Stability Enhancement of DFIG Based Wind Turbine Under Three Phase Fault with STATCOM

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Abstract. The main aim of this paper is to improve the transient stability of Doubly Fed Induction Generator (DFIG) based wind turbine using Static Synchronous Compensator (STATCOM). In this paper, a multi-objective problem is formulated to minimize voltage deviations at the point of common coupling (PCC) and mitigate low frequency oscillations after clearing the faults. Genetic algorithm based STATCOM controller is used to enhance the stability of a grid-connected wind farm composed of a variable-speed wind turbine generator system (WTGS). The transient performance of the proposed control scheme is analyzed with a three-phase fault. The Simulations are carried out in MATLAB/Simulink environment.

Keywords: Stability Indices, Wind turbine, Reactive power, Fault, Genetic Algorithm, STATCOM.

1. Introduction

Wind power is being used as a clean and safe energy resource for electricity generation. Many types of generators have been used to convert wind power into electricity, especially the Doubly Fed Induction Generator (DFIG) is becoming increasingly popular in large wind power conversion systems. It is because of its flexible control and decoupled control at variable speed wind turbines. The optimization-based stability analysis and optimal control of the DFIG based Wind Turbines have been studied by many researchers. Particle Swarm Optimization (PSO) based optimal reactive power and voltage control strategy of the wind turbine is discussed in [1]. Advanced differential evolution algorithm-based vector control of DFIG in Multi machine system is discussed in [2]. Transient stability problem is one of the important factor for the secure operation of heavily loaded power systems. Transient Stability Enhancement of a Multi-machine power system [3] is done using Static VAR Compensator (SVC) and Static Synchronous Compensator (STATCOM). In [4] an auxiliary controller based STATCOM has been employed for transient stability improvement of multimachine system. SVC and Power system Stabilizer are used in [5] for transient stability improvement of DFIG based offshore wind farm. In [6] STATCOM and SVC based Fuzzy Logic Controller is used for transient stability enhancement of DFIG based wind farm. Transient stability enhancement of grid connected wind farm using DFIG based flywheel energy storage system is discussed in [7]. Transient stability improvement of a two-area power system by various FACTS devices is discussed in [8]. In this paper, Genetic Algorithm(GA) based STATCOM Controller is used to minimize the voltage deviations at the point of common coupling in the system even during fault. Simulation is carried out for Multi-machine benchmark power system.
2. STATCOM

FACTS are powerful devices to improve the voltage profile and for power system Transient stability enhancement. The Basic structure of the STATCOM is shown in figure 1. Static Synchronous Compensator is a shunt device, which is used to improve the transient stability and to control power flow control in power networks. Static Synchronous Compensators are installed at selected points in the power system to perform the following:

- Voltage Support and Control.
- Voltage fluctuation and flicker mitigation.
- Unsymmetrical load balancing.
- Power factor correction.
- Active harmonics Cancellation.

![Figure 1. Basic Structure of STATCOM](image)

The Static Synchronous Compensator regulates Voltage at its connection point by controlling the amount of the reactive power that is absorbed from or injected into the power system through a Voltage-Source Converter. STATCOM can be used in different modes for Voltage regulation and VAr control.

3. Problem formulation

Objective function

This paper uses voltage severity index (VSI) to evaluate the voltage deviations at the point of common coupling and transient power severity index (TPSI) to evaluate the transient power performance of the system. The objective is to minimize Voltage Severity Index (VSI) and Transient Power Severity Index (TPSI) and they are expressed as:

$$ VSI = \frac{\sum_{t=t_{st}}^{T} \Delta V_{PCC}^t}{T - T_s} $$  \hspace{1cm} (1) $$

$$ TPSI = \frac{\sum_{d=1}^{N} \sum_{t=t_{st}}^{T} \left( \frac{P_i^t - P_i^0}{P_i^0} \right)}{N * (T - T_c)} $$  \hspace{1cm} (2) $$

$$ V_{PCC}^0 $$ - Voltage at PCC at time, T=0
The real and reactive power balances are given by equations 3 and 4. The control variables ($Q_{RSC}$ and $Q_{STATCOM}$) are adjusted with the help of the two parameters namely $y_1$ and $y_2$ is shown in equation 5.

\begin{align*}
P_G - P_L - P(V, \theta) &= 0 \\
Q_G - Q_L - Q(V, \theta) &= 0
\end{align*}

\begin{align*}
0.3 &\leq Q_{RSC} \leq 2 \text{ Mvar} \\
0.5 &\leq Q_{STAT} \leq 2 \text{ Mvar} \\
0.7 &\leq y_1 \leq 0.8, 0.7 \leq y_2 \leq 0.8
\end{align*}

4. Multi-machine benchmark power system used for simulation

Figure 2 shows the single-line diagram of 4-machine 12 bus power system modified by placing a DFIG based wind Turbine with STATCOM at bus 6 (PCC). The system is divided into three areas. The first area represents the generators G1 as well as G2. The second area consists of Generator G3 in the load side. The Third area represents the proposed combination of the DFIG-based Wind Turbine and the 1.5 MVar STATCOM. The rated capacity of DFIG is 1.5 MW and the wind speed is considered to be constant at 11 m/s. The speed of the rotor is 1.2 p.u. A 3-phase fault is simulated at bus 6.

Figure 2. Multi-machine benchmark power system with STATCOM

A transformer, rated at 0.69/25 kV is used to connect the DFIG to the grid. A three phase PWM converter is used to supply the rotor. The STATCOM is connected to the Point of Common Coupling through a 13.8/25 kV transformer.

5. Results and discussion

The parameters of Doubly-Fed induction generator are shown in the Table 1. The system is simulated with three phase symmetrical fault at bus 6. Figure 3 shows that the transient stability of the power system is optimally maintained, after clearing the fