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Power Flicker Mitigation of Wind Farm Based Power System Using Static Synchronous Compensator

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***Abstract*-The paper investigate the role of STATCOM in power system network for enhancement of system stability and reduction of voltage as well as power fluctuations. The power system consists of 60MW wind farm (IG Based) connected to 132 KV Grid with the help of a transmission line and step up transformer. The wind speed variation causes power fluctuation subsequently voltage fluctuations. The MATLAB simulation result shows that STATCOM gives satisfactory result in the process of enhancement of power quality of the system.**

***Index Terms*- STATCOM; Wind Farm; Induction Generator; System Stability; Voltage Control.**

I- INTRODUCTION

In modern era due to technology innovation renewable energy resource such as wind energy are very popular and is a better substitution for fossil fuels. The commercially available wind farms have rating 2MW, 3MW and 5MW.[1],[2]. The availability of wind depends on climate and geographical conditions that is why an induction generator is allowed to couple with wind turbine for production of electrical power with considerable amount of flickers.

The active power produced by IG based wind turbine has significant fluctuations due to uncertain nature of wind [3]. The output power fluctuation results in voltage fluctuation. These voltage flickers must be minimized because they have adverse effect on power quality and also affect consumers. When any fault takes place near the wind turbine, the turbine starts over speeding and results in system instability.

A wind farm consists of number of wind turbine coupled with induction generators. These Induction generators have squirrel cage rotor provides active power to the system but it takes reactive power from the system for operation in steady state. The reactive power demands depend directly on rotor slip. So continuous reactive power is required for steady state stability of the system.

The conventional mechanically switched capacitors along with tap changing transformers are used to rectify these power quality problems. These devices have capability of increasing steady state voltage regulation and system power factor. The use of MSC and TCs does not give satisfactory results in the power quality issues such as voltage flickers power flickers and system harmonics. The frequent switching of TCs and MSC results in transient voltage and stress on gear box of wind turbine [7], [8]. A STATCOM is a type of dynamic reactive power compensator which provides better voltage stability during faulty grid condition. The response time of dynamic reactive power compensator is very low i.e. 1-2cycle.

In this paper an investigation is conducted on the effect of using STATCOM to enhance power system quality and stability. The stability issues whether it is steady state stability or dynamic voltage control is effectively achieved with the application of STATCOM.

In this paper we study the use of STATCOM to improve the power quality and fault ride through capability of wind farm equipped with SCIGs. The issues related to steady state and dynamic voltage control can be effectively achieved by using STATCOM. An investigation is conducted on the impact of STATCOM on system recovery after a network fault.

II- SYSTEM DESCRIPTION

The system consists of a wind farm connected to 132KV grid with the help of 200 Km transmission line. The generation of voltage is 11KV that is stepped up by transformer T_1 to the voltage 132KV and then transmitted to the grid with the help of transmission line. A single line diagram of the wind farm is shown in Fig.(1). Wind farm has capability of 60MW active power. Since the system requires reactive power for operation. Here a compensating capacitor of 23MVAR is connected to 11KV bus bar. STATCOM is connected at 132 KV bus bar which provides dynamic reactive power requirement of the system.

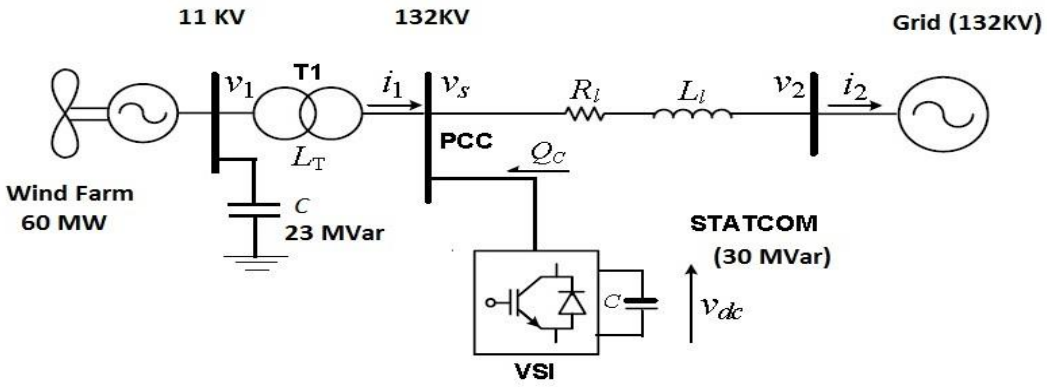

Figure-1. Single line diagram of wind farm energy system connected to grid

The parameters of all components connected in the system are as follows-

Wind turbine with SCIG = 60MW rated, stator voltage = 11KV rated. Rotor resistance = 0.0124 per unit; Stator resistance =0.0108 per unit; Leakage reactance of rotor=0.1407 per unit; Mutual Inductance =4.5 per unit, Transformer (T_1) turns ratio132/11KV; STATCOM D.C. link capacitor 300μF; lumped inertia constant=375; D.C. link voltage =40 KV.

III- MODELLING OF WIND FARM

A wind farm is a combination of number of wind turbines mechanically coupled with squirrel cage induction generator at a location to generate electrical power. In a wind turbine power generation system SCIG generators are rotated by turbine which is mechanically coupled with generator and operate at a certain speed. The speed of wind turbine directly depends on wind velocity.

The power produced by a wind turbine is given by following formula

$$P_e \alpha V_w^3$$

$$P_w = \frac{1}{2} \rho A_r V_w^3 (\beta\lambda)$$

Where, ρ= Air density in Kg/m^3

A_r= Blade impact area

V_w= Wind velocity in m/sec

C_p= Power coefficient of wind turbine

IV-MODELLING OF STATCOM

A static compensator consists of a storage capacitor and a VSC. The storage capacitor is connected at shunt. The main purpose of dynamic compensator (STATCOM) to get fast and smooth voltage control that is why IGBT based voltage source converter is used. All the three inductance branches provide high frequency harmonics elimination in V_{sc} . Fig.2 shows six pulse PWM IGBT VSC model.

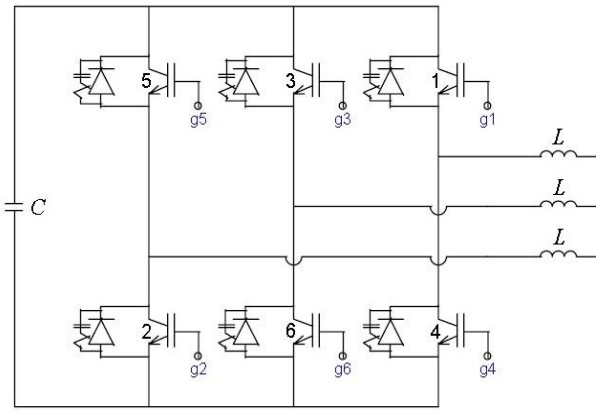

Figure-2. Six pulse PWM IGBT VSC model

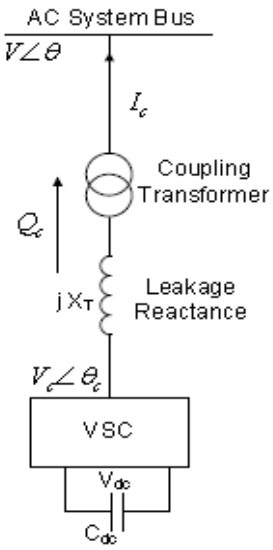

Figure-3:- Basic circuit of STATCOM

Fig-3 shows equivalent circuit of STATCOM. The reactive power support provided by STATCOM is given by

$$Q_c = \frac{V(V_c - V)}{x_T} \qquad (2)$$

Where V_c =VSC output voltage

V = AC line voltage

X_r = Reactance

Q_c is very clear from formula that reactive power supplied by STATCOM is directly proportional to difference between VSC voltage and line voltage. If difference is more reactive power is supplied to the system. If V_c and V are equal, then no reactive power is supplied by STATCOM. If $V_c < V$ i.e. reactive power is absorbed by STATCOM. Thus we can say the STATCOM reactive power can be controlled by simply controlling V_c.

V- MATLAB SIMULATION AND RESULTS

MATLAB simulation is performed in MATLAB11A. In fig.4 the wind speed variation with respect to time is shown. The system is subjected to wind input speed ranging from 5-13 m/s for a time 12 seconds. This wind input causes voltage variation approximately 91% to 103%. These voltage fluctuations are not good for power quality. The voltage fluctuations are shown in fig.5. Fig.6 shows the voltage profile of the system after the application of STATCOM and it is observed that voltage fluctuations are limited to less than 1%. Fig.7 shows the reactive power supplied by STATCOM and it is very clear that reactive power supply is increases with increase in voltage fluctuations. In fig.8 MATLAB simulation model is shown.

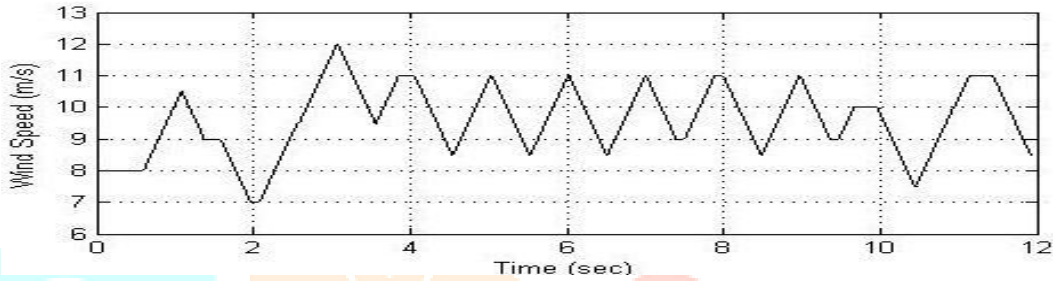

Figure-4. Wind speed variations for 12 sec

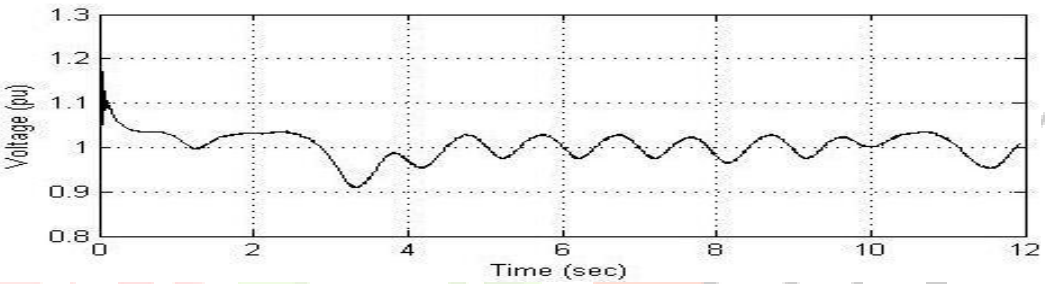

Figure-5:-. Voltage fluctuations due to wind speed variation (without STATCOM)

