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REACTIVE POWER MANAGEMENT OF GRID ASSOCIATED WIND FARMS IN THE STATE OF GUJARAT

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Abstract: This manuscript deals with reactive power management, analysis and solution with the static Var compensator (SVC) and UPFC for Grid connected DFIG wind farm system mitigation. The purpose of the paper is to derive and analyze a reactive power control strategy of SVC dedicated for DFIG mitigation. The FACT device Static Var compensator is connected with load bus. Paper has demonstrated the improvement in voltages, power transferred to grid, active and reactive power control. Simulink software is used for the work. Paper demonstrated the simulation results for with and without SVC and UPFC for Grid connected Doubly Fed Induction Generator wind farm system.
Keywords: Wind Farm, DFIG, SVC, UPFC, FACT, Grid.

I. INTRODUCTION

Wind turbines produce power fluctuations due to their aerodynamic behavior and wind speed variability, where the wind turbulence influence is indeed the main contribution to voltage fluctuations. Therefore, it would be interesting to know in advance how a group of wind turbines fed into the local distribution network or a large wind farm connected to a high voltage network that may affect the power quality. Power fluctuations play an important role in the evaluation of the impact of wind turbines on the power quality, as stated in the IEC Std 61400-21 which addresses the measurement and assessment of power quality of grid connected wind turbines.[1]

In this paper, it is suggested to use the FACT Device such as static series Var compensator (SVC) for grid connected wind farm system to improve the stability in wind farm. Generally, stability means the capability of power system to hold synchronism during occurrence of a severe transient disturbance such as fault in equipment and transmission line or loss of generation or lumped load. This paper proposes the use of either the Static Var compensator to improve stability of wind farm that is connected to power system. Firstly, stability analysis of DFIG based on wind turbine is explained. Furthermore, the wind farm model based on DFIG, equipped with SVC, connected to power system is developed using MATLAB-SIMULINK. Then the impact of SVC on power system during and after fault is investigated. Afterward the effect of ratings of SVC and the Short Circuit Ratio (SCR) of network on the system recovery is analyzed. Finally, as a conclusion, the performance of SVC is compared during disturbances [2-7].

II. REVIEW OF WIND TURBINE SYSTEMS

There are three types of commonly seen wind turbines: fixed-speed wind turbines with a generator directly connected to the grid, and variable-speed wind turbines with either a synchronous generator with a full power converter in the stator circuit or with a slip-ringed induction generator and a converter in the rotor circuit, as shown in Figs. 1-3, respectively. Fixed speed systems use a squirrel cage induction generator directly connected to the grid. This type of generator needs to be turned at a fixed speed (or within 1% of rated speed). A gearbox is used between the generator and turbine shaft to adjust the speed appropriately. In a stall controlled, fixed speed system the blades are firmly bolted to the hub. The pitch angle is set so that the blade will stall and limit the power when the wind speed becomes too high. Often the blade will be slightly twisted so as to gradually stall the blade and ensure smoother transitions, reducing fatigue causing vibrations [8-10].

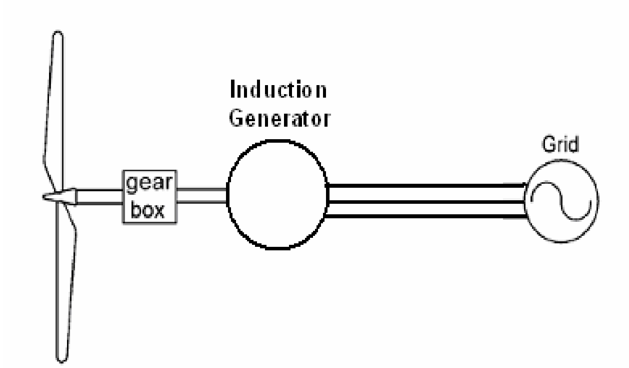

Fig.1 Fixed speed system

The disadvantage of fixed speed systems is that, because the rotor speed must remain fixed, fluctuations in wind speed cause fluctuations in torque. This has the consequence of causing voltage fluctuations on the electrical grid, especially when connected to a weak grid. The shaft pulsations will also result in high stresses on the rotor, shaft, gearbox and generator. In a variable speed system the generator rotor speed can be changed. By allowing the rotor speed to change, power fluctuations can be more or less absorbed by increasing the speed. Combined with full pitch aerodynamic control, this allows for smoother power output, and a reduction in fatigue on the gearbox and drive train. Variable speed, in some instances can allow for greater energy capture and more efficient operation.

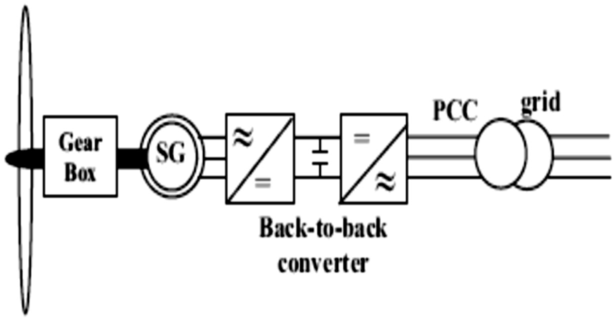

Fig.2 Variable Speed System with Synchronous Generator

Grid compatibility is achieved by the use of a voltage converter. The converter can be connected between the stator of a synchronous generator and the grid, or between the rotor of a Doubly-Fed Induction Generator (D-FIG) and the stator/grid. Most modern systems will use a D-FIG as the power converter only has to convert the rotor power, which is a fraction of the power of the stator. The D-FIG will be discussed in detail later in this thesis. In a fixed speed system with a squirrel cage generator, a capacitor bank is needed for power factor adjustment. In a D-FIG the use of a voltage converter allows for real and reactive power control. This feature may become more important as the amount of wind capacity on the grid increases. Wind farms may be called on to regulate reactive power. This is already underway in Spain. Another advantage of variable speed operation is that noise levels can be reduced.

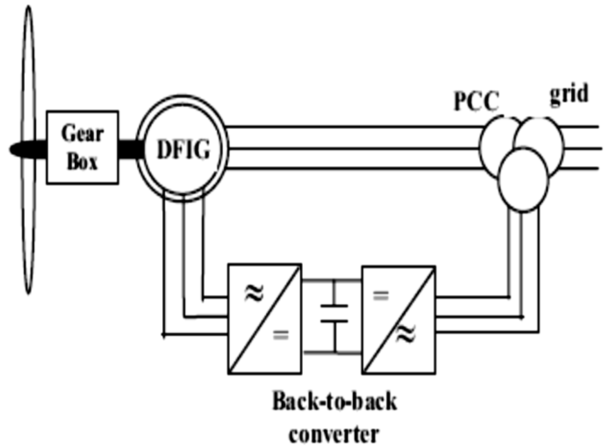

Figure 3. Variable-speed wind turbine with doubly-fed induction generator.

III. INTRODUCTION OF SVC

One kinds of FACTS devices that connected to system in parallel are SVC. An SVC consists of a combination of fixed capacitors or reactors, thyristor switched capacitors (TSC), and thyristor controlled reactors (TCR), connected in parallel with the electrical system. The TSC splits up a capacitor bank into sufficiently small capacitance steps and switches these steps on and off individually, using anti-parallel connected thyristors as switching elements. TCR controls the fundamental-frequency current component through the reactor by delaying the closing of the thyristor switches with respect to the natural zero crossing of the current. Equivalent circuit of SVC connected to HV bus is shown in Figure 4. In addition, SVC can be seen as the adjustable suseptance and its maximum reactive current is proportional to the network voltage.

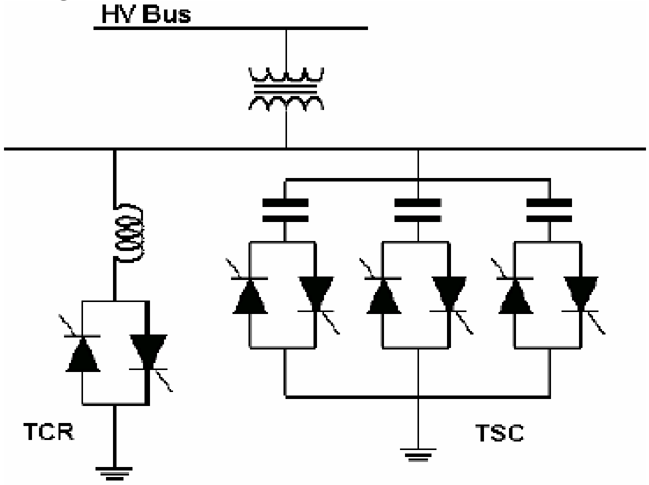

Fig-4. SVC

A. Simulated System :

This case study shows a 9-MW wind farm consisting of six 1.5 MW wind turbines connected to a 25-kV distribution system exports power to a 120-kV grid through a 30-km, 25-kV feeder. A 2300V, 2-MVA plant consisting of a motor load (1.68 MW induction motor at 0.93 PF) and of a 200-kW resistive load is connected on the same feeder at bus B25. Both the wind turbine and the motor load have a protection system monitoring voltage, current and machine speed. The DC link voltage of the DFIG is also monitored. Wind turbines use a doubly-fed induction generator (DFIG) consisting of a wound rotor induction generator and an AC/DC/AC IGBT-based PWM converter. The DFIG technology allows extracting maximum energy from the wind for low wind speeds by optimizing the turbine speed, while minimizing mechanical stresses on the turbine during gusts of wind. The optimum turbine speed producing maximum mechanical energy for a given wind speed is proportional to the wind speed. For wind speeds lower than 10 m/s the rotor is running at sub synchronous speed. At high wind speed it is running at hyper synchronous speed. Advantage of the DFIG technology is the ability for power electronic converters to generate or absorb reactive power, thus eliminating the need for installing capacitor banks as in the case of squirrel cage induction generator.

In this case study first we simulated the DFIG based wind farm system with fault and without FACT device SVC and then we simulated the DFIG based wind farm system with fault and with FACT device SVC and showed that the improvement and impact of FACT device on the Load Bus. Figures 5 and 6 show the simulation of system with and without FACT device SVC.

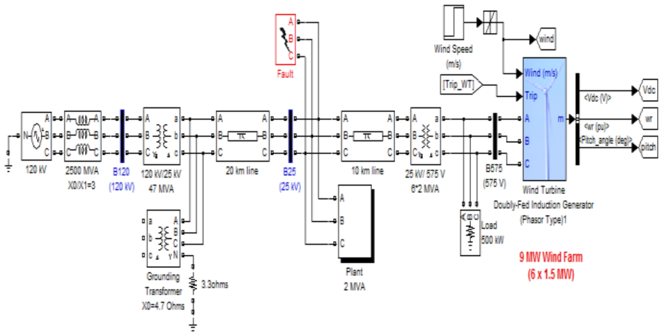

Fig.-5 DFIG wind farm system without SVC

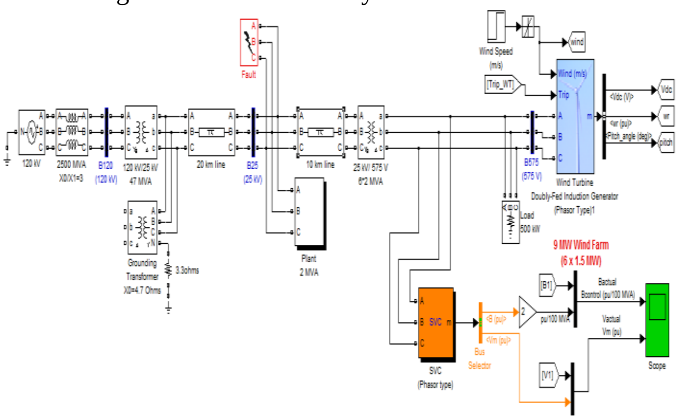

Fig.-6 DFIG wind farm system with SVC

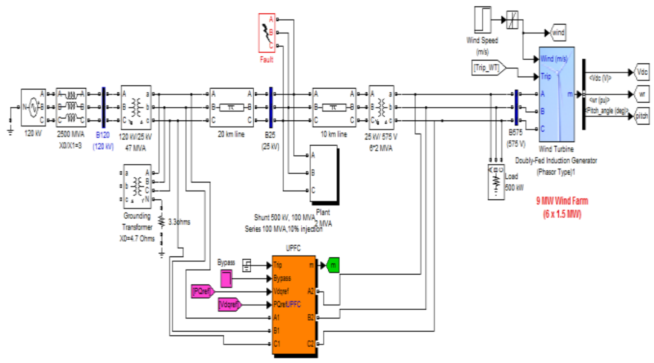

Fig.-7 DFIG wind farm system with UPFC.

SIMULATION RESULTS

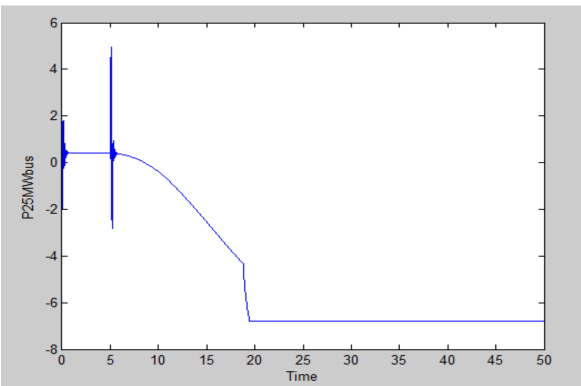

Fig.-7 P25MWbus without SVC

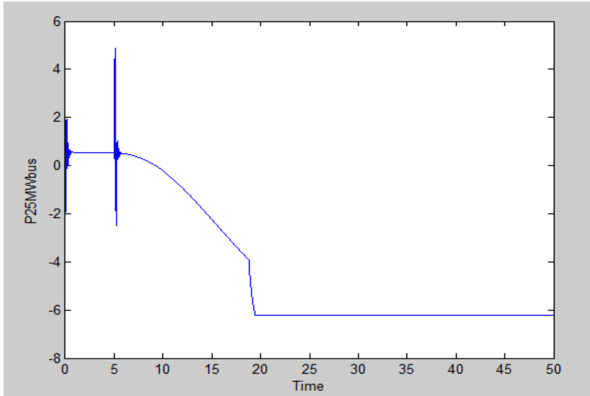

Fig.-8 P25MWbus with SVC

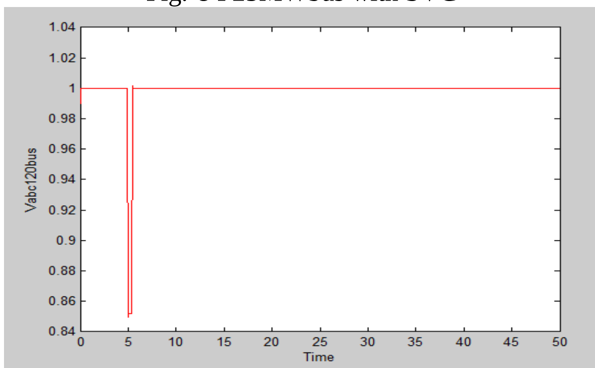

Fig.-9 Vabc120 bus without SVC

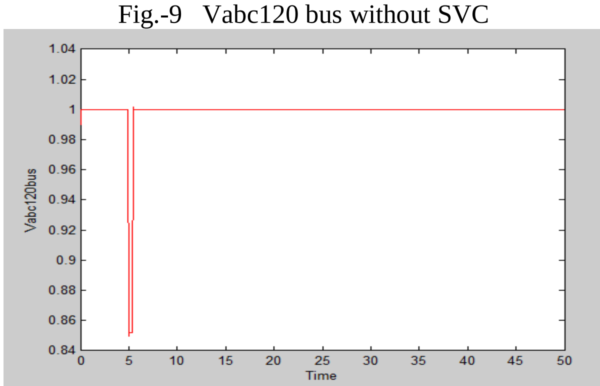

Fig.-10 Vabc bus with SVC

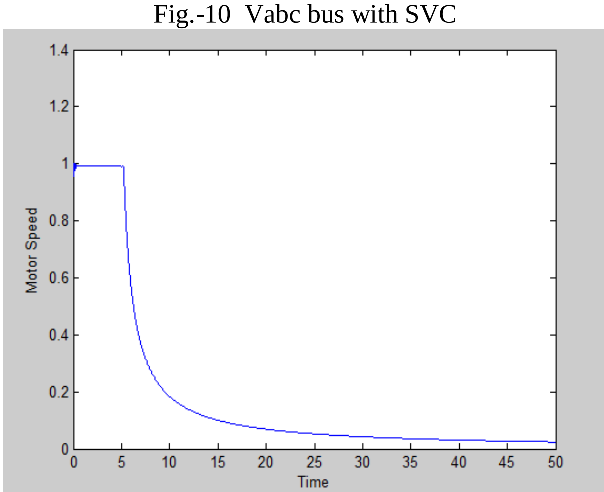

Fig.-11 Motor speed without SVC

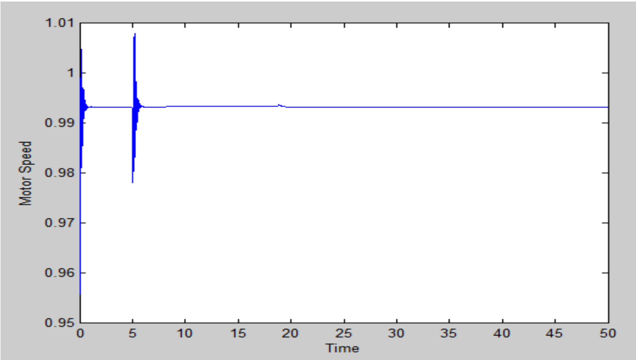

Fig.12- Motor speed with SVC

Simulation Results for UPFC:

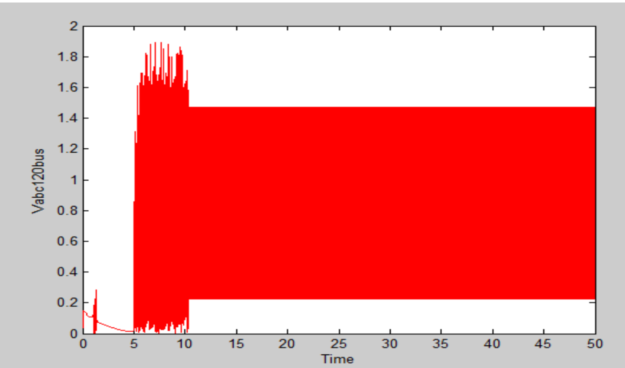

Fig.-13 Vabc120Bus With UPFC

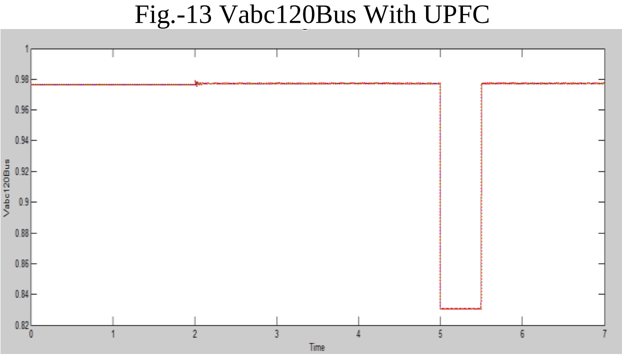

Fig.-14 Vabc Without UPFC

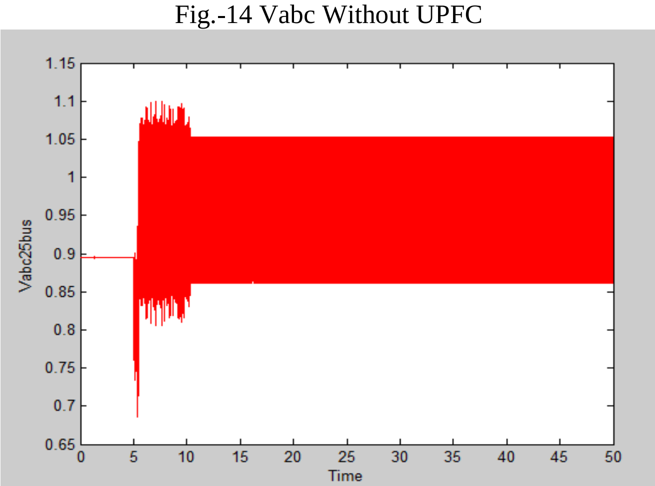

Fig.-15 Vabc25Bus with SSSC

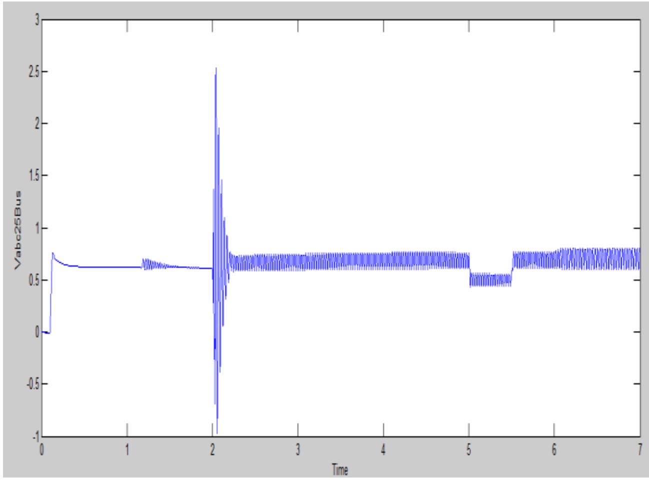

Fig.-16 Vabc25Bus without SSSC

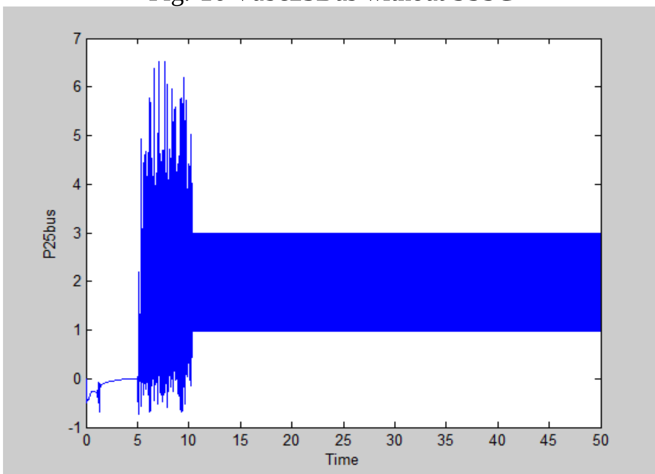

Fig.-17 P25Bus with UPFC

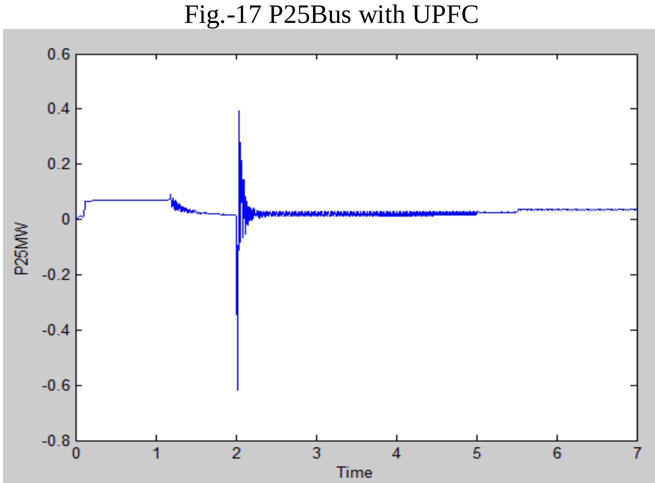

Fig.-18 P25Bus without UPFC

IV. CONCLUSION

Paper has demonstrated the performance of DFIG based wind farm system with and without FACT device SVC and UPFC. The simulation result showed that voltage of 120bus, Motor speed and Voltage level at 25bus system with SVC are improved than without SVC under fault conditions in both the cases. So SVC has improved performance of DFIG based grid connected wind farm system.

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