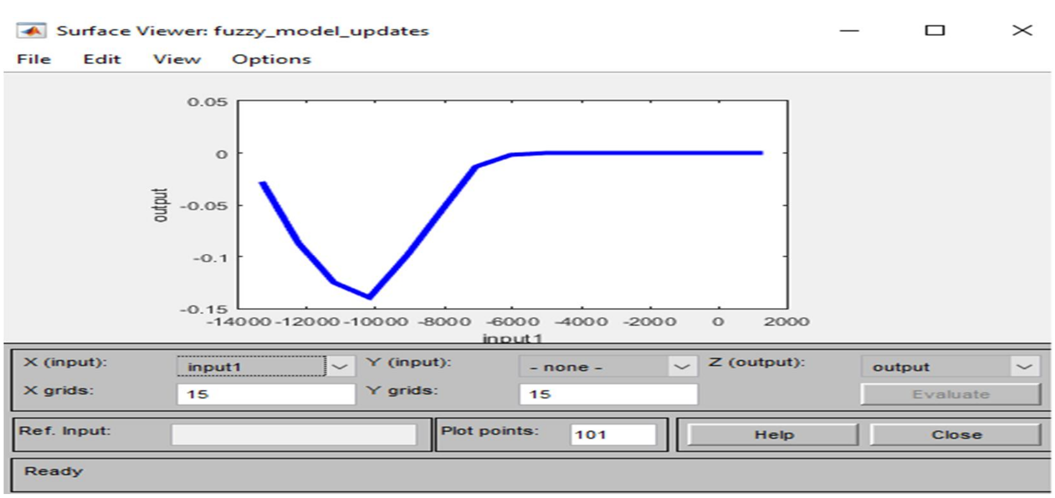

Fig.16 Fuzzy logic controller controlling surface

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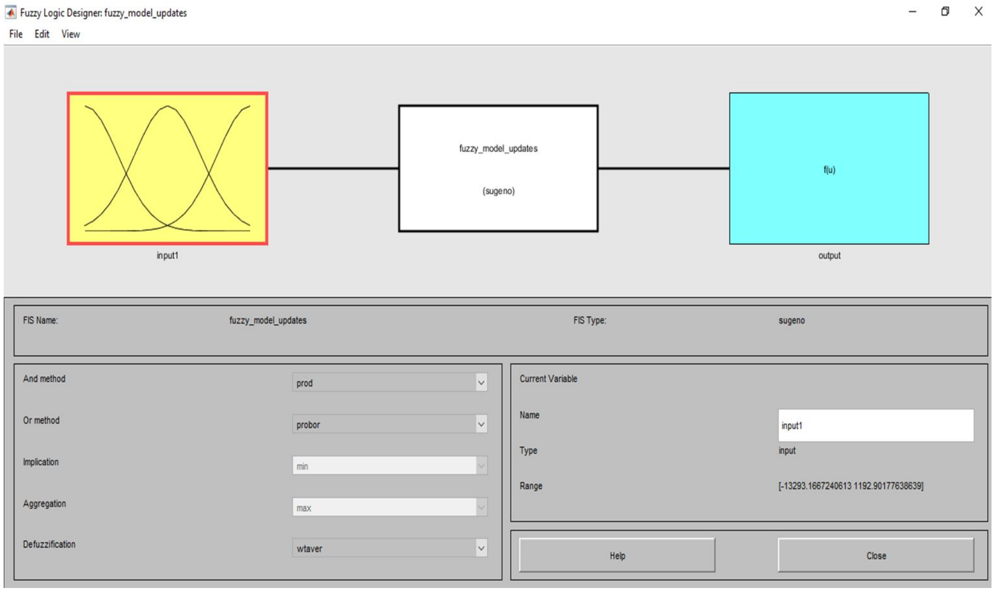

Fig.17Fuzzy logic controller input and output structure

IV. CONCLUSION

This paper presents the FACTS device (D-STATCOM) -based control scheme for power quality improvement in grid connected wind generating system and with nonlinear load. The power quality issues and its consequences on the consumer and electric utility are presented. The operation of the control system developed for the D-STATCOM in MATLAB/SIMULINK for maintaining the power quality is to be simulated. It has a capability to cancel out the harmonic parts of the load current. It maintains the source voltage and current in-phase and support their active power demand for the wind generator and load at PCC in the grid system, thus it gives an opportunity to enhance the utilization factor of transmission line. The integrated wind generation and FACTS device with BESS have shown the outstanding performance. Thus, the proposed scheme in the grid connected system fulfills the power quality norms as per the IEC standard 61400-21.

Most of the objectives stated in the initial phase of the project were fulfilled. The investigation of ancillary service requested from wind power plant in terms of reactive power generation/absorption was performed. For us, master students it was a new research topic. In addition to the review of SOA of FACTS it is shown that grid codes from different transmission system operator (TSO) are becoming more and more demanding in term of grid voltage support. Modeling and simulation model implementation of the proposed system was completed successfully.

In this project report work, following work done:

A. Literature survey for different types of FACTS controller with different controlling technique studied in this work.
B. Design of IEEE 5 bus system done using IEEE standard data set which identical with real time power system.
C. Design of hybrid controller for control of D-STATCOM firing angles for voltage profile control.
D. Result analysis of system during normal and abnormal conditions like voltage sag and swell condition.
E. Also proposed system is design with fuzzy logic controller for power loss calibration.
F. Result analysis for fuzzy logic-based D-STATCOM system done like voltage sag and swell condition.

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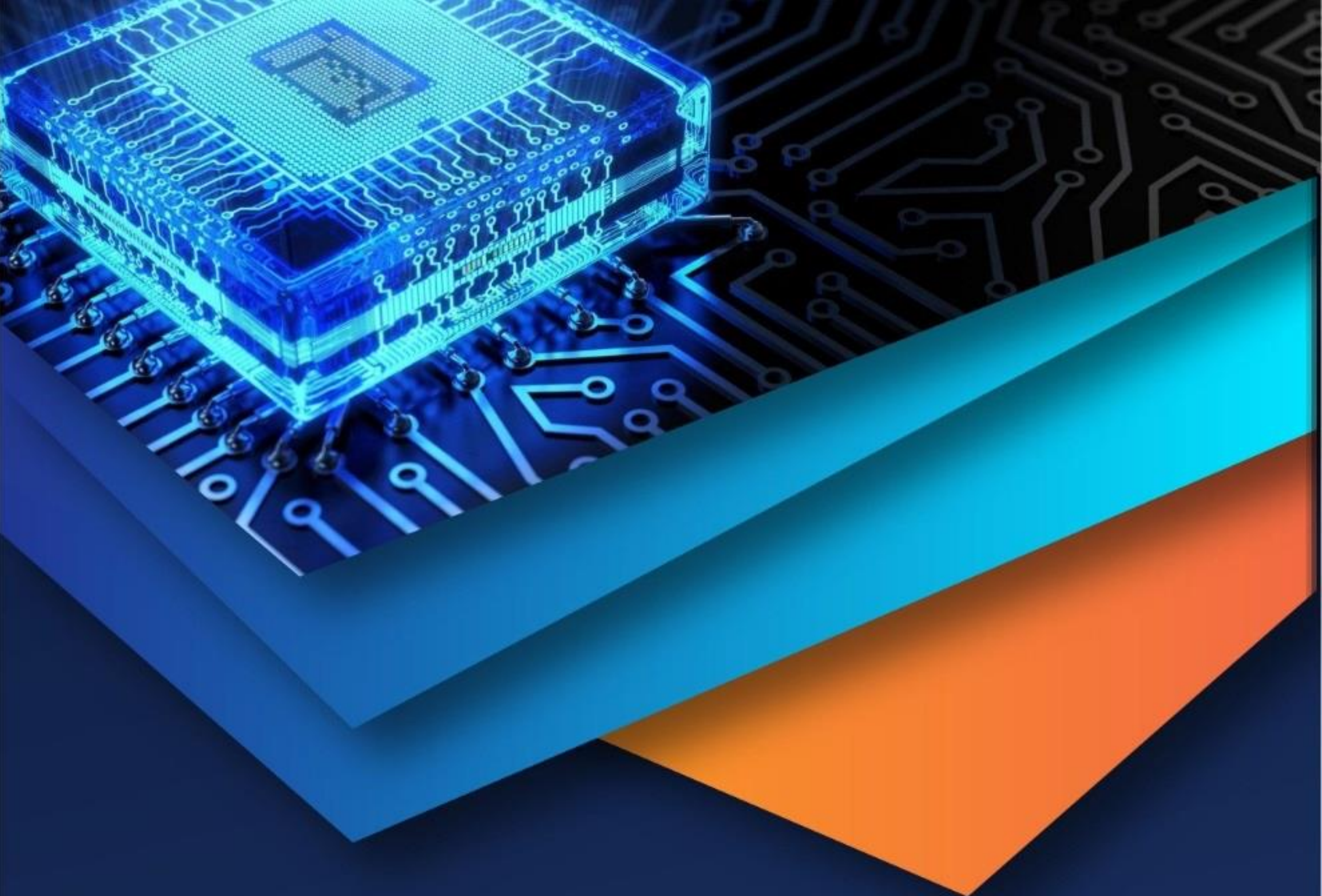

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