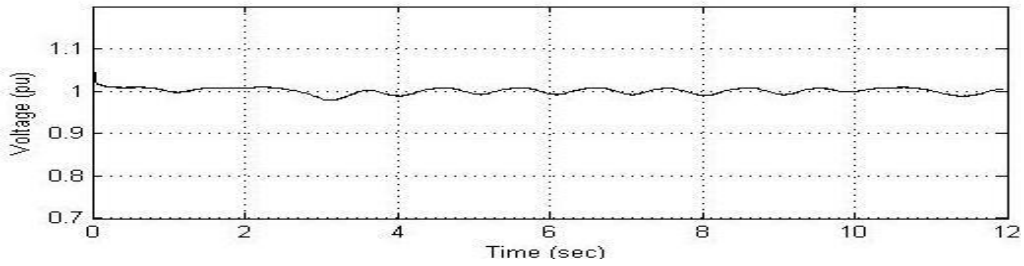

Figure-6:-. Voltage profile with STATCOM

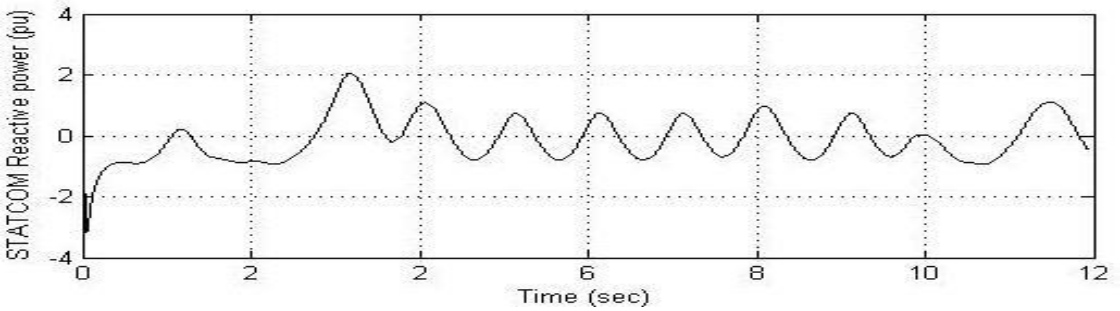

Figure-7:-. Reactive power supplied by STATCOM

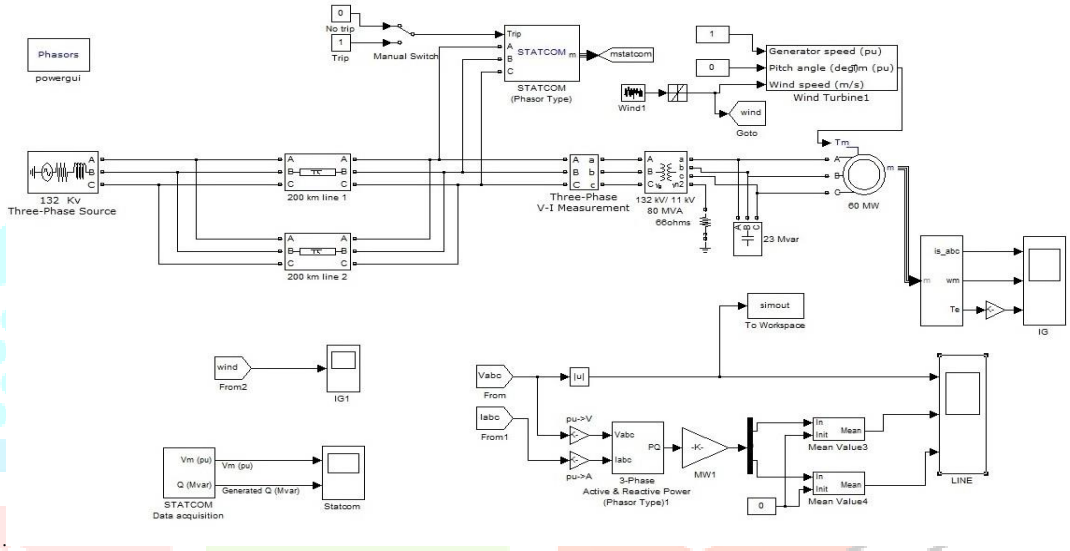

Fig-8- MATLAB SIMULATION MODEL

VI- CONCLUSIONS

Wind is a widely available and uncontrollable source of energy. The power produced from wind farm has voltage fluctuations due to wind speed variations. The voltage fluctuations could not be mitigated efficiency with the help of static capacitor compensator. It requires a dynamic reactive compensator that is why STATCOM is used for such purpose. And it is found that STATCOM provides suitable reactive power compensation to get desired power quality requirement.

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