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Power Quality Improvement of SCIG Wind Farm Using UPFC and STATCOM

Ajay Kumar[1] and Ratna Dahiya[2]

[1,2]Department of Electrical Engineering N.I.T. Kurukshetra, Haryana (India)
E-mail: [1]ajaychaudhary.ee10@gmail.com, [2]ratna_dahiya@yahoo.co.in

Abstract: *This paper deals with the improvement of voltage stability, reactive power, speed oscillations and pitch angle of Squirrel Cage Induction Generator (SCIG) 9 MW(1.5*6) 120 KV wind farm. To get these results used STATCOM and UPFC Flexible Alternating Current Transmitting System (FACTS) Controller. The optimal location of FACTS devices are more important for stability and controlling. The simulation results has been done on MATLAB/SIMULINK software with these proposed models and the results are presented. The effect of STATCOM and UPFC on active power, reactive power, voltage stability and pitch angle are also presented.*

1. INTRODUCTION

The demand of wind energy is an increasing in whole world in recent days. Due to less availability of Conventional fuels to meet the load demands. India is now more focusing on wind power generation. Thus India got fifth rank in wind power generation in the world. The wind turbines are of fixed speed type equipped with squirrel cage induction generation(SCIG) in India[2]. Because of its robustness and simplicity is become more popular. The major drawback of SCIG is poor voltage regulation under changing loads, because of this the wide applicability of SCIG is restricted. So FACTS Controllers are generally used to overcome this problem.

The Flexible Alternating Current Transmission System (FACTS) technology was invented in 1980s[1].

FACTS technology consists reliable and high speed power electronic devices instead of mechanical controllers. Thus the controllability, stability and utilization of the existing power system is increased. The STATCOM and UPFC are the most comprehensive FACTS devices[3]. A STATCOM is the shunt FACTS controller and UPFC is the series-shunt FACTS. The UPFC and STATCOM are basically deals with voltage control, stability and damping of speed oscillations.

This paper compute the result of SCIG wind farm 9MW without UPFC and STATCOM, with STATCOM and with UPFC simultaneously in MATLAB/SIMULINK software. A STATCOM improved the voltage stability, reactive power and UPFC improved the speed oscillations, pitch angle and reactive power. There is a lot of work has been done on DFIG wind farm with SVC, STATCOM and UPFC[4], but less work done on SCIG wind farm.

2. PROPOSED SCIG WIND FARM

A wind farm consisting of six 1.5 MW wind turbines is connected to a 25 KV distribution system exports power to a 120 KV grid through a 25 Km 25 KV feeder. By three pairs of 1.5 MW wind turbines simulated of 9 MW wind farm The Squirrel-cage induction generator(IG) used in this wind turbines as shown in Fig 7. The rotor winding is connected directly to the stator and stator winding is connected directly to the 60 Hz grid driven by a variable pitch wind turbine[2,4]. The pitch angle is controlled the output power of generator for winds exceeding the nominal speed(9m/s). The IG speed must be above the synchronous speed to generate power. The speed varies approximately between 1 p.u. at no load and 1.005 p.u. at full speed . These three wind turbine has a protection system monitoring current, machine speed and voltage. At each wind turbine low voltage bus(400KVar for each pair of 1.5MW turbine) connected capacitor banks, absorbed reactive power by the IGs is partly compensated by capacitor bank. A 3-MVar STATCOM with a 3% droop setting provide the rest of reactive power required to maintain the 25 KV voltage at bus B25 close to 1 p.u[5]. A schematic diagram of a fixed speed wind turbine are shown in Fig. 1

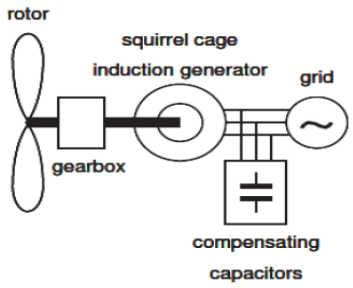

Fig. 1: Schematic diagram of a fixed speed wind turbine

3. STATCOM CONTROLLER

The Static Synchronous Compensator (STATCOM) is a shunt connected VSC based FACTS Controller to stabilize grid connected squirrel cage induction generator system. A STATCOM has the ability to inject or absorb quickly the reactive power with power grid. The voltage control, stability issue , size and location of STATCOM has been analyzed using simulated QV and PV curves[5]. A STATCOM is generally used for voltage control of bus by shunt reactive power compensation. The maximum inductive or capacitive current of the STATCOM may be showed independently of the AC system voltage. A STATCOM can supply the voltage and reactive power during grid fault and steady states[6]. A STATCOM model and simulink model are shown in Fig. 2 and Fig. 4. The simulation model of SCIG wind farm with STATCOM are shown in Fig. 8.

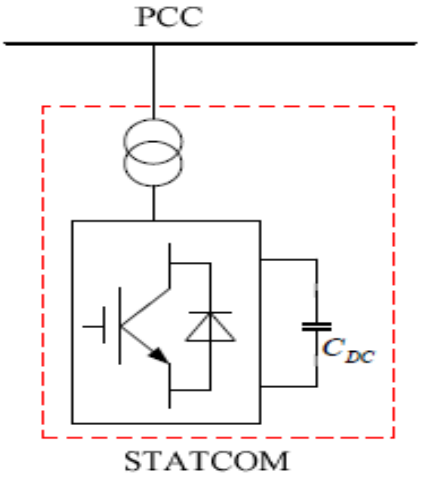

Fig. 2: STATCOM model

The Volt-Ampere characteristics of STATCOM is shown in Fig. 3.

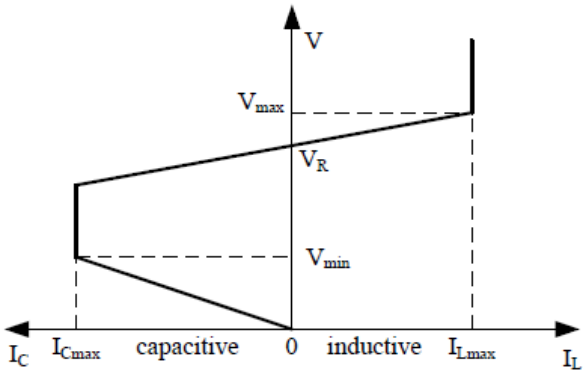

Fig. 3: V-I characteristic curve of STATCOM

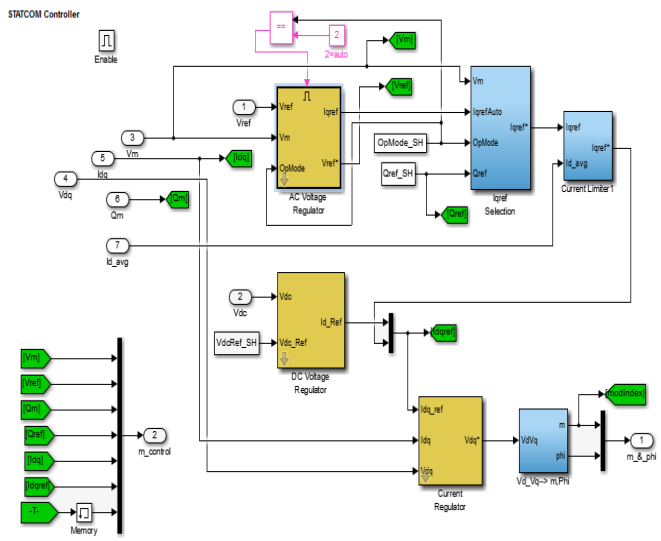

Fig. 4: Simulation model of STATCOM

4. UPFC CONTROLLER

The Unified power flow controller(UPFC) consist one parallel and series converter connected to the transmission line as Fig. 5. To improve the damping of rotor speed oscillations and voltage ride-through of wind farms, UPFC is generally used[7]. UPFC gives good voltage control as compare to STATCOM, due to high cost it is very important for satisfactory performance that the placement of these devices should proper and optimize. Shunt converter is used to inject or absorbed reactive power based on the variation in load. Phase angle and AC voltage is injected with the transmission line with series converter. To match the voltage levels between the power system, to isolate the UPFC and the power electronic inverters used two transformers in UPFC[8]. The simulation model of SCIG wind farm with UPFC are shown in Fig. 9.

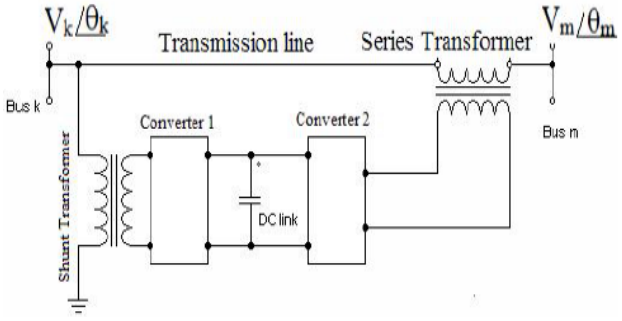

Fig. 5: UPFC model

The simulation model of UPFC are shown in Fig. 6.

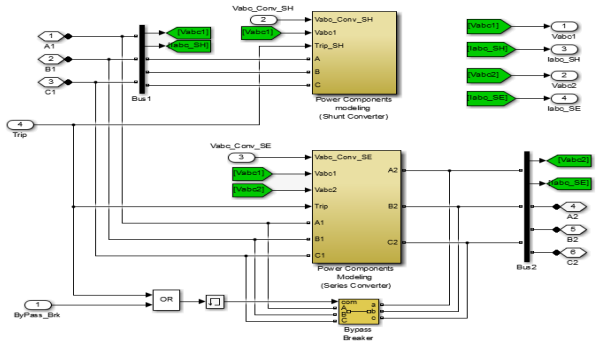

Fig. 6 Simulation model of UPFC

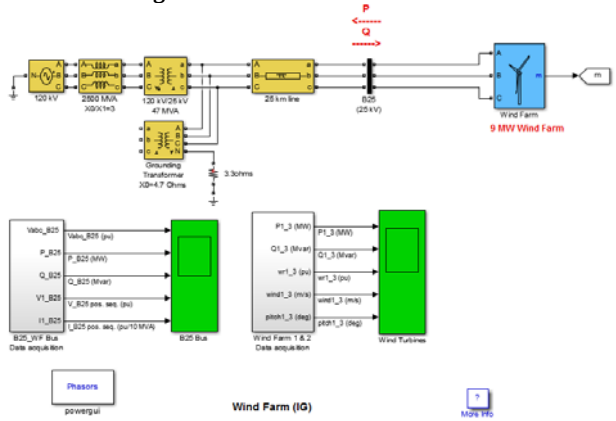

Fig. 7 Simulation model of SCIG wind farm without STATCOM and UPFC

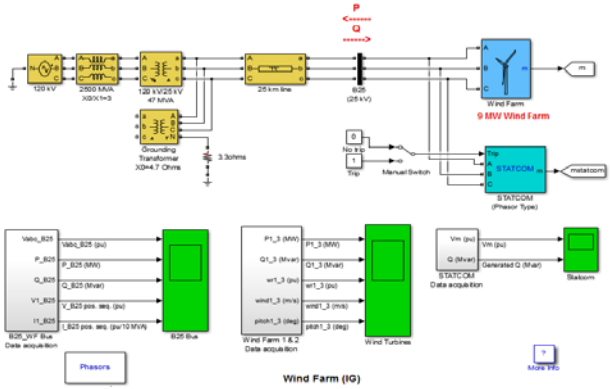

Fig. 8: Simulation model of SCIG wind farm with STATCOM

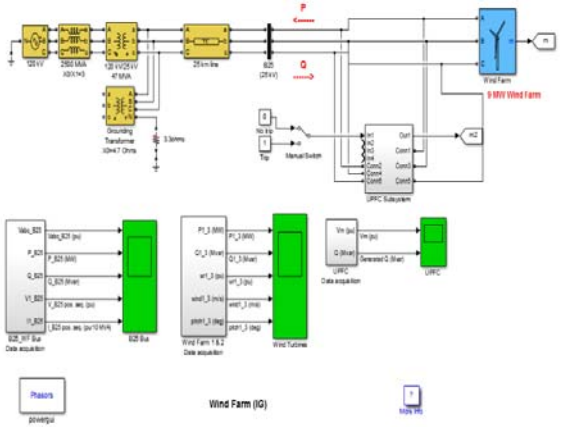

Fig. 9 Simulation model of SCIG wind farm with UPFC

5. SIMULATION RESULTS

The simulation results of SCIG wind farm without compensator, with STATCOM and with UPFC are shown in these figures.

(1) Turbine speed increased from 0.0028p.u. to 1.0047p.u.Pitch angle of the turbine blades is 0 deg. upto 3MW, if exceed from 3MW pitch angle increased 0-8 deg.. In order to bring output power back to its nominal value. The STATCOM maintains voltage at 0.984p.u. by generating 1.62MVar. Each pair of wind turbine absorbs 1.47 MVar.

(2) A phase to phase fault is applied at wind turbine2 terminals at 15 sec causing the turbine to trip at t =15.11sec.

(3) It is observe on “B25 Bus” scope that because of the lack of reactive power support the voltage at “Bus B25” now drops to 0.91 p.u. This low voltage condition is an overload of the IG of wind turbine1.

As the results clearly shows that the voltage stability, power quality and pitch angle has been improved using STATCOM and UPFC in Fig. 10,11,12,13,14,15,16,17.

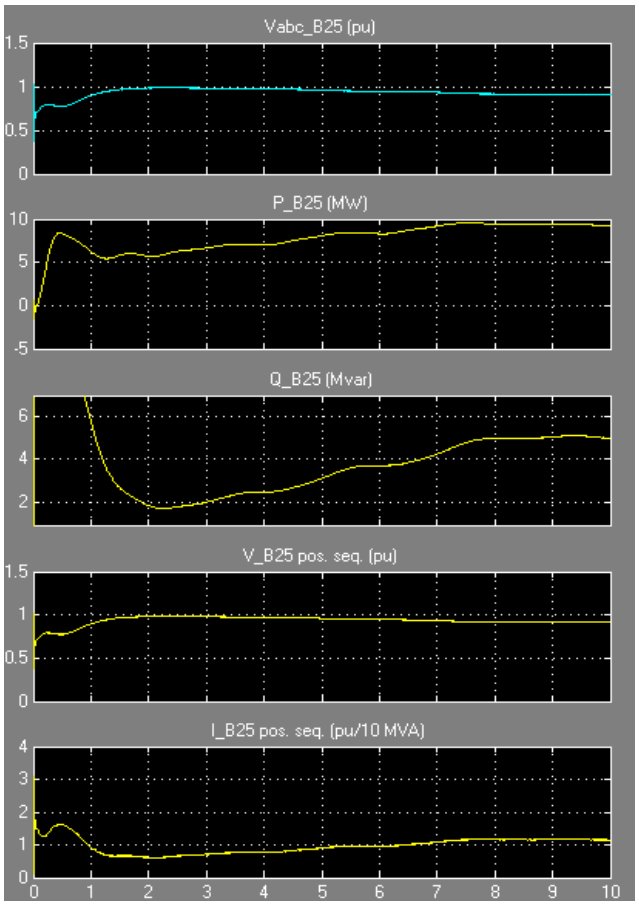

Fig. 10: Simulation result at Bus25 without controller

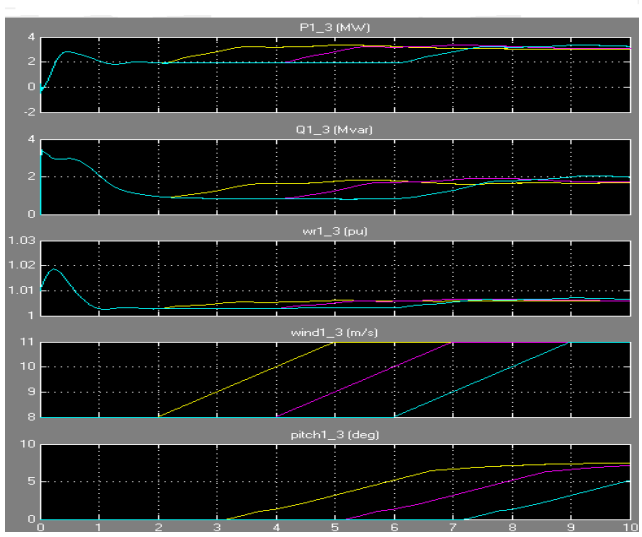

Fig. 11 Simulation result of wind turbine without controller

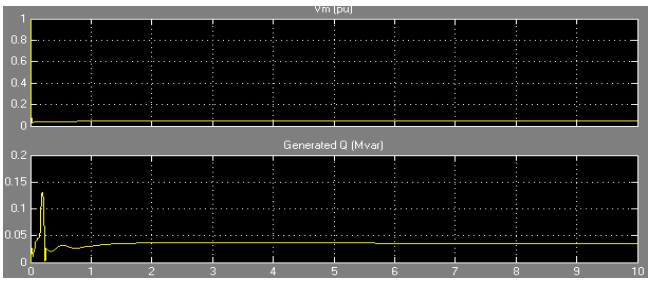

Fig. 12 Simulation result of UPFC

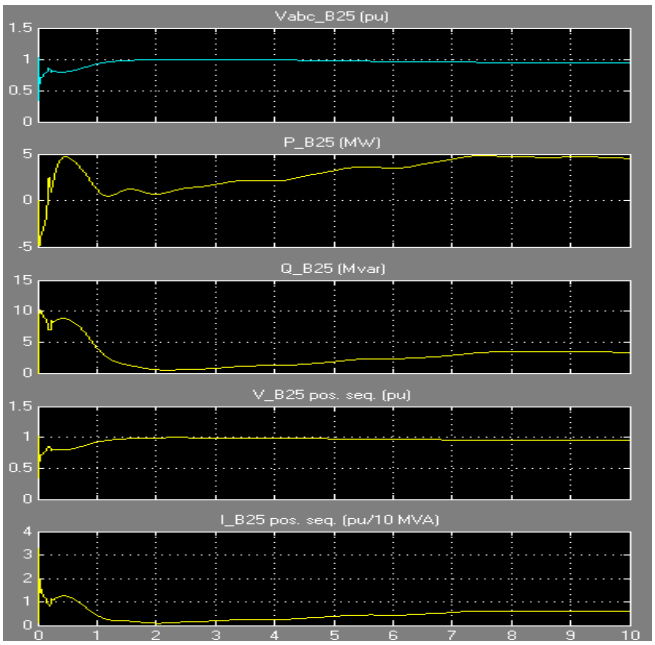

Fig. 13 Simulation result at Bus25 with UPFC

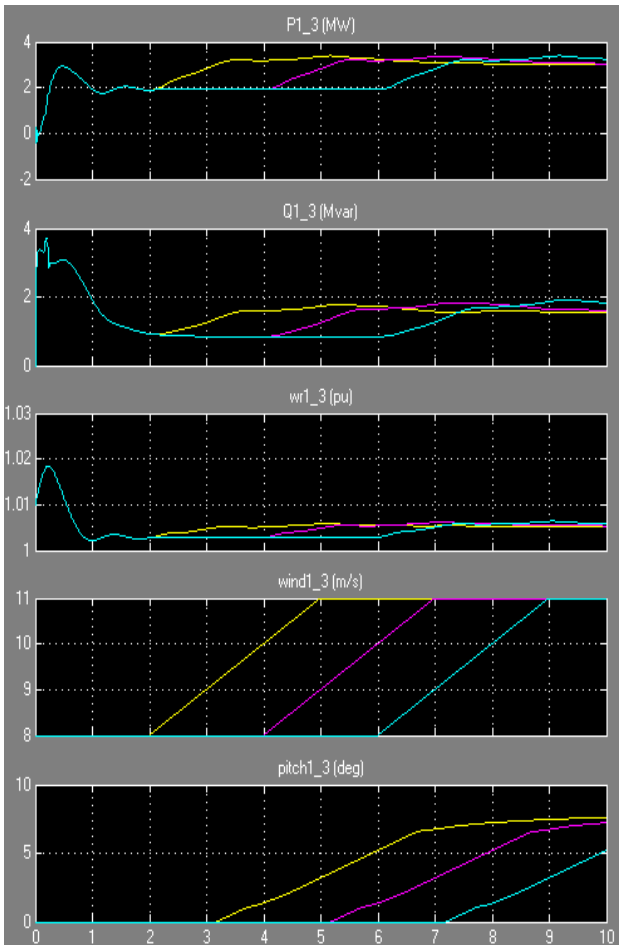

Fig. 14 Simulation result of wind turbine with UPFC

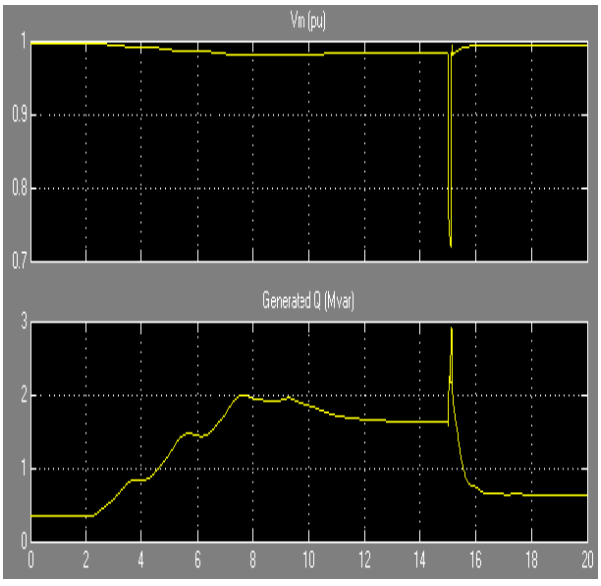

Fig. 15 Simulation result of STATCOM

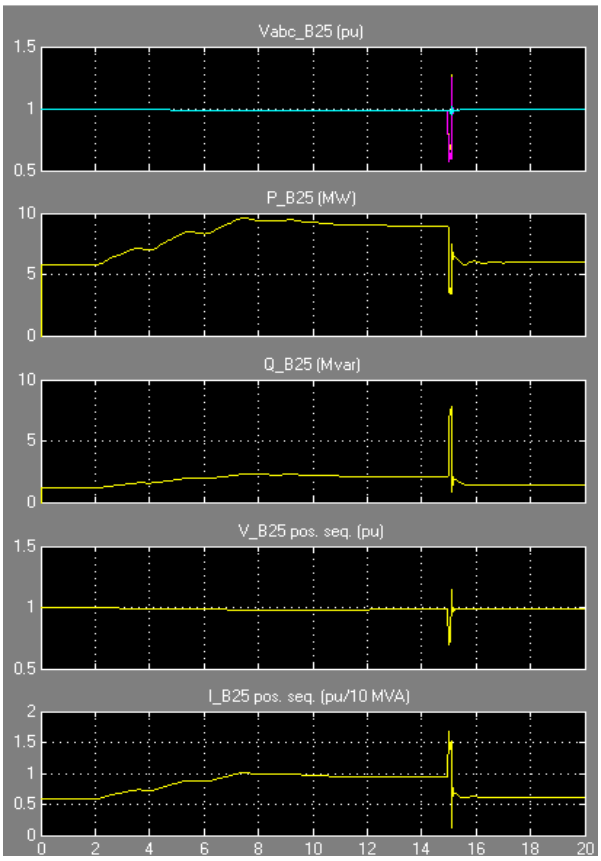

Fig. 16 Simulation result at Bus25 STATCOM

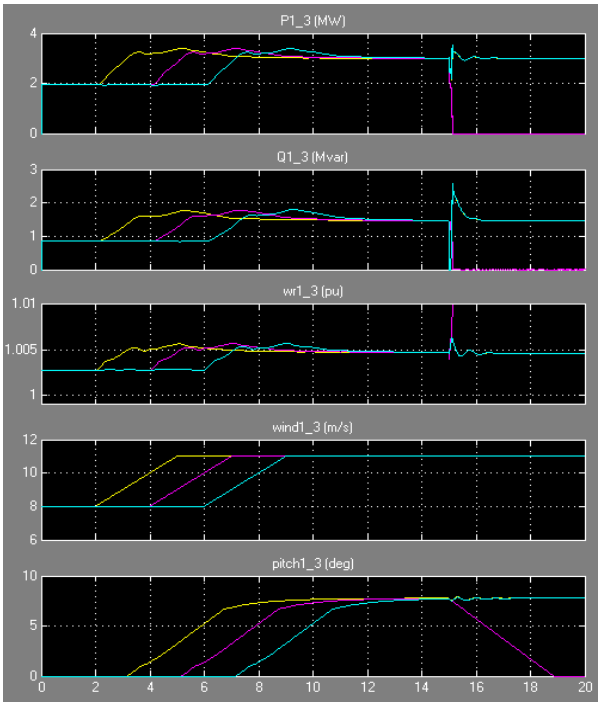

Fig. 17 Simulation result of wind turbine with STATCOM

6. CONCLUSION

The Renewable energy sources has become a good substitute of Conventional energy sources, due to limitations of conventional energy sources. The proposed model of squirrel cage induction generator (SCIG) wind farm 9MW with STATCOM and UPFC gave the better voltage stability, controllability and power quality. A UPFC has given the better power quality as compare to STATCOM.

In future can add the other FACTS devices and compare the results which one is more efficient. Similarly, FACTS devices can joint with other renewable energy sources and compute the results.

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