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Improvement of Transient Stability Margin in RES Based Power Systems Using STATCOM

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Abstract: Renewable energy sources (RES), one of the most prominent energy sources, are also gaining significant popularity around the globe. RES based energy systems designed with asynchronous generators with constant speed yield a very cost effective solution for power generation and nowadays are generally used to represent the renewable energy sources in power systems. These asynchronous generators used to consume reactive VARs. For the compensation of these consumable reactive VARs, shunt condensers can be inserted in the system, but these devices usually display very poor results during the transient behaviour of the system. Therefore, powerful and continuous reactive power controllers, such as Flexible Alternating Current Transmission Systems (FACTS), are necessary in these cases. In the present paper, the increment in the stability margin of power systems during the transient turbulences with integrated RES generation using the Static VAR Compensator (STATCOM) is investigated. The RES generators considered are the squirrel cage induction generators (SCIG). Simulation studies are carried out on the IEEE-9 bus design system. Studied results prove that the SCIG with STATCOM device significantly enhances the performance of the designed power network during transient disturbances.

Key words: Distributed generation, renewable energy, power quality, STATCOM, MATLAB/Simulink.

Introduction

There has been a growing interest in distributed generation by renewable energy resources. Wind energy, as one of the foremost distinguished renewable energy sources, is gaining increasing significance throughout the globe. Currently, there are several thousands of wind turbines in operation worldwide. More than 54 GW of clean renewable wind power was installed across the global market in 2016, which currently contains more than 90 countries, together with nine with more than 10,000 MW installed, and 29 that have currently passed the 1000 MW mark. Additive capability grew by 12.6% to achieve a total of 486.8 GW (Global Wind Report, 2017). It offers a cost effective solution for wind power generation by using wind turbine with mounted speed induction generators, a foremost commonly used type of wind turbine. However, a notable characteristic of the fixed speed induction generators is that this kind of generator always consumes reactive power whereas shunt capacitors are usually used to fully compensate for this reactive power consumption throughout steady state operation. These devices exhibit rather poor performance during transient events (Aekcrmann et al., 2001; Qi, L. et al., 2008). Therefore, controllable reactive power (VAR) supporters like flexible alternating current transmission systems (FACTS) are in some cases necessary to supply dynamic voltage support with their actively controllable volt ampere injection, particularly under voltage depression. With FACTS, variety of

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valuable advantages will be attained in power systems (Grünbaum, 2010):

- Dynamic voltage control to modify limiting of over-voltages over long, lightly loaded lines and cable systems, as well as prevent voltage depressions or perhaps collapses in heavily loaded or faulty systems.
- Magnified power transmission capability and stability, without any need to build new lines. This is often an extremely attractive option, costing less than new lines, with less time expenditure or environmental impact.
- Facilitating integration of renewable power by maintaining grid stability and fulfilling grid codes, as well as making room for this extra power in existing grids.

This paper presents a transient performance of wind energy source based micro power system. Investigations are carried out on IEEE 9-bus system for evaluating the transient stability performance. Simulation studies are also performed to record the improvement in the transient stability performance when the STATCOM has been connected in the system. All transient behaviour results are presented with STATCOM and without STATCOM.

The Static Synchronous Compensator (STATCOM)

The Static Synchronous Compensator (STATCOM) is a shunt FACTS device which uses power electronics for controlling the power flow and improving the transient stability in power grids. It controls the voltage at its terminal by regulating reactive power injecting into or absorbing from the power system. When the voltage of the system becomes low, STATCOM generates reactive power and it absorbs reactive power when the voltage of the system becomes high (Grünbaum, 2010; Gandhar et al., 2014).

The variation of reactive power is done by means of a Voltage-Sourced Convertor (VSC) connected on the secondary side of a coupling transformer. It uses forced-commutated power electronic devices (GTOs, IGBTs or IGCTs) to synthesize a voltage V_2 from a DC voltage supply. The principle of operation of the STATCOM is explained in Figure 1 reprensenting the active and reactive power transfer between V_1 and V_2. In the given figure, the system voltage to be controlled is represented by V_1 and the voltage generated by the VSC is represented by V_2.

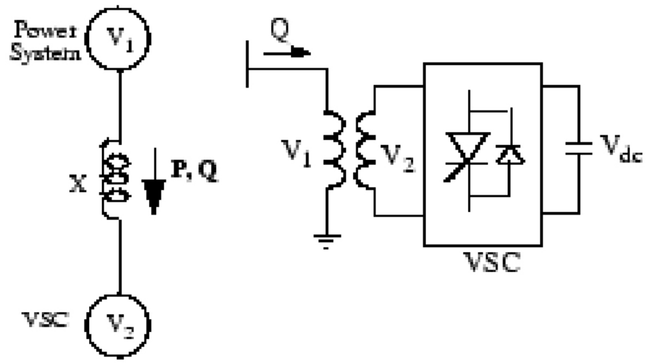

Figure 1: Operating principle of the STATCOM.

