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Stability Improvement of FSIG based Grid Connected Wind Farm Using STATCOM/SVC during different Fault Locations

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Abstract-The effect of fault locations on the behavior of the FSIG based wind farm interconnected grid during different fault types is investigated in this paper. The effects of fault locations are studied for different fault types. The contribution of Static Synchronous Compensator STATCOM and Static Var Compensator (SVC) to support the FSIG based wind farm interconnected electric grid during different fault locations are investigated. The wind farm terminal voltage, the exported active power, and the absorbed reactive power are monitored in different fault conditions.Simulation test cases using MATLAB-Simulink are implemented on a 13.5 MW wind farm exports power to a 220 KV grid.
Keywords-Static Var Compensator (SVC); Static Synchronous Compensator (STATCOM); Fixed Speed Induction Generator (FSIG).

I. INTRODUCTION

An increasing demand for more electric power coupled with depleting natural resources has led to an increased need for energy production from renewable energy sources such as wind and solar. The recent technological advancements in wind energy conversion and an increased support from governmental and private institutions have led to increased wind power generation in recent years. Wind power is the fastest growing renewable source of electrical energy. In the past, the total installed wind power capacity was a small fraction of the power system and continuous connection of the wind farm to the grid was not a major concern. With an increasing share derived from wind power sources, continuous conection of wind farms to the system has played an increasing role in enabling uninterrupted power supply to the load, even in the case of minor disturbances.

Voltage stability and an efficient fault ride through capability are the basic requirements for higher penetration. Wind turbines have to be able to continue uninterrupted operation under transient voltage conditions to be in accordance with the grid codes [2]. Grid codes are certain standards set by regulating agencies. Wind power systems should meet these requirements for interconnection to the grid. Different grid code standards are established by different regulating bodies, but Nordic grid codes are becoming increasingly popular [3].One of the major issues concerning a wind farm interconnection to a power grid concerns its dynamic stability on the power system [4]. Voltage instability problems occur in a power system that is not able to meet the reactive power demand during faults and heavy loading conditions. Stand alone systems are easier to model, analyze, and control than large power systems in simulation studies. A wind farm is usually spread over a wide area and has many wind generators, which produce different amounts of power as they are exposed to different wind patterns.

In past years, various researchers have studied the performance improvement methods using FACTS devices that are being researched upon in the field of grid connect wind farm network. The flexible alternating current transmission systems (FACTs) devices are the most suitable promise tools for voltage and dynamic stability improvement of wind energy systems connected to grid as well as sand alone. There are many useful types of FACTs devices are applied successfully for improving the dynamic stability of wind energy systems connected to grid. Flexible AC Transmission Systems (FACTS) such as the Static Synchronous Compensator (STATCOM) and the Unified Power Flow Controller (UPFC) are being used extensively in power systems because of their ability to provide flexible power flow control [5]. Static synchronous compensators (STATCOM) and static VAR compensators are used widely for improving the voltage and dynamic stability of wind energy systemss

The stability of wind farms based on fixed speed induction generators have been studied in [6]. The use of the SVC and STATCOM is investigated for wind farm integration. The effect of location and its duration time is studied for different fault types. The simulation results show the influence of fault location and its duration on active power, reactive power, and bus voltage of the wind farm. A Comparative analysis of the transient stability improvement of a FSIG based wind farm illustrates that, these devices

considerably improve wind farm stability [7]. In comparison with SVC, STATCOM is best choice for increasing stability of grid connected wind farms. It is necessary to examine the responses of SCIG wind farm during the faults
and possible impacts on the system stability. In this paper, theimpacts of fault location on 13.5 MW windfarm interconnected grid are studied by monitoring the activepower, reactive power, and bus voltage of the wind farm. Also,the contribution of STATCOM and SVC to support the wind farm duringdifferent fault locations are studied.

II. SIMULATED NETWORK

The single line diagram of a typical fixed speed wind power plant under study is shown in Figure 1. The simulation model is carried out using the MATLAB SimPowerSystems toolbox. A power system model of wind farm distribution network is shown in Figure 2. The system consists of a 220 KV,50-Hz, sub transmission system with short circuit level of 2500 MVA, feeds a 33 KV distribution system through 220 kV/33 V step down transformer. A test system consisting of three wind farm of 13.5 MW (each 4.5 MW) and each wind farm having three equal capacity (1.5 MW) wind turbine induction generators (WTIGs) are connected to the 33 KV distribution system, exports power to 220 KV grid through a 50 km transmission line and two loads have been connected to the network.

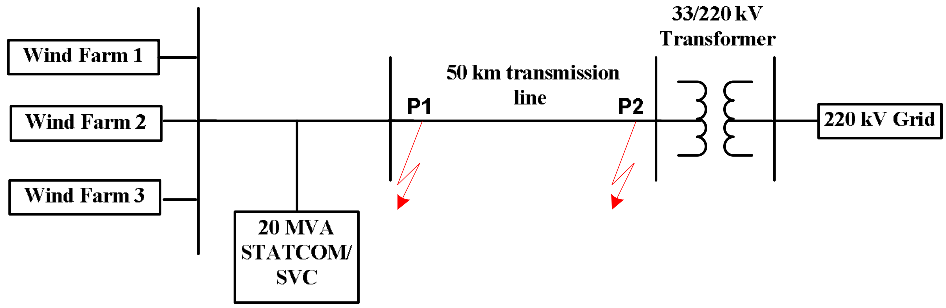

Figure 1: Single line diagram of the studied system

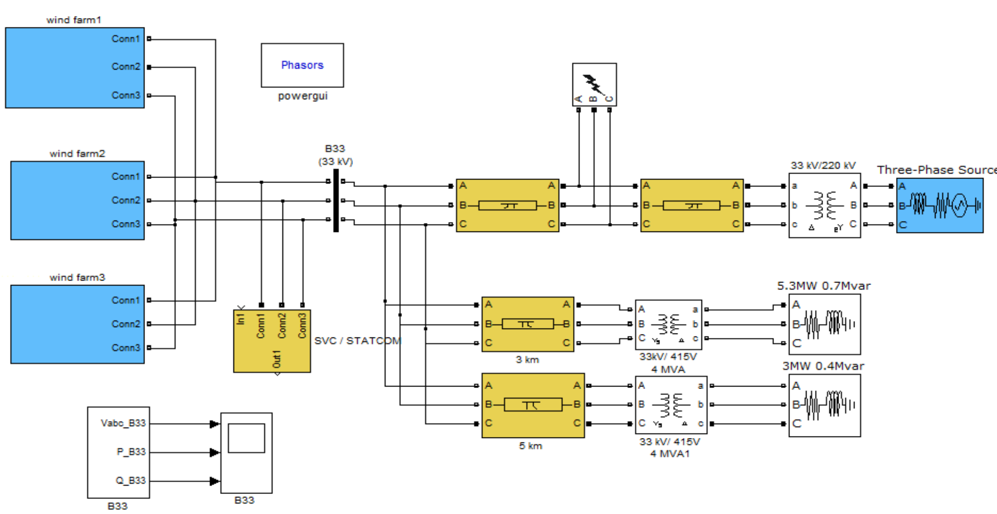

Figure 2: Simulation model of Wind Farm distribution network

Fixed capacitor banks are connected at low voltage bus of each wind turbine (400 KVAR for each pair of 1.5 MW turbines) which supplies the constant no load demand of the induction machine. A 20 MVAR STATCOM is connected at the main bus B33. The bus B33 is the main bus of the wind farm which connects the wind farm with the grid, so in this work this bus is taken as the monitoring point of the whole studied wind farm. The monitoring equipments (measuring equipments) are placed at the main bus B33 for monitoring: the total exported (generated) active power from the wind farm to the grid, the total absorbed reactive power from the grid and the terminal voltage at the main bus of the wind farm.

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III. SIMULATION SCENARIO

The test system is studied at steady state condition and fault state condition. At the fault state, the voltage, active power and reactive power are monitored at the main bus B33. The behavior of the wind power plant is recorded during fault events and after fault clearance. The studied wind farm operates at the nominal wind speed of 11 m/s, so the wind turbines operate at nominal values. During fault period, it can be assumed that the wind speed does not change and to study the effect of various fault types and fault location, the simulation is performed when the fault occurs at points P1 and P2 as shown in Fig. 1. The first faults location at the point P1 about 1 km from the wind turbines and the second fault location at the point P2, about 49 km from the main wind farm main bus B33. The system is studied thrice: one without STATCOM/SVC connection, second with STATCOM connection and other with SVC connection.

IV. SIMULATION RESULTS AND DISCUSSIONS

The effect of fault location on the stability of the wind farm connected grid are studied for different fault types as single line to ground fault, double line to ground fault, and three-line to ground fault. To study the effect of fault location on the behavior of the wind farm, the operation of the wind farm under different fault types are monitored twice, one when the fault occurs at the first fault location P1 about 1 km from wind turbines, and the other when the fault occurs at the second fault location P2 about 49 km from wind turbines. The effect of a 20 MVAR STATCOM and 20 MVAR SVC on the behavior of the wind farm are studied for all cases.

A. Effect of Fault LocationUnder LG Fault

Fig. 3-5 shows the variations of wind farm terminal voltage, generated active power, and absorbed reactive power when a single line to ground fault occurs at the points P1 and P2. A constant wind speed of 11 m/s is applied to the wind turbine. It is clear from Fig. 3-5 that during the fault at point P1 the voltage, active power reduces drastically (when a fault is applied at 1.5 sec and cleared at 1.6 sec.) as compared to fault at P2. And the total reactive power absorbed from grid increase when fault occurs at point P1 as compared to fault at point P2. After fault clearance the wind farm equipped with STATCOM is reaching steady state soon as compared to SVC.

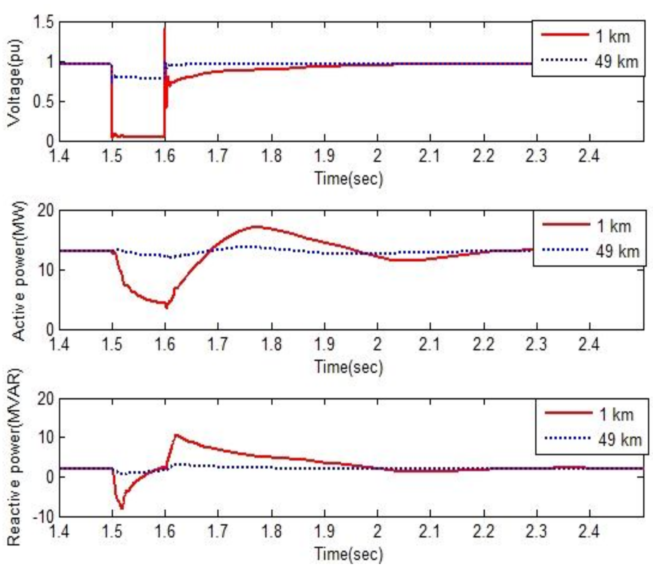

Figure 3: Variations of the voltage, active power, and total absorbed reactive power during single line to ground fault at different fault locations – without

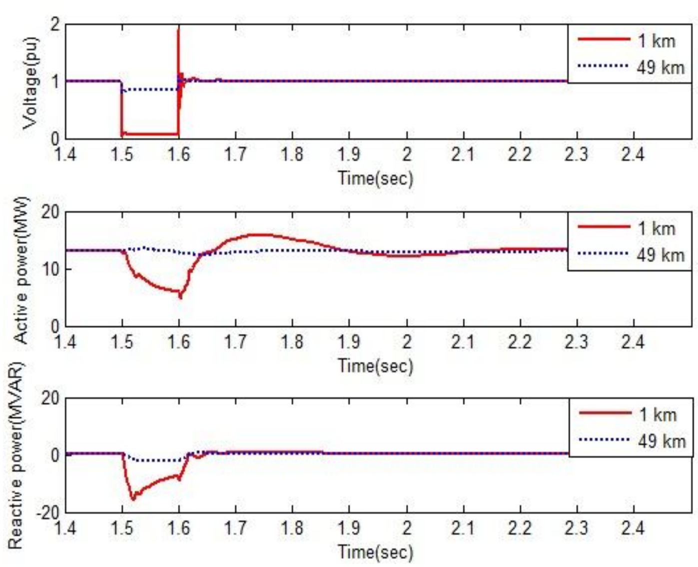

Figure 4: Variations of the voltage, active power, and total absorbed reactive power during single line to ground fault at different fault locations – with STATCOM

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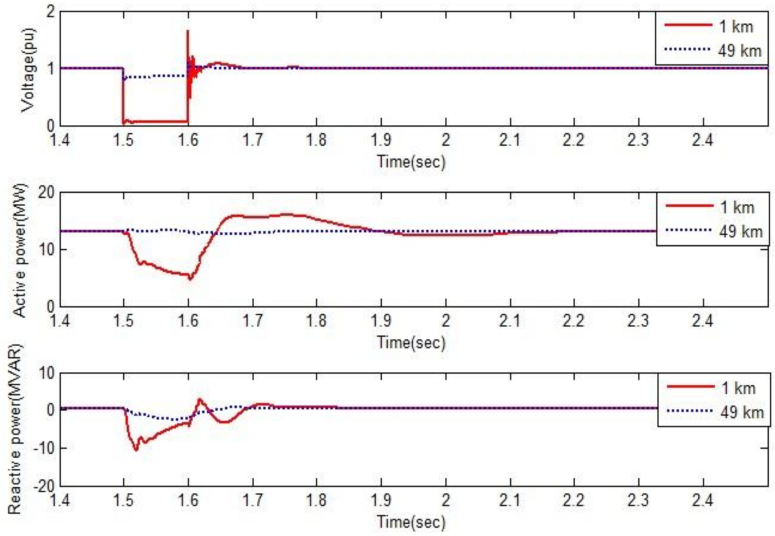

Figure 5: Variations of the voltage, active power, and total absorbed reactive power during single line to ground fault at different fault locations – with SVC

B. Effect of Fault Location Under LLG Fault

Fig. 6-8 shows the variations of wind farm terminal voltage, generated active power, and absorbed reactive power when a double line to ground fault occurs at the points P1 and P2. A constant wind speed of 11 m/s is applied to the wind turbine. It is clear from Fig. 6-8 that during the fault at point P1 the voltage, active power reduces drastically (when a fault is applied at 1.5 sec and cleared at 1.6 sec.) as compared to fault at P2. And the total reactive power absorbed from grid increase when fault occurs at point P1 as compared to fault at point P2. After fault clearance the wind farm equipped with STATCOM is reaching steady state soon as compared to SVC.

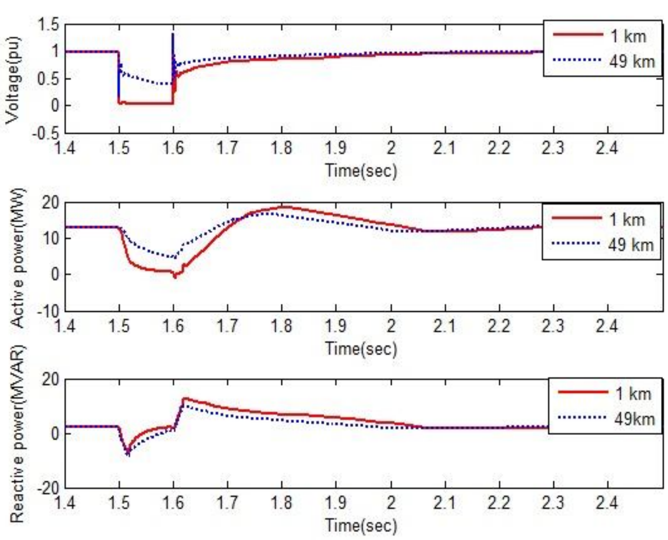

Figure 6: Variations of the voltage, active power, and total absorbed reactive power during double line to ground fault at different fault locations – without STATCOM/SVC

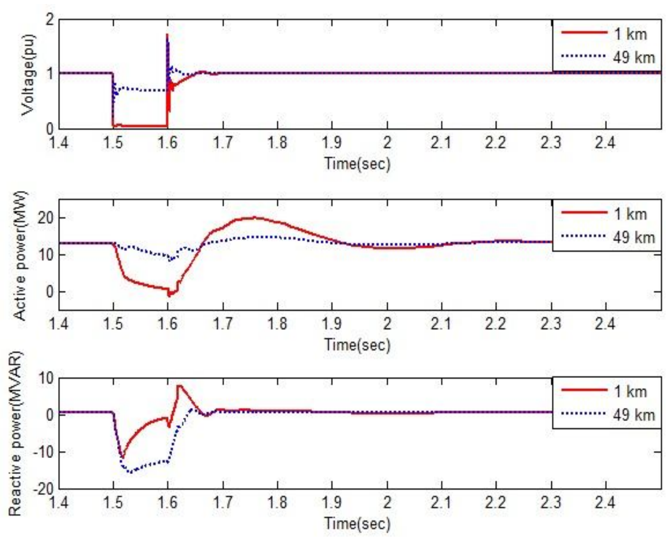

Figure 7: Variations of the voltage, active power, and total absorbed reactive power during double line to ground fault at different fault locations – with STATCOM

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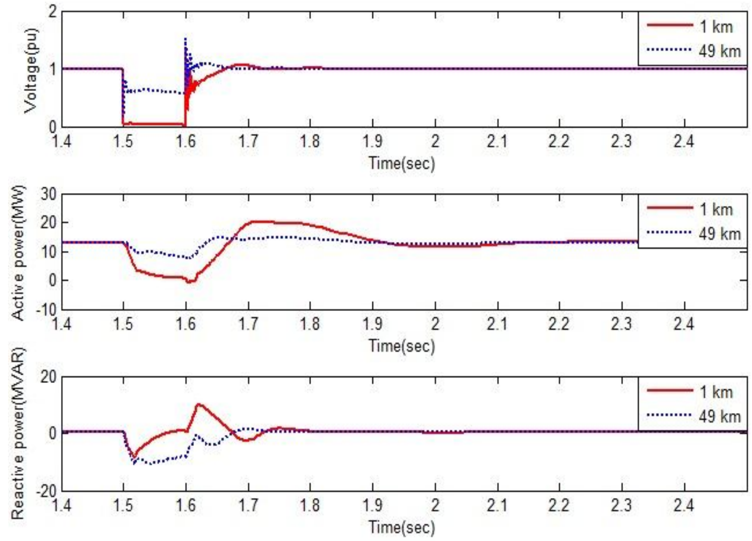

Figure 8: Variations of the voltage, active power, and total absorbed reactive power during double line to ground fault at different fault locations – with SVC

C. Effect of Fault Location Under LLLG Fault

Fig. 9-11 shows the variations of wind farm terminal voltage, generated active power, and absorbed reactive power when a three line to ground fault occurs at the points P1 and P2. A constant wind speed of 11 m/s is applied to the wind turbine. It is clear from Fig. 9-11 that during the fault at point P1 the voltage, active power reduces drastically (when a fault is applied at 1.5 sec and cleared at 1.6 sec.) as compared to fault at P2. And the total reactive power absorbed from grid increase when fault occurs at point P1 as compared to fault at point P2. After fault clearance the wind farm equipped with STATCOM is reaching steady state soon as compared to SVC.

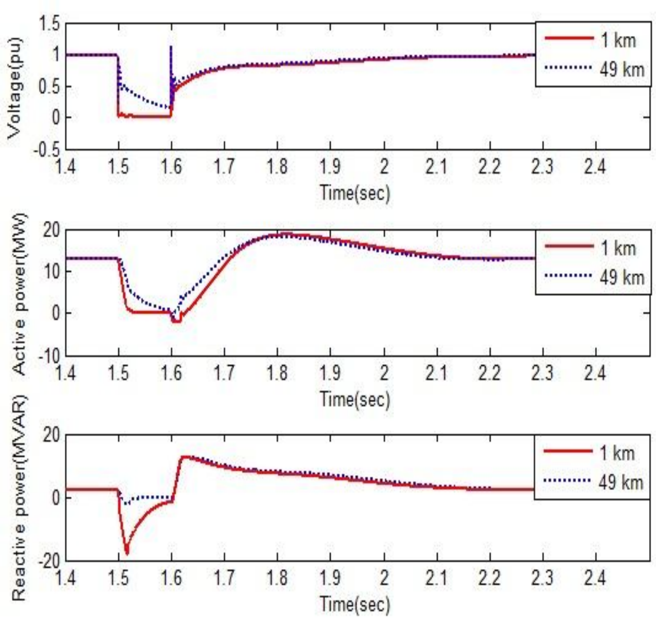

Figure 9: Variations of the voltage, active power, and total absorbed reactive power during three line to ground fault at different fault locations – without STATCOM/SVC

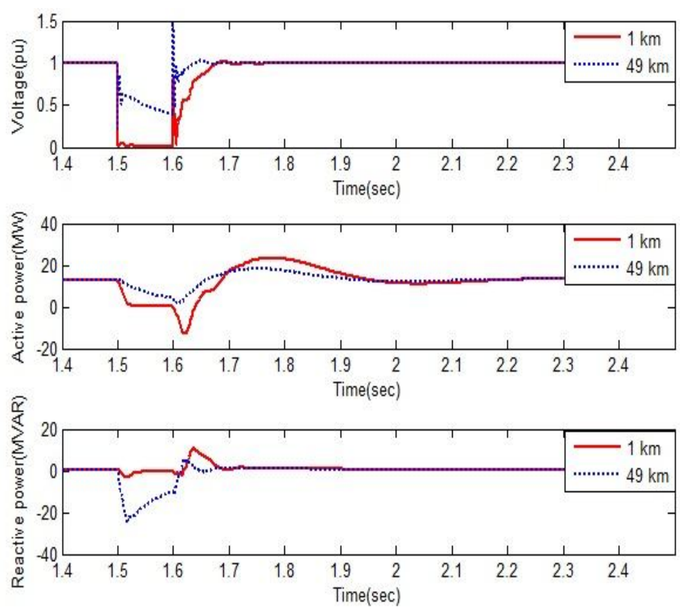

Figure 10: Variations of the voltage, active power, and total absorbed reactive power during three line to ground fault at different fault locations – with STATCOM

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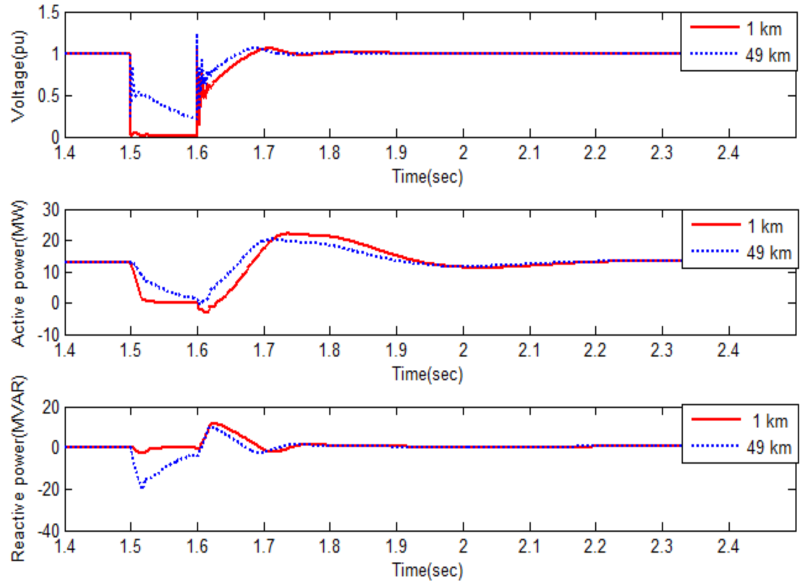

Figure 11: Variations of the voltage, active power, and total absorbed reactive power during three line to ground fault at different fault locations – with SVC

V. CONCLUSIONS

The effect of fault locations on the behavior of the FSIG based wind farm interconnected grid during different fault conditions are studied in this work. Also, the impacts of the Static Synchronous Compensator STATCOM and Static Var Compensator (SVC) on the stability of the system during different fault locations are studied. A simulation model of 13.5MW FSIG based wind farm interconnected grid is investigated. The wind farm terminal voltage, the exported active power, and the absorbed reactive power are monitored in different fault conditions. The fault occurs at two fault locations P1 and P2. Where P1 is located at 1 km from the wind turbines and P2 is located at 49 km from then wind turbines.

By studying the effect of fault location, in the cases of single line to ground fault and double line to ground fault and three line to ground fault it can be concluded that the STATCOM provides better wind farm voltage stability as compared to that with SVC during after fault occurrence. In fault case system with STATCOM gives more voltage, large active power, low value of reactive power supplied by grid to wind farms as compared to that of SVC. The STATCOM has better performance than that of SVC and also STATCOM has faster response than SVC. Thus, the large amount of wind power can be penetrated in to the grid without affecting the machine stability by controlling reactive power flow in the grid using STATCOM of suitable rating.

VI. ACKNOWLEDGMENT

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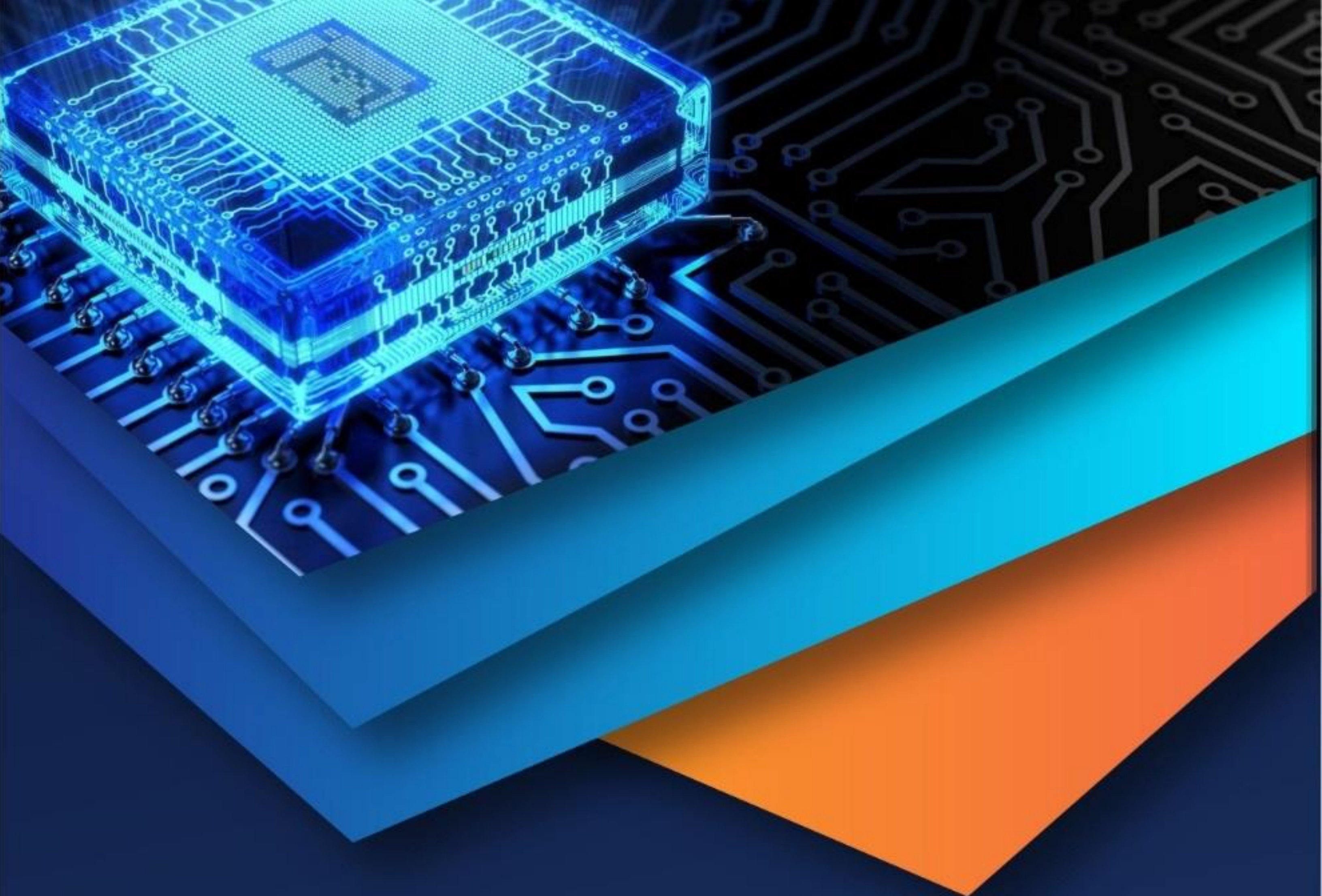

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