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Transient Stability Enhancement of Hybrid Power System with Wind Generator

Surbhi Sharma[1], Anant Thakur[2]

[1]M.E. student, IES College of Technology, RGPV Bhopal (M. P.), India

[2]Assistant Professor, Electrical & Electronics Department, IES College of Technology, RGPV Bhopal (M. P.), India

Abstract: ***Flexible AC transmission systems (FACTS) controllers have been mainly used to solve various power system control problems. Many controllers of Flexible AC Transmission Systems (FACTS) like SVC, STATCOM, Unified Power Flow Controller (UPFC), PWM asynchronous dc link, Thyristor-Controlled Series Capacitor (TCSC) and PWM Series Static VAR compensator gives stabilized voltage support. So they can be placed at the mid-point of the transmission line, which has been proven by the late E.W. Kimbark, as the optimum location for shunt capacitor compensation. In this paper a shunt FACTS device (STATCOM) on transmission line to improve transient stability with predefined real power flow. Voltage stability is a key issue to achieve the uninterrupted operation of wind farms equipped with squirrel cage induction generators (SCIG) during grid faults. A Static Synchronous Compensator (STATCOM) is applied to a power network which includes a SCIG driven by a wind turbine, for steady state voltage regulation and transient voltage stability support. The system is implemented using MATLAB/ SIMULINK. Results illustrate that the STATCOM improves the transient voltage stability and therefore helps the wind turbine generator system to remain in service during faults.***

Keywords: Transient Stability, FACTS Device, PSS, Wind Generator

1. Introduction

In recent years, demand of electrical power has increased considerably while the development of power generation and transmission has been severely limited due to limited resources and environmental restrictions. As a result, some transmission lines are on heavy load and the system stability becomes a power transfer-limiting factor [1, 7]. Flexible AC transmission systems (FACTS) controllers are used to control such severe conditions like transient stability control and control of reactive power. Previous works prove that shunt FACTS device gives maximum benefit from their stabilized voltage support when placed at the middle of the long transmission line [11, 9].

This paper consists a simulated model of two machine systems with wind farm for 50 Hz fundamental frequency and comparison of various results of simulated two area machine system for with and without STATCOM and PSS in a long transmission line the actual models of the line for the study of transient stability. MATLAB simulation results in a severe disturbance (three phase fault) with STATCOM are analyzed here. Complete study is done here at 50 Hz frequency. It is shown that for a actual long transmission line model with a predefined real power flow, STATCOM needs to be located off-centre on a long transmission line.

To have sustainable growth and social progress, it is necessary to meet the energy need by utilizing the renewable energy resources like wind, biomass, hydro, co-generation, etc. In sustainable energy system, energy conservation and the use of renewable source are the key paradigm. The need to integrate the renewable energy like wind energy into power system is to make it possible to minimize the environmental impact on conventional plant [1].

The integration of wind energy into existing power system presents a technical challenges and that requires consideration of voltage regulation, stability, power quality problems. The power quality is an essential customer-focused measure and is greatly affected by the operation of a distribution and transmission network. The issue of power quality is of great importance to the wind turbine [2]. Today, more than 28000 wind generating turbine plants are successfully operating all over the world. In the fixed- speed wind turbine operation, all the fluctuation in the wind speed are transmitted as fluctuations in the mechanical torque, electrical power on the grid and leads to large voltage fluctuations.

During the normal operation, wind turbine produces a continuous variable output power. These power variations are mainly caused by the effect of turbulence, wind shear, and tower-shadow and of control system in the power system. There has to be a protection for such situations. Thus, the network needs to manage for such fluctuations.

2. Two Area System With Shunt Facts Device (STATCOM)

Consider a two area system (area 1 & area 2), which is connected by a single circuit long transmission line as shown in fig. 1.

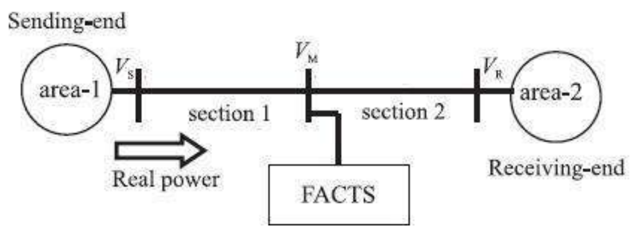

Figure 1: Two area system with shunt FACTS device

The real power flow is from area 1 to area 2. Here the transmission line is divided in two sections (section 1 and section 2). For a long transmission line of length l, having a series impedance of z ohm/km and shunt admittance of y mho/km, the relationship between the sending-end and receiving-end quantities with A, B, C, D constants of the line can be written as:

$$V_S = AV_R + BI_R \quad (1)$$

$$I_S = CV_R + DI_R \quad (2)$$

sending end power (PS) and receiving end power (PR) become maximum at power angle δ = 90°. When a shunt FACTS device is connected to a long transmission line to increase the power transfer capability, the above simplifications may provide following results for active power flow at sending and receiving end side:

$$P_S = K_1 \cos(\theta_2 - \theta_1) - K_2 \cos(\theta_2 - \delta), \quad (3)$$

$$P_R = K_2 \cos(\theta_2 - \delta) - K_3 \cos(\theta_2 - \theta_1), \quad (4)$$

It is clear from Eqn. 4 that the receiving end power PR reaches the maximum value when the angle δ becomes θ2. [19, 2]However, the sending end power PS of Eqn. 3 becomes maximum at δ = (180 − θ2).

3. Simulation And Modeling

Fig. 3 shows the Simulink model of two hydraulic generating units of 1400 MVA and 700 MVA nominal power rating and generate 13.8 KV line voltages at 50 Hz line frequency. There is also a wind generator of 50MVA, 0.69KV, 50 Hz nominal rating and this is connected in parallel with the 1400 MVA hydraulic generator at the same bus b1. These hydraulic units are equipped with a hydraulic turbine and governor (HTG), excitation system. These components are included in Subsystem1 and Subsystem2 blocks as shown in figure 5.1. Reference mechanical power or initial power outputs of the generators are taken as Pref1 = 0.8 pu and Pref2 = 0.4 pu.

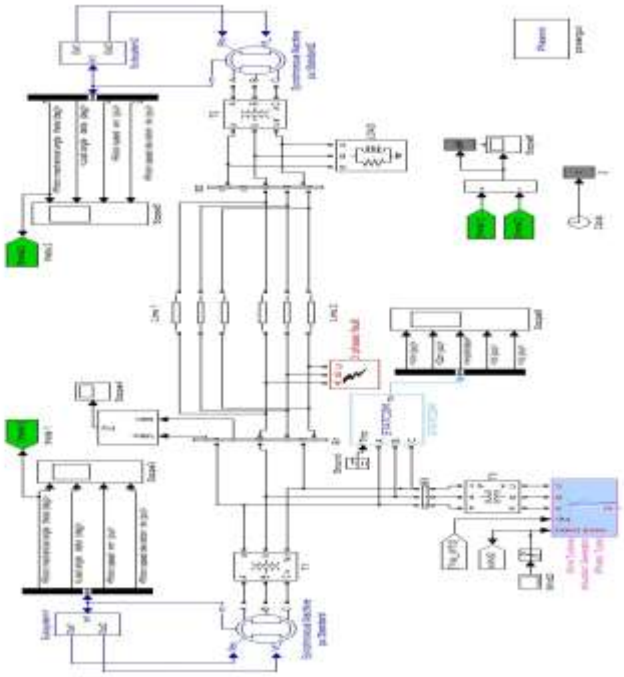

Figure 3: Simulink model of Hybrid Power System for transient stability study with STATCOM and PSS

Three step up transformers T1, T2 and T3 are connected at the each end of the generating units, which gives 500 KV as transmission voltage. All these components are connected via two parallel 250 km long transmission lines, Line 1 and Line 2 as shown in figure 5.1. A STATCOM is used for this model which has the rating of 100 MVA and reference voltage is set to 500 KV as 1 pu.

The 1400 MVA unit with 50 MVA unit is considered as sending end unit and 700 MVA unit as receiving end unit. A reactive load of 1415 MW/500 MVAR is connected towards receiving end as shown in fig. 5.1. A three phase fault occurs at one of the parallel lines for the period of t=2 - 5 sec. the system is restored after the clearance of the fault. PSS considered here gives effective damping for power swings over a wide range of time.

This system consists two subsystem blocks as shown in Figure 5.1, which contain three blocks:

- Hydraulic Turbine and Governor (HTG)
- Power System Stabilizer (PSS)
- Excitation System

4. Simulation Result

Figure 4.1 shows the simulation results of rotor angle difference (diff) without the effect of STATCOM and PSS on hybrid power system. We can see that without considering STATCOM and PSS in the system, the system attains the stability in more than 10 sec. Here the damping of rotor oscillations is low. As we can see in the figure 4.1, the maximum overshoot of rotor angle difference angle is 46°

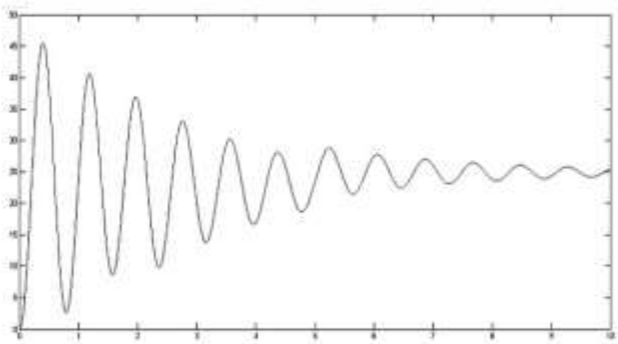

Figure 4.1: Rotor angle difference without STATCOM and PSS

Figure 4.2 shows the active and reactive power flow at bus B1 of the hybrid power system considered. In the fault duration i.e. between 2-5 sec., both active and reactive power varies accordingly. At 2 sec., there is a fall in both the powers and at 5 sec., both the power rises because fault is cleared at t=5 sec. After then, they reduce to attain a constant value.

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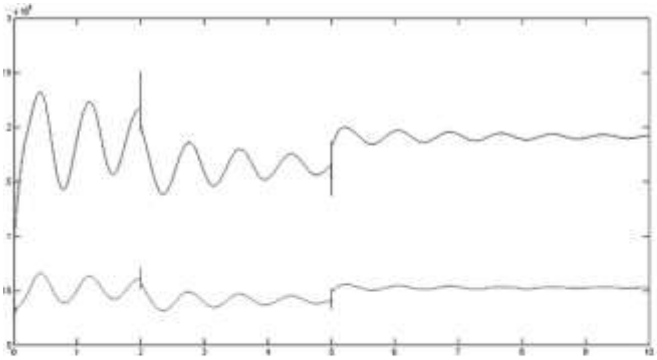

Figure 4.2: Active and reactive power flow without STATCOM and PSS

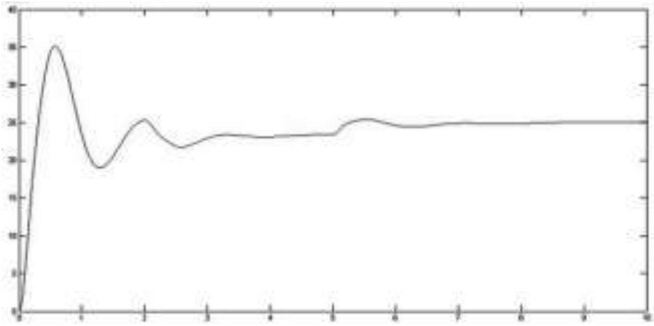

Figure 4.3: Rotor angle difference with STATCOM and PSS

Figure 4.3 shows the simulation results of rotor angle difference (diff) with the effect of STATCOM and PSS on hybrid power system. We can see that with considering STATCOM and PSS in the system, oscillations in rotor angles are damped out and system attains stability in less time compared to previous result. Here the damping effect on rotor oscillations is high. As we can see in the figure 4.3, the maximum overshoot of rotor angle difference angle is 35°. As we can see in the figure 6.3, the rotor angle difference is almost constant during the fault time. So we can say that system is stable if the hybrid power system, considered here, is used with STATCOM and PSS.

Figure 4.4 shows the active and reactive power flow at bus B1 of the hybrid power system considered. In the fault duration i.e. between 2-5 sec., both active and reactive power is almost constant as compared to figure 4.2. So when the hybrid power system is used with STATCOM and PSS, it gives better stability. With STATCOM and PSS, the system is very less affected by transients.

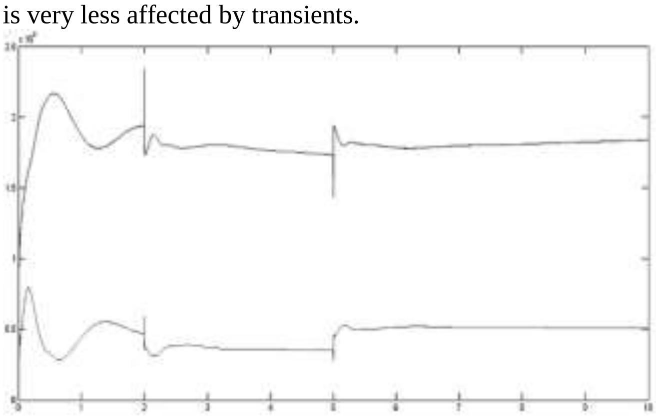

Figure 4.4: Active and reactive power flow with STATCOM and PSS

If you are using *Word*, use either the Microsoft Equation Editor or the *MathType* add-on (http://www.mathtype.com) for equations in your paper (Insert | Object | Create New | Microsoft Equation *or* MathType Equation). "Float over text" should not be selected.

Number equations consecutively with equation numbers in parentheses flush with the right margin, as in (1). First use the equation editor to create the equation. Then select the "Equation" markup style. Press the tab key and write the equation number in parentheses.

$$E = \sum_{p=1}^{P}\sum_{k=1}^{K}(\delta_{pk}^{o})^2 \qquad (1)$$

5. Conclusion

In this Power System Model of two hydraulic turbine synchronous generators with one wind turbine operated induction generator is simulated with STATCOM and PSS. The transient stability has been determined when a wind farm is integrated with the power system. The wind penetration into the system causes deterioration in stability depending on the wind penetration level into the system. The stability of the wind integrated system during the network disturbance under normal condition is improved by incorporating a PSS with the exciter circuit of the alternator, which damps out oscillations and hence stabilizing the system. However, the settling time is quite high even in presence of PSS.

The installation of a shunt device like STATCOM enhances further the stability by reducing the settling time of oscillations both in voltage and rotor angle. The impact level in the presence of STATCOM and excitation controllers (AVR and PSS) is highly reduced. The STATCOM also reduces the shaft speed oscillations at the turbine end permitting a safe operation of wind turbine without fatigue during network disturbances. Percentages of impact index Without STATCOM and PSS is 28.9% and With STATCOM and PSS is 27.1 %, So when PSS and STATCOM are used with the power system, TSI factor increases and % impact is decreases. As a result of this system becomes more stable.

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