$$P = (V_1V_2)\sin\delta/X,\ Q = V_1(V_1 - V_2\cos\delta)/X$$

In steady state operation, the voltage V_2 generated by the VSC is partly with V_1 ($\delta = 0$), in order that only reactive power is flowing ($P = 0$). If $V_2 < V_1$, than q is flowing from V_1 to V_2 (STATCOM is absorbing reactive power). On the reverse, if $V_2 > V_1$, than q is flowing from V_2 to V_1 (STATCOM is generating reactive power). The quantity of reactive power is given by

$$Q = (V_1(V_1 - V_2))/X.$$

A capacitance connected on the DC side of the VSC acts as a DC voltage supply. In steady state, the voltage V_2 needs to be phase shifted slightly behind V_1 so as to compensate for transformer and VSC losses and to remain the capacitor charged. Two VSC technologies can be used for the VSC (Amroune et al., 2012; Tasneem and Sheikh, 2014).

The STATCOM (Phasor type) block models an IGBT-based STATCOM (fixed DC voltage). However, as details of the inverter and harmonics are not represented, it can be conjointly used to model a GTO-based STATCOM in transient stability studies (Al-Majed and Fujigaki, 2010). Figure 2 shows a single-line diagram of the STATCOM and a simplified diagram of its control system.

Simulation Test System and Results

Simulation studies are carried out in this section to demonstrate the transient performance of the power system with wind generation using the Static VAR Compensator. IEEE 9-bus system is considered for analysis, shown in Figure 4 (Ahilan et al., 2009; Kundur, 1994; Milano, 2010). It is connected with two Induction generators. In this paper, the investigations are executed on the assumption that the wind turbine is operating at rated speed (9 m/s). The induction generator of Group

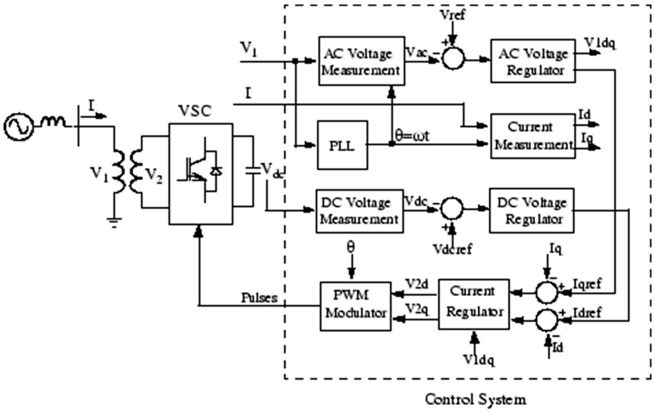

Figure 2: Diagram of a STATCOM and its control system.

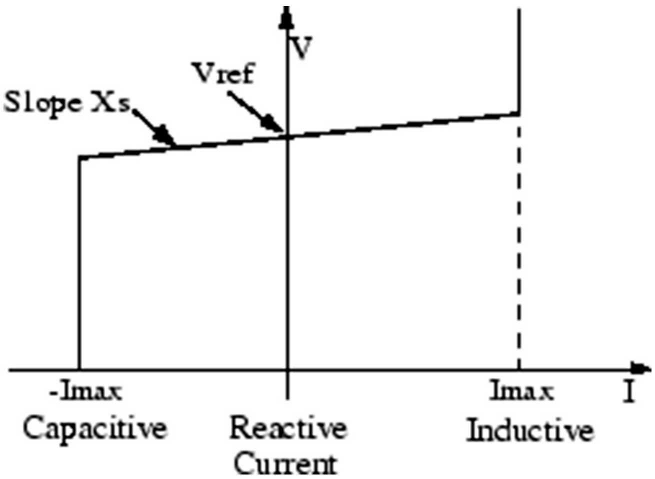

Figure 3: STATCOM V-I characteristic.

1 is of rating 1.5 KVA nominal power and connected at bus '1'. The second generator is having nominal power of 3 KVA and connected at bus '4'. Different types of loads are connected with this 9 bus system. The peak values of bus voltages are employed as indices to evaluate transient stability and therefore the IEEE 9-bus test system shown in Figure 4 is used to conduct the transient stability simulation.

A STATCOM is to be installed at the point of Common Coupling (PCC), wherever the wind energy facility is integrated with the utility system. Time simulation studies are carried out for 1 sec on the test system. STATCOM has been inserted in these

Table 1: Bus voltages (pu) of IEEE 9-Bus test system with and without STATCOM

Sr No	*Buses*	*Bus voltages without STATCOM (p.u.)*	*Bus voltages with STATCOM (p.u.)*
1	Bus '1'	0.8517	0.9658
2	Bus '2'	0.8442	0.9598
3	Bus '3'	0.8302	0.9475
4	Bus '4'	0.8517	0.9658
5	Bus '5'	0.8456	0.9603
6	Bus '6'	0.8464	0.9626
7	Bus '7'	0.8442	0.9598
8	Bus '8'	0.8426	0.9599
9	Bus '9'	0.8438	0.9628

