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Comparative Analysis of DFIG based Wind Farm Connected Power System using Fuzzy Controller based FACTS

Chhaya Pal[1], Varun Kumar[2], Amit Kumar Yadav[3]
[1]*Department of Electrical engineering Government Polytechnic Kursi Road Fatehpur Barabanki*
[2, 3]*Department of Electrical engineering KNIT Sultanpur India*

Abstract: Stabilization of wind farms (WF) is considered the main problem in the development of power systems Based on renewable energy sources. A comparative analysis of dynamic performances for like STATCOM and SVC is presented in this paper. Device like that Used to stabilize multi- Machine integrated power system. The Fuzzy logic controller (FLC) based FACTS devices enhance wind farm integrated multi- Machine power system (WFMPS) performance under different abnormal conditions. Three-phase short circuit occurred in system Considers different location system. MATLAB /Simulink is used for modelling and simulation for WFMPS. Results show improved system performance using SVC and FLC-based STATCOM on damping the oscillations, and improving system dynamic performance under fault condition. The comparison shows superior dynamic performance and fast fault recovery of STATCOM-based FLC through different fault conditions compared with SVC-based FLC.
Keywords: wind farm, STATCOM, SVC, fuzzy logic control (FLC)

I. INTRODUCTION

Rapid urbanization and growth have created massive power provide demand which may not be met by perpetually depleting fossil fuels. Because of scarceness of fossil fuels, increasing power supply demand and severe environmental problems, renewable energy resources are the new supply for power generation. And currently energy generation because of non-conventional energy resources is increasing terribly quickly and shortly renewable are alone ready to meet the ability demand. The current situation of power generation with renewable energy is given in figure one. Thirty-nine GW has been additional throughout 2017, therefore, the total put in capability is 539 GW worldwide.

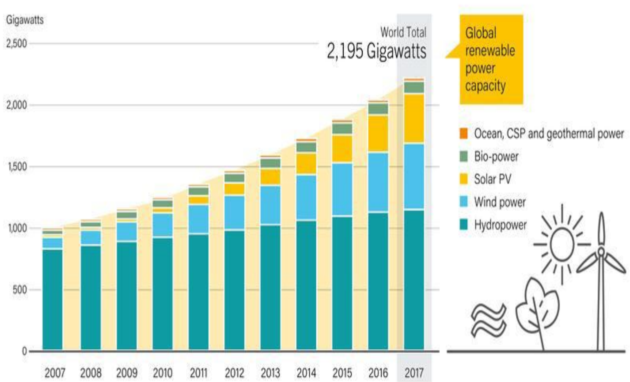

Fig 1. Worldwide wind power capacity during the period from 2007 to 2017[1]

Total world wind generation capability & per year additions throughout from 2007 to 2017 is shown in figure 1. Doubly fed induction generator is broadly used in the Wind energy systems because of its adaptability up to the mark and high potency [1]. The flexible AC transmission systems is utilized for guaranteeing quality of power of WF. They. It is thought-about the simplest resolution to boost execution of wind farm feeding power to utility grid and multi-machine systems too. STATCOM works as a reactive power compensation for WES. Execution of Wind energy systems connected to utility grid has been studied for many years' victimization FACTS gadgets for each steady and transient states [2, 3,4]. Here In this case, the test system which is a WSCC system is connected with wind farm. Wind farm stability performance enhances by using FACTS devices

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II. SYSTEM CONFIGURATION

In this the study is done using MATLAB/SIMULINK. Studied system consists of a WSCC system with DFIG wind farm as shown in fig2. WSCC system includes three machine nine bus connected to three loads of different ratings. WF is designed as a total of around 90 MW capacity using sixty numbers of DFIG based WF. FLC based FACTS devices have been used. Each facts device used is of 40 MVAR rating.

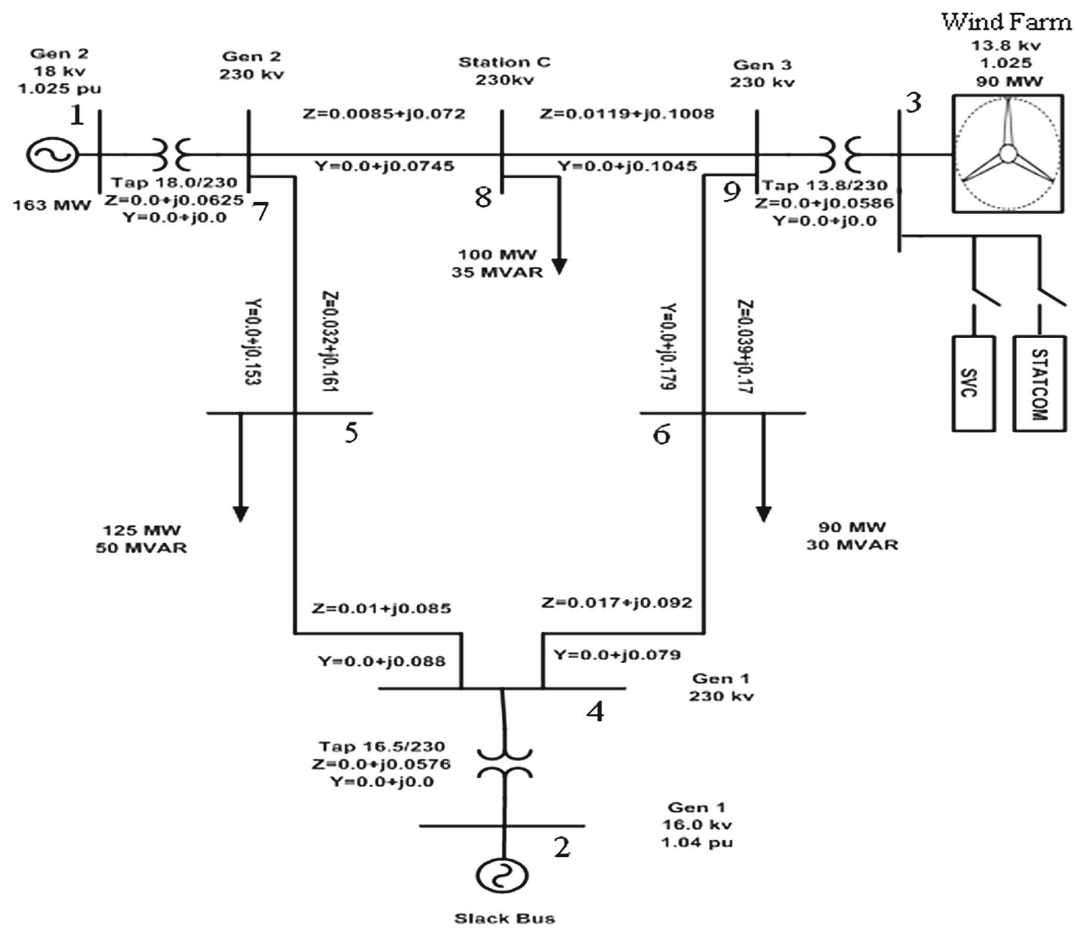

Fig 2. WSCC system with wind farm

A. Wind Farm Model

The coordination of dynamic speed wind turbine and doubly fed induction generator is gotten expanding consideration. DFIG's stator is legitimately taken care of a 3-stage framework, while its rotor is taken care of to UG through transformer and consecutive converter. Converter at rotor end, Converter at grid end, and direct current-interface capacitor are the fundamental part of the convertor [5]. Converter at rotor end is used as a controlling converter for the reactive and active power of the system. Then again, DC-connect voltage is controlled by grid side converter. Moreover, it guarantees activity of converter with a solidarity power factor.

B. Fuzzy Logic Control

In this studied system triangular type of membership function has been used with mamdani type of FLC. The contribution to fuzzy logic controller is the error voltage sign and change of error. The information sources and yield part transport work comprise of 7 etymology of triangle shaped kind. The semantic factors E abbreviation of error, CE abbreviation of change in error, and the controller yield will take on the accompanying etymological qualities: Negative Big abbreviated as NB; Negative Medium abbreviated as NM; Negative Small abbreviated as NS; Zero abbreviated as Z; Positive Small abbreviated as PS; Positive Medium abbreviated as PM; Positive Big abbreviated as PB. The standard framework is a basic graphical device for mapping the FL control framework rules. It suits two info factors and communicates their intelligent item (AND) as one yield reaction variable. To utilize, characterize the framework utilizing The FLC rules has two input and one output and each has 7 linguistics which gives out 49 rules [5][6]. The rules for FLC is shown in table I and surface view of the output can be presented as shown in figure 3.

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TABLE I FLC RULES [7]

E/CE	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

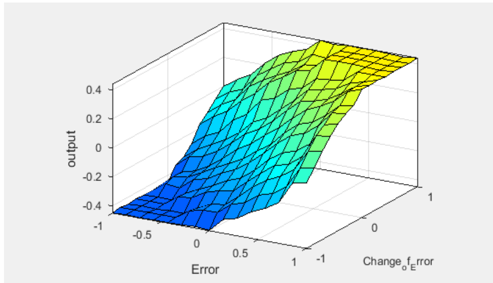

Fig.3 Surface view of FLC rules

C. FLC Based SVC

SVC (static var compensator) is a thyristor switched reactor (TSR), thyristor control reactor (TCR), thyristor switched capacitor (TSC) or a parallel combination of these reactors. It is a shunt connected device and output power is controlled by varying firing angle of SCR [8]. The control parameter in SVC is susceptance(β) which is given as

$$B=\frac{2\beta-\sin 2\beta-\pi\omega^2 LC}{\pi\omega L} \qquad (1)$$

Where, β = π-α, α is firing angle

And the reactive power compensation is given as

Q=-BSVCV2 (2)

The operating principle of SVC has been explained in numerous papers [10]. The MATLAB/Simulink model of SVC based FLC is shown in figure 4. The change in error and error signal is generated by comparing system voltage with reference voltage. SVC's susceptance is generated by FLC output. The output of the SVC is used for regulation of PWM inverter by changing the firing angle. By using SVC the low voltage ride through capability of the system improves by maintain the system voltage within permissible limits. The dynamic voltage control of the system can be achieved by using SVC in the system. SVC reduces the impacts of faults or the disturbances on the system [9,10].

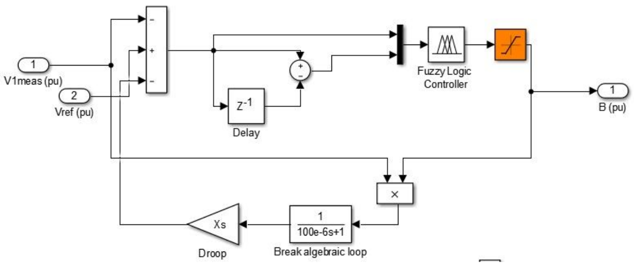

Fig.4 Simulink model of FLC based SVC

D. FLC based STATCOM

STATCOM is a shunt connected device, it regulates system voltage by either generating reactive power in case of low system voltage or by absorbing reactive power in case of high system voltage. A voltage source converter (VSC) is connected with the secondary side of a coupling transformer to ensure the proper variation of the reactive power [9]. The real (P) and reactive power (Q) can be given as follows:

$$P=\frac{V_1V_2\sin\delta}{X} \qquad (3)$$

$$Q=\frac{V_1(V_1-V_2\cos\delta)}{X} \qquad (4)$$

V1, V2 Line to line voltages

X Reactance of the interconnection of transformer and filters

Δ Phase angle of V1 with respect to V2

The purpose of employing STATCOM to the system is to improve the dynamic and transient stability of WECs and improving overall power quality of the system [8,9]. The design of the FLC for AC voltage regulator has been shown in the figure 5. The system voltage is measured at PCC (point of common coupling) and then is compared with reference value. The output of the FLC is Iqref that is then compared with STATCOM reactive current Iq and the output is of the current regulator is the phase shift of the PWM inverter [8].

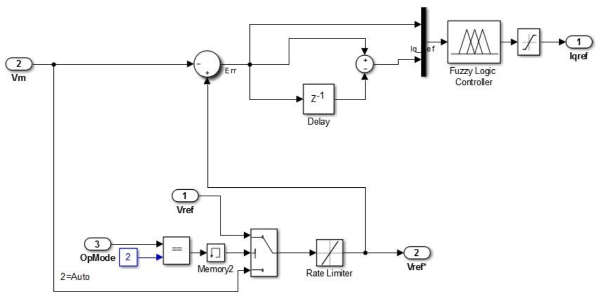

Fig.5 Simulink model of FLC based STATCOM

III. PERFORMANCE ANALYSIS

To bring down an examination among the transient dependability of the UG with WF by utilizing FLC based FACTS that is STATCOM and SVC, a large portion of the past research right now subbing DFIG of a known framework with WF of same size. Same approach is bring down here utilizing the WSCC 9 bus framework. CCT is utilized to comprehend the stability by re-enacting a 3 phase fault at PCC, which is two distinct bus for two unique cases.

A. Fault Analysis when Fault is at bus 8

Bus number 8 of wind farm is integrated with fault. The fault time was 0.1 s. it happens at 1.0 sec and gets cleared after 0.1sec. fig 7 shows voltage Response of different bus. Fig. 6 presentations the dynamic reaction of current, voltage, reactive power and active power of generator one. it could be observed that the system under failure is unstable for a brief time on the grounds that the fault location is very distant from this bus. Those system which utilizing FACTs devices arrives at consistent state inside practically half of time required by the system without utilizing FACTs.

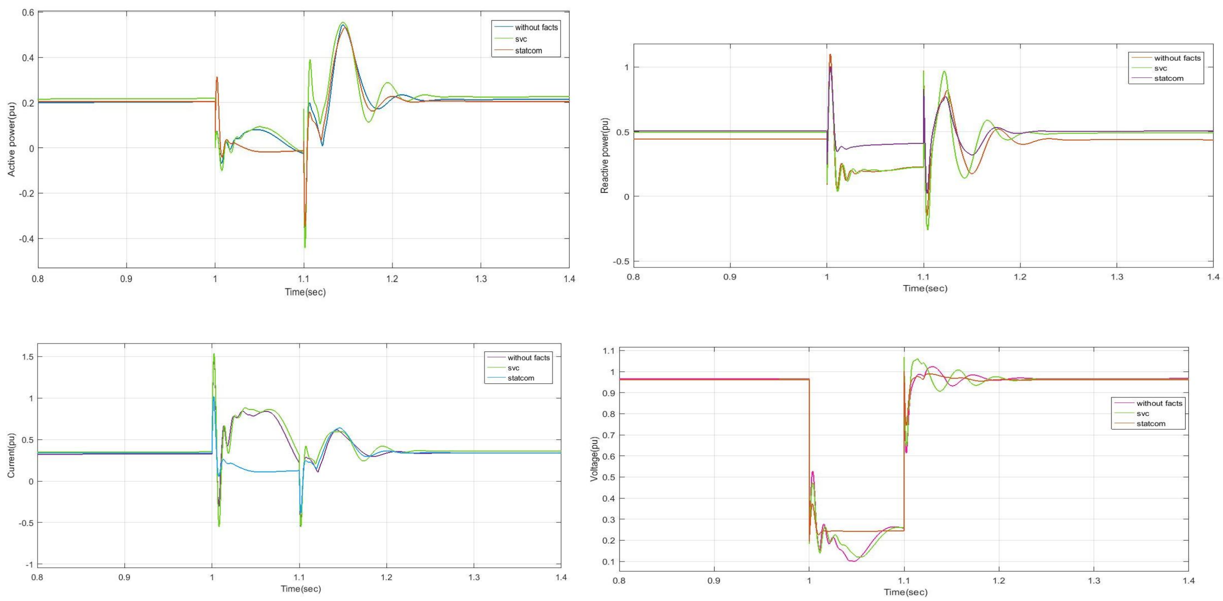

Fig6.Response of active power, reactive power, current, and voltage of wind farm

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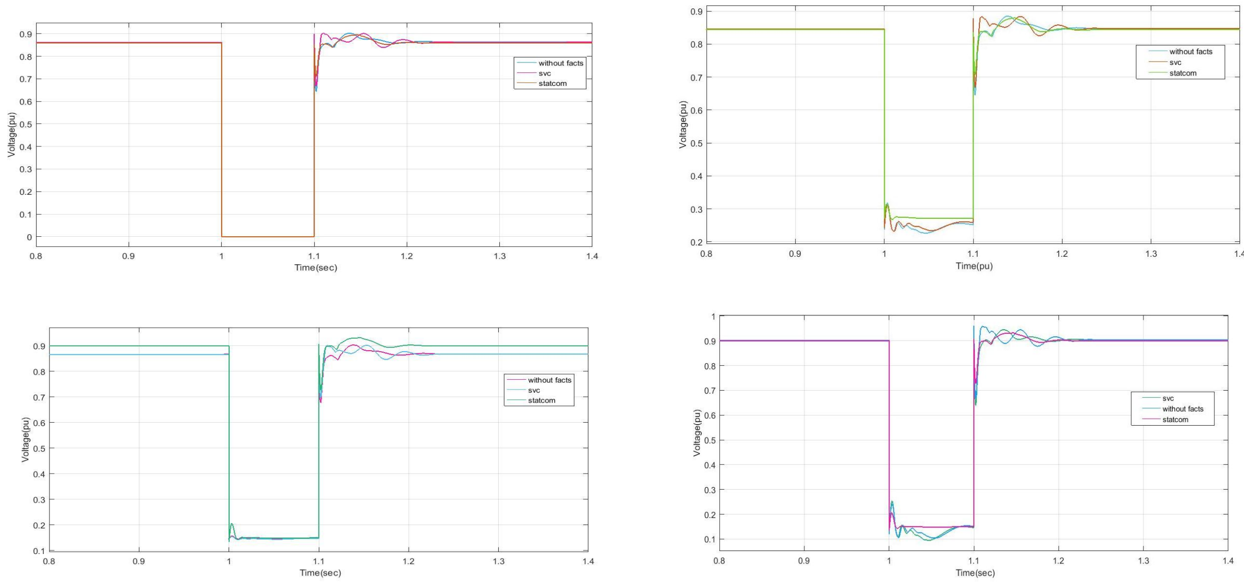

Fig 7. Response of voltages at buses (a) Bus 6 (b) Bus 7 (c) Bus 8 (d) Bus 9

B. Fault analysis when fault is at bus number 3

The response of current (I), voltage (V), reactive power (Q) and active power (P) of wind farm is presented in fig.8. It is observed that the system integrated with STATCOM have less steady state time. The framework with SVC takes more time to be stable. The response of voltages of framework Buses numbered at 6, 7, 8 and 9 is shown in Fig9.

It is to be notice that the framework is unstable for a brief period on the grounds that the disturbance is distant from this bus. The framework utilizing STATCOM arrives at consistent state inside half of time that the framework utilizing SVC arrives at consistent state rapidly. The system with SVC sets aside longer effort to be steady.

From above waveforms it is noticed that system with STATCOM shows efficiently improved time response than SVC. It has less over shooting and the system with SVC has more overshooting.

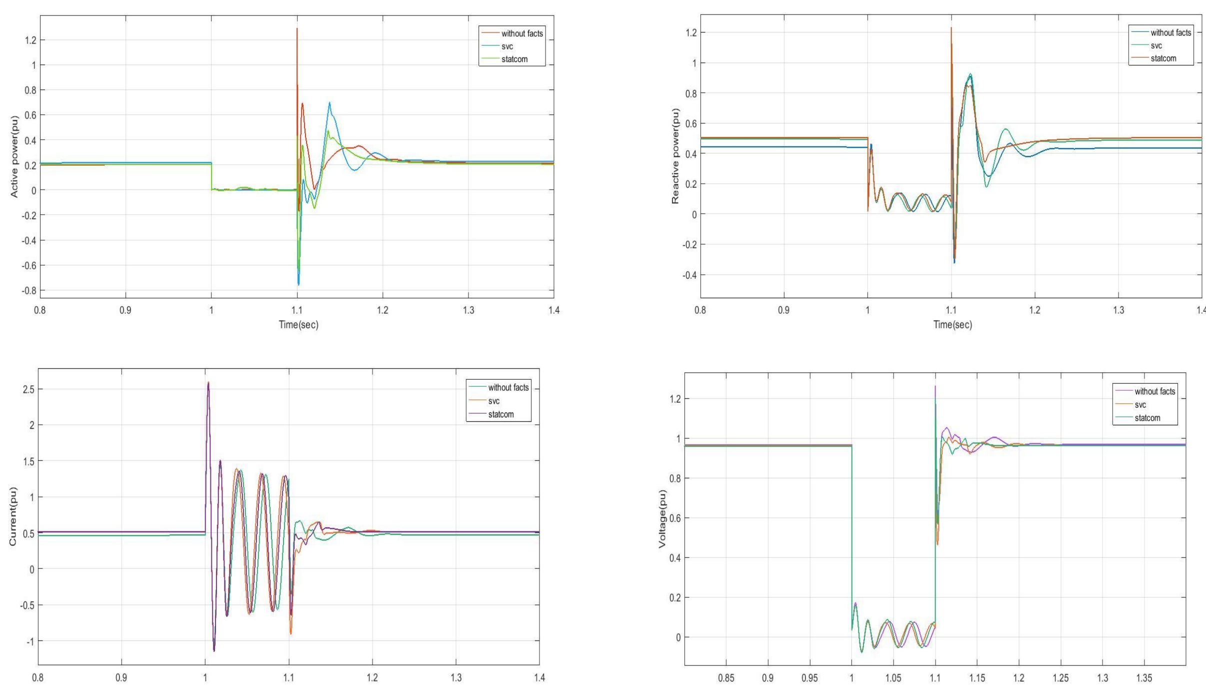

Fig 8. Dynamic time response of wind farm parameters

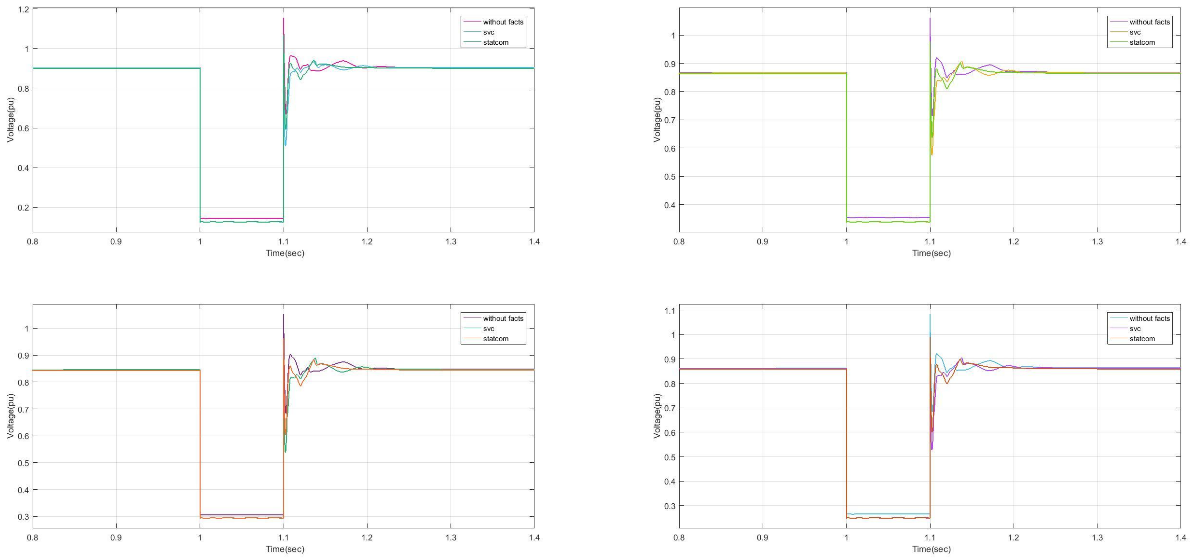

Fig 9. Response of voltage at buses Bus 6 , Bus 7 ,Bus 8 and Bus 9

IV. CONCLUSION

In this paper, the stability analysis DFIG based wind farm connected with WSCC nine bus system has been performed. To play out the investigation a 3-Ø to ground fault is integrated with the system at different areas. Areas chosen depend upon the area of WF association terminal with the framework having multi machine in its network, areas chosen are the points at which bus number three is located and bus number eight is placed that is bus number 3 being the closest association purpose of basic coupling and bus number 8 which is a long way from the association point of common coupling from the wind farm association point. Mamdani's kind of FLC has been utilized. The examination investigation of FACTS devices shows that the presentation of FLC incorporated STATCOM is superior to that of SVC incorporated with FLC for the control architecture, with STATCOM the performance parameters is not as much as contrasting and SVC. Both the FACTS provided reactive power to the force framework under unsettling influence or may be the deficiency condition. Fuzzy logic controller gives enhanced damping execution less quantities of harmonics and quicker reaction with decreased settling time when the framework is under aggravation. The incorporation of FLC with FACTS devices improves the framework execution in correlation with the framework without utilizing any realities gadgets. The incorporation of FLC gives preferable outcome over other traditional controllers. From the investigation done it very well may be at long last said that the STATCOM incorporated with FLC shows preferable execution over with the SVC incorporated with FLC when framework is exposed to any extreme deficiency or an aggravation.

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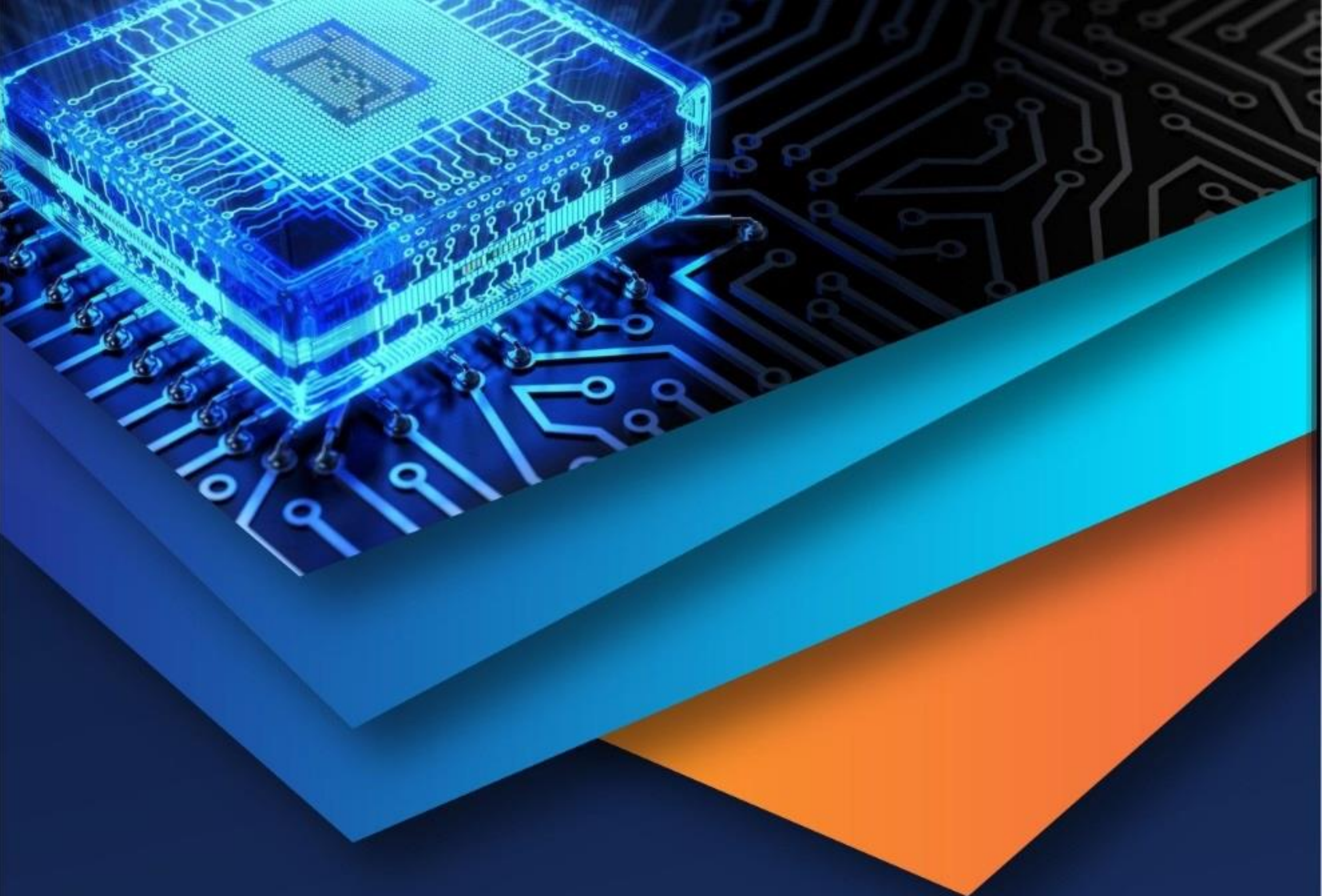

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