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Enhancement of Transient Stability Using UPFC for 11 Bus Systems

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Abstract*—FACTS devices are available, which can help Power Engineers to deal with problems like Large Signal Stability and economic Factors that gives strong incentives to raise the Stability limit of the System, depending upon the diverse conditions. Among the converter based FACTS devices Static Synchronous Compensator (STATCOM) and Unified Power Flow Controller (UPFC) are the popular FACTS devices. Unified Power Flow Controller (UPFC) is a power electronic based device that has capability of controlling the power flow through the line by controlling appropriate its series and shunt parameter. UPFC is a versatile FACTS controller that can regulate the Power Flow through the Line by controlling its Series and shunt parameters. In shunt it is having STATCOM and in series SSSC are employed can independently control the Line Power Flow. Two Converters improves the flexibility and provide additional degree of freedom in Power System. With the application of UPFC, Transient stability of the system can be improved. This Paper shows that how Transient Stability of the Inter Area system is Improved. In this paper, we analyze the transient stability of simple two area system of 11 bus test system of two area system with and without UPFC by comparing the rotor angles, voltage at buses, and angular frequency plots using the Time Domain feature in PSAT software.
***Keywords*—Power system, FACTS, Transient stability, Inter area power system.**

I. INTRODUCTION

In recent years, energy, environment, deregulation of power utilities have delayed the construction of both generation facilities and new transmission lines. FACTS devices are available, which can help Power Engineers to deal with problems like Large Signal Stability and economic Factors that gives strong incentives to raise the Stability limit of the System, depending upon the diverse conditions. Facts devices can provide fast control of Active and Reactive power through Power system. Among the converter based FACTS devices Static Synchronous Compensator (STATCOM) and Unified Power Flow Controller (UPFC) are the popular FACTS devices. They play an important role, not only in increasing the amount of energy transported over the lines, but also in oscillatory and transient-stability enhancement, system reliability, and controllability over the power flow. Considering the practical application of the UPFC in power systems, it is of importance and interest to investigate the benefits as well as model of these devices for power system Transient Analysis. Unified Power Flow Controller (UPFC) is a power electronic based device that has capability of controlling the power flow through the line by controlling appropriate its series and shunt parameter. It has been reported that UPFC can improve transient stability of a system.

II. PRINCIPLE OF UPFC

One FACTS controller in particular, the Unified Power Flow Controller (UPFC), is capable of concurrently or selectively controlling transmission line power flows, voltage magnitudes and phase angles in a power system. Here in fig.1 given below UPFC is shown with both PWM and Phase Control strategy. The Unified Power Flow Controller (UPFC) concept was proposed by Gyugi in 1991. UPFC is an electrical device for providing fast-acting reactive power compensation on high-voltage electricity transmission networks. The UPFC is a combination of a Static Synchronous Compensator (STATCOM) and a Static Synchronous Series Compensator (SSSC) coupled via a common DC voltage link. The UPFC is made out of two voltage-source converters (VSC) with semiconductor devices having turn-off capability, sharing a common dc capacitor and connected to a power system through coupling transformers. The basic UPFC structure is depicted in Figure shown above. This figure represents control strategies (pulse-width modulation (PWM) and phase control). The reactive power is generated/absorbed independently by each converter and does not flow through the dc link. There are two basic control strategies that can be utilized to control the switching of the semiconductor switches in the converters, i.e., PWM and phase controls. GTO switches operate adequately at the “low” switching frequencies required in phase control, but present high losses at the “high” switching frequencies needed for PWM control.

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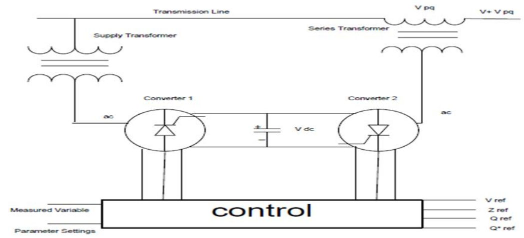

Figure 1.UPFC is shown with both PWM and Phase Control strategy.

However, recent advances in high voltage IGBT technology have led to the development of the Integrated Gate Commutated Thyristor (IGCT), which is basically an optimum combination of thyristor and GTO technology at low cost, low complexity, and high efficiency. It can handle higher switching frequencies with relatively low losses, allowing for the practical implementation of PWM control methodologies.

III. PSAT SIMULATION MODEL

A. *System (I)Under Study*

In this Model there are 11 Buses, Bus No. 3 is kept as Slack bus which maintain its voltage at 1 p.u. and Bus 1,2 & 4 are Generator (PV) Buses. Fault is simulated at Bus 8 at 1sec. and Fault clearing time at 1.05 sec.

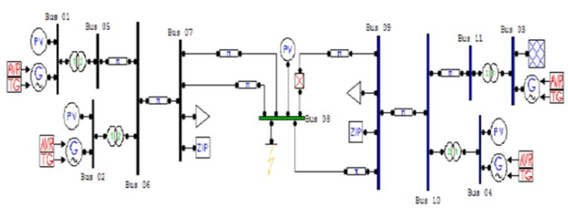
Figure 2 11 Bus test System Without FACTS devices

The all four Generators has been modelled with Power Rating of 900MVA and 20KV at 60HZ frequency. All buses connected to each other by π- Section of transmission line. The automatic voltage regulator used is type 3 in PSAT tool of MATLAB with the range of +100KV to -100KV and having the gain of 200p.u. for maintaining the voltage level as near to 1p.u. Turbine Governor is used of type 2 and having the ref. speed of 1 p.u. and the droop is kept 0.02p.u. with max. torque and min. torque limit at1.2 and 0.3p.u. Generators are connected to the system via transformers maintaining the system voltage at 230KV and 100MVA. Load is also connected to the Bus7 and Bus8. In this Model, Voltage profile at all 11 buses and Rotor angle are studied without any FACTS devices.

B. *System (II)Under Study*

The all the parameters of Generators, Slack bus, Transformers and Load are kept same as were in above given Model. UPFC is employed in between Bus8 where fault is simulated and Bus9 POD controller for maintaining the voltage at faulty bus. The Voltage profile of all the buses and Rotor angle are studied at different Fault clearing time with UPFC and the results are compared with the results of 11Bus test system without any FACTS device.

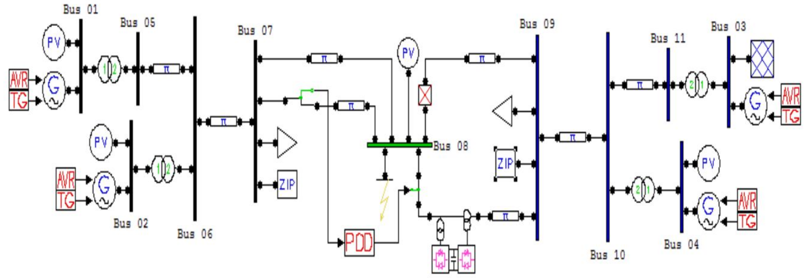

Figure 3. 11Bus test System With United Power Flow Controller

C. *System (III) Under Study*

The all the parameters of Generators, Slack bus, Transformers and Load are kept same as were in above given Model. Additionally, another four more buses are added to the above system, two buses in area 1 and two buses in area 2 .UPFC is employed in between Bus8 where fault is simulated and Bus9 POD controller for maintaining the voltage at faulty bus. The Voltage profile of all the buses and Rotor angle are studied at different Fault clearing time with UPFC and the results are compared with the results of 11Bus test system with and without any FACTS device.

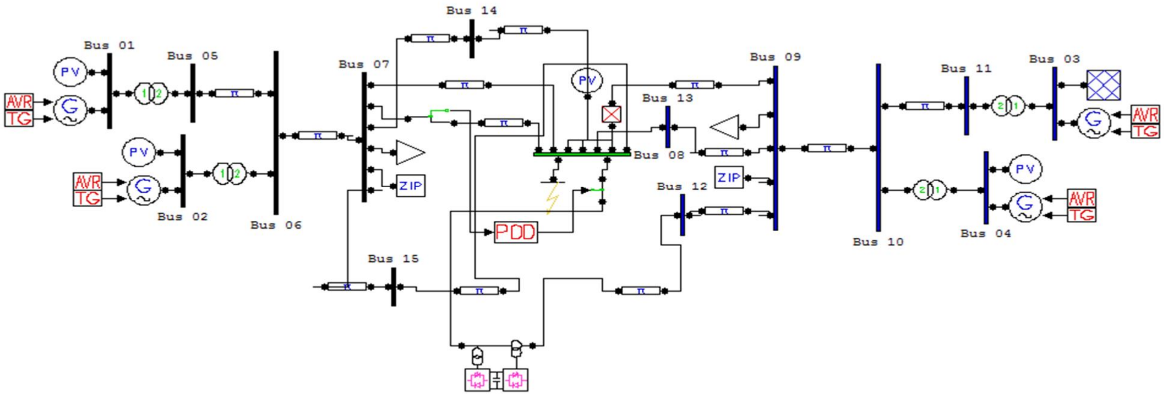

Fig 4. Simple Two Area System of 15 Bus With UPFC

IV. SIMULATION RESULTS

Fig 5 – 14 show the simulation results of rotor angle, voltage at different buses and angular frequencies in PSAT

A. Rotor Angle

The graphs shows the Generator rotor angles w.r.t. time in case with and without UPFC of 11 bus and with UPFC of 15 bus system

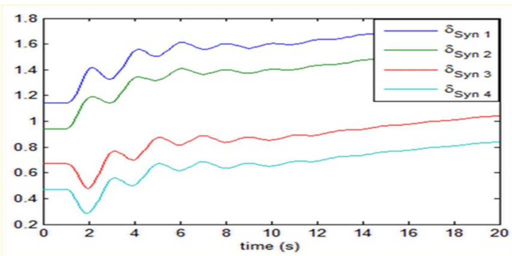

Fig. 5 Rotor angles 1, 2,3& 4 of a simple two area 11 bus test system without UPFC

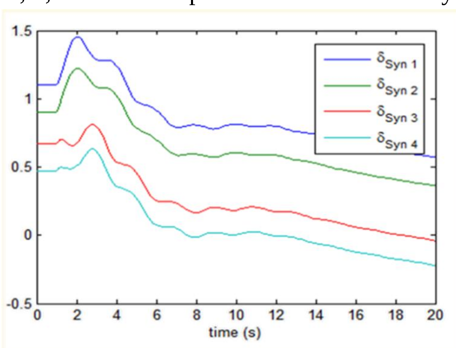

Fig. 6 Rotor angles 1,2,3& 4 of a simple two area 11 bus test system with UPFC

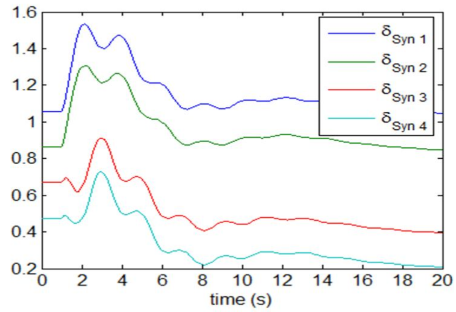

Fig. 7 Rotor angles 1,2,3& 4 of a simple two area 15 bus test system with UPFC

Without using the UPFC the rotor angles are increasing and go out of synchronism. But, with UPFC they remain in synchronism in both 11-bus and 15-bus system. A slight variation is observed between the rotor angles of 11-bus and 15-bus test system at fault clearing time 1.05 sec. But, both remain in synchronism.

B. Voltage Profile

The graphs shows the voltages at various buses with and without UPFC of 11 bus and 15 bus systems

C. Voltage At Bus1

The graphs shows the voltage at bus 1 of the simple two area 11 bus, 15 bus test system without and with UPFC.

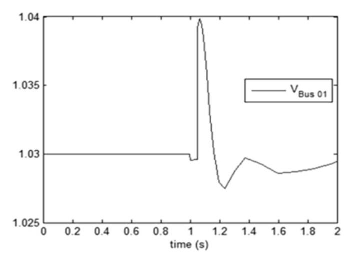

Fig. 8 Voltage at bus 1 of a simple two area 11 bus test system without UPFC

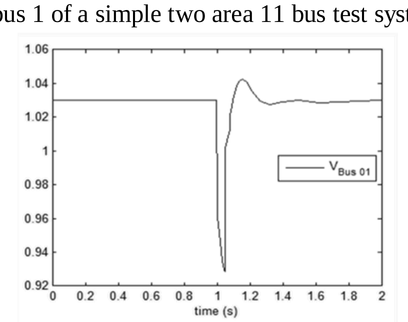

Fig. 9 Voltage at bus 1 of a simple two area 11 bus test system with UPFC

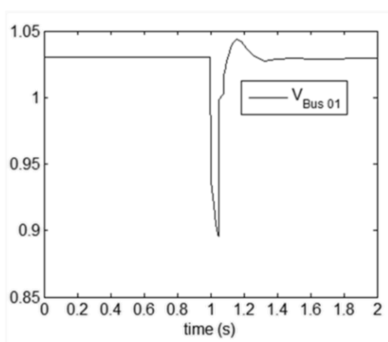

Fig. 10 voltage at bus 1 of a simple two area 15 bus test system with UPFC

Bus 1 is a PV bus. Without UPFC, the voltage at bus 1 takes more than 2 sec to settle down after the major disturbance settles at 1.05 sec. With UPFC, the voltage at bus 1 settles down at 1.2 sec.

D. Voltage at Bus2

The graphs shows the voltage at bus 2 of the simple two area 11 bus, 15 bus test system without and with UPFC.

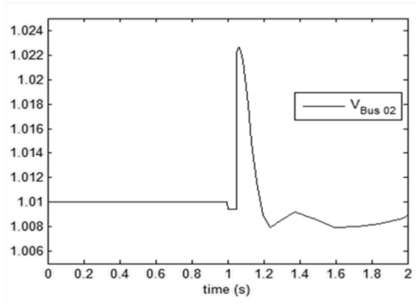

Fig. 11 Voltage at bus 2 of a simple two area 11 bus test system without UPFC

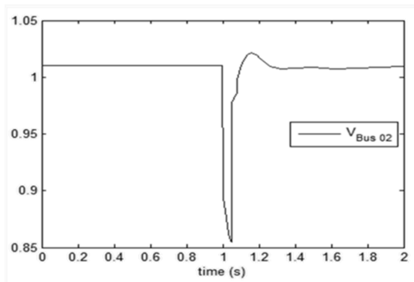

Fig. 12 Voltage at bus 2 of a simple two area 11 bus test system with UPFC

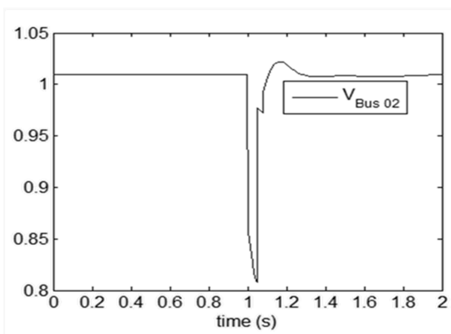

Fig. 13 Voltage at bus 2 of a simple two area 15 bus test system with UPFC

Bus 2 is again a PV bus. The graph showing voltage rise after fault clearance time without UPFC and take more time to settle down. But with UPFC it follows the normal profile and settles down quickly in both 11 bus and 15 bus test systems.

E. Voltage At Bus 3

The graphs shows the voltage at bus 3 of the simple two area 11 bus, 15 bus test system without and with UPFC.

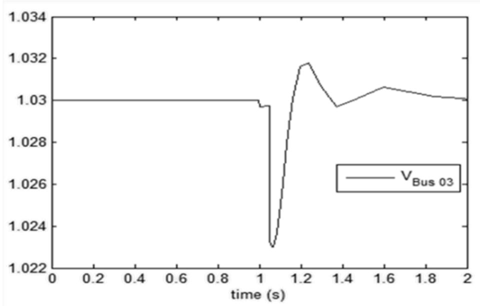

Fig. 14 voltage at bus 3 of a simple two area 11 bus test system without UPFC

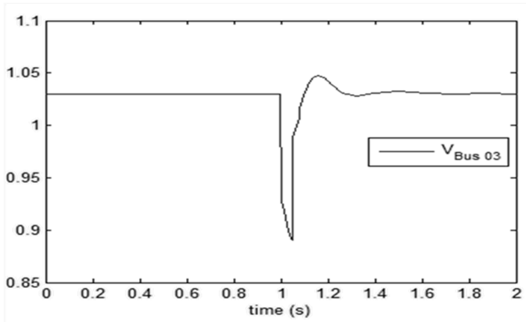

Fig. 15 Voltage at bus 3 of a simple two area 11 bus test system with UPFC

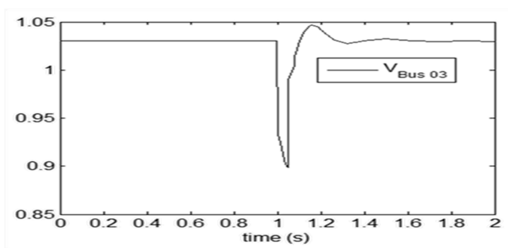

Fig. 16 Voltage at bus 3 of a simple two area 15 bus test system with UPFC

Bus 3 is a Slack bus so Voltage profile will be same with and without UPFC.

F. Voltage At Bus 4

The graphs shows the voltage at bus 3 of the simple two area 11 bus, 15 bus test system without and with UPFC.

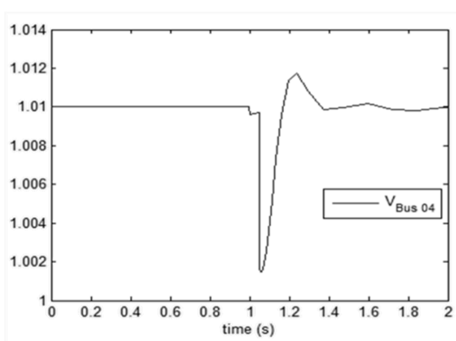

Fig. 17 Voltage at bus 4 of a simple two area 11 bus test system without UPFC

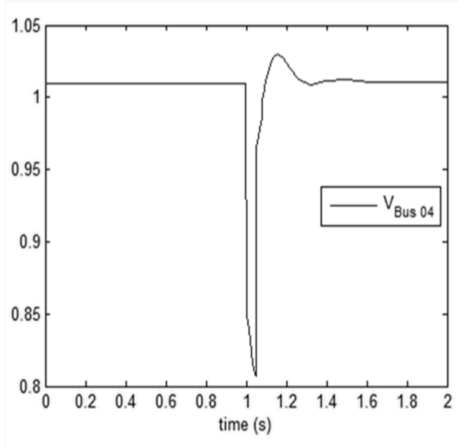

Fig. 18 Voltage at bus 4 of a simple two area 11 bus test system with UPFC

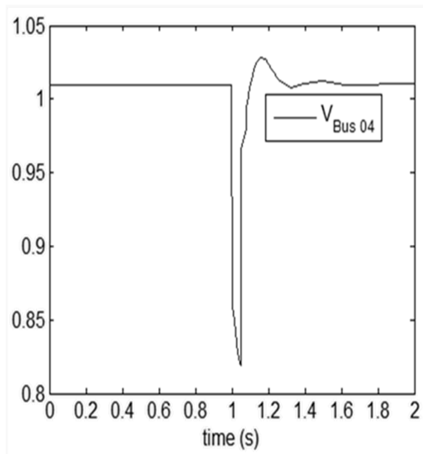

Fig. 19 Voltage at bus 4 of a simple two area 15 bus test system with UPFC

Bus 4 is a PV Bus. The settling time is reduced with UPFC.

G. Voltage At Bus 11

The graphs shows voltages at bus 3 of the simple two area 11 bus, 15 bus test system without and with UPFC.

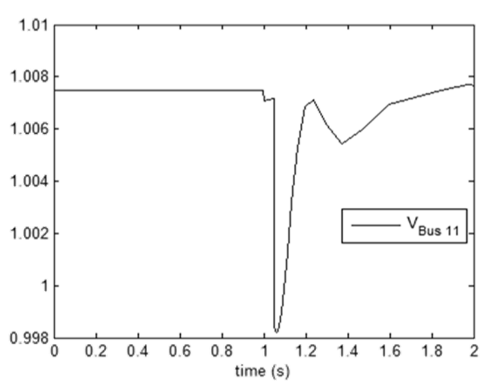

Fig. 20 Voltage at bus 11 of a simple two area 11 bus test system without UPFC

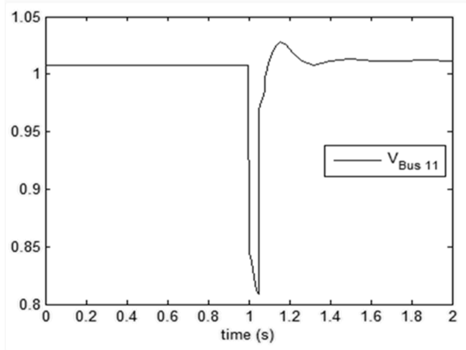

Fig. 21 Voltage at bus 11 of a simple two area 11 bus test system with UPFC

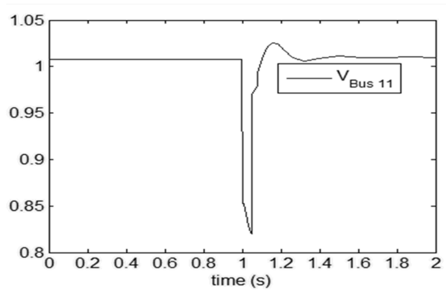

Fig. 22 Voltage at bus 4 of a simple two area 15 bus test system with UPFC

At Bus11 settling time is reduced and Voltage reaches to its pre fault value quickly without oscillations.

H. Angular Frequency

The graphs shows angular frequencies of all generator buses of the simple two area 11 bus, 15 bus test system without and with UPFC.

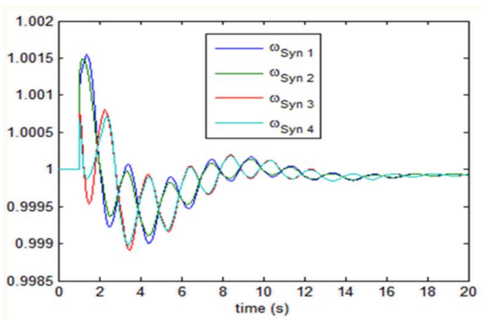

Fig. 23 Angular frequency of a simple two area 11 bus test system without UPFC

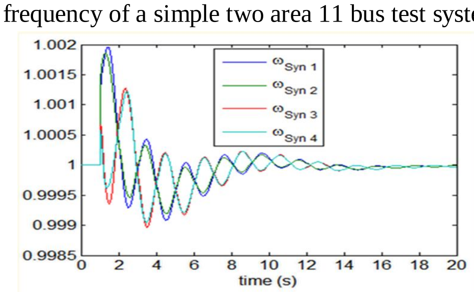

Fig. 24 Angular frequency of a simple two area 11 bus test system with UPFC

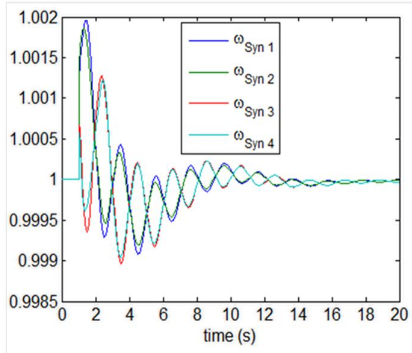

Fig. 25 Angular frequency of a simple two area 15 bus test system with UPFC

The angular frequency value settles to 1 p.u value after 20 sec without UPFC. The angular frequency value settles to 1 p.u value after 15 sec for both 11-bus system and 15-bus system.

V. CONCLUSIONS

This project investigated the capability of UPFC on transient stability of a Two-area power system. Here, we have two area test system i.e. 11 bus system and 15 bus system. The analysis of Generator Rotor angle, Voltage Profile and Angular Frequency is done with and without UPFC of simple two area 11 bus and 15 bus test systems and the obtained results are compared when the fault is created at bus 8.Without UPFC the Rotor angle of all the buses increases and will lead the system out of synchronism whereas with UPFC they are decreasing and settling down. So, system attain in synchronism. The Buses of Area 1 and The Buses of area 2 their settling time is more than 2sec without UPFC. With the application of UPFC the settling time is reduced to 1.18 sec. for all buses. The Angular Frequency without UPFC settles to 1 p.u. value after 20sec. with UPFC Angular frequency starts settling down after 15sec. at fault clearing time 1.05 sec. Hence, transient stability analysis of simple two area 11 bus systems without any FACTS is done and obtained, almost similar results to simple two area 15 bus power system with UPFC and analyzed the effect of UPFC on 15 bus two area power system in damping oscillation while improving transient stability. Thus, it is verified that UPFC can improve the transient stability of power system.

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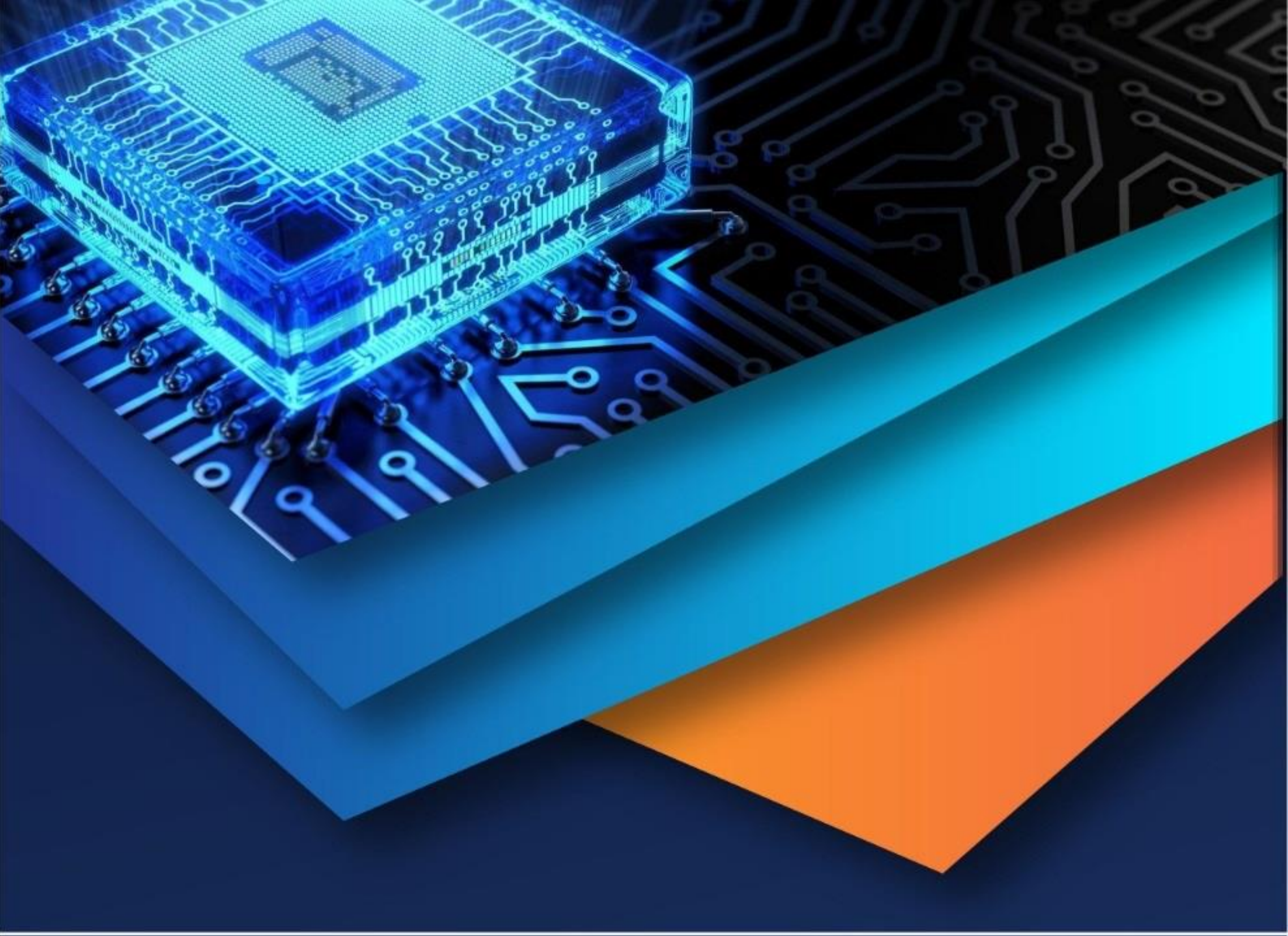

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