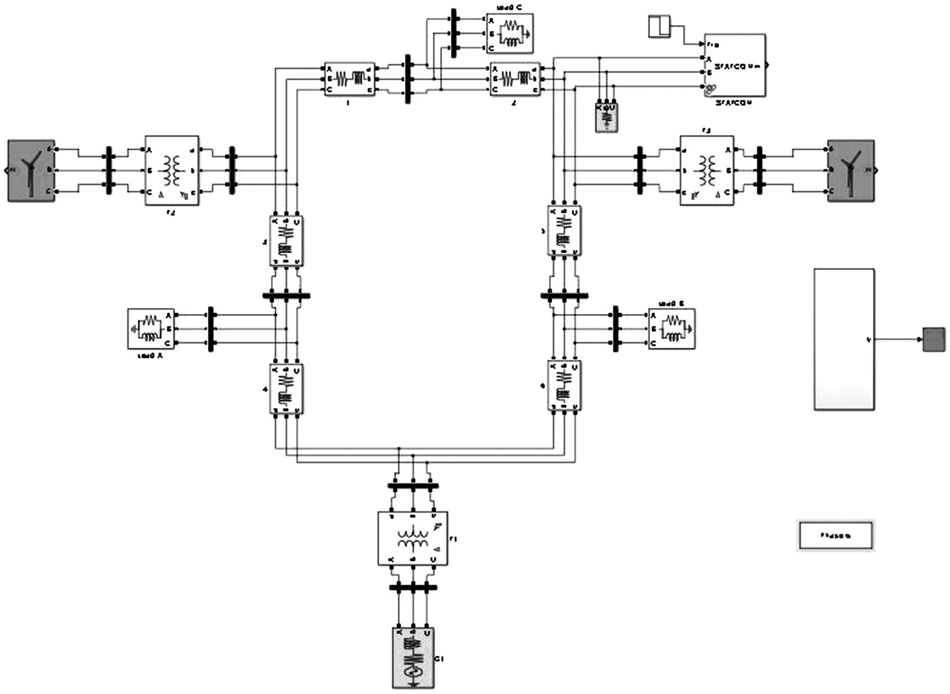

Figure 4: Simulation test system.

time simulations at 0.5 secs and it is clearly visible in Figure 6. It is helping the turbulent energy system. The STACOM is also improving the voltage profiles of the buses in tests system presented in Fiqure 6 whereas Figure 5 shows the transient behaviour of the system without STATCOM. Thus STATCOM is playing pivotal role of a Dynamic Compensator of given test system and to be proved as important FACTS controller of the family.

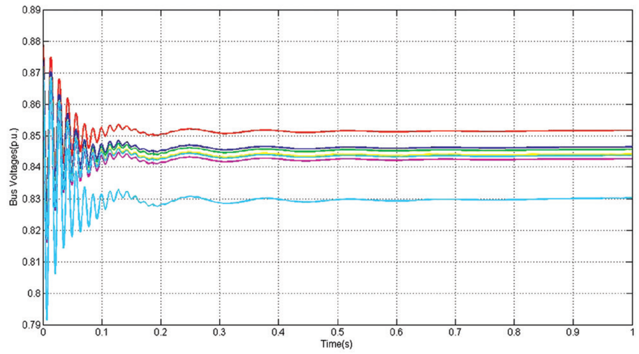

Figure 5: Transient stability performance of test system without STATCOM.

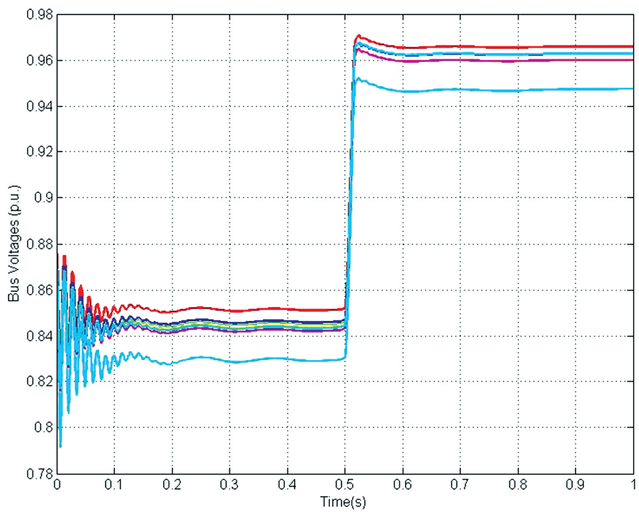

Figure 6: Transient stability performance of test system with STATCOM.

Conclusion

With increment in the popularity, wind generation globally needs powerful solutions for stability problems with power system. Herein, the transient stability improvement of an existing wind energy system with the help of a STATCOM is analyzed and presented. The wind generators considered are the squirrel cage induction generators (SCIG) with IEEE 9-Bus system. A STATCOM is placed in multi-machine power system with this test system. Obtained results show the improvement in voltage profiles of buses of test power system using the STATCOM. The results reveal that, in such cases, deployment of the shunt capacitor banks are incapable, so adequate VAR compensation can be achieved by using the FACTS controllers like STATCOM only. Therefore, the need of compensating controller for the proposed RES based power system has been discussed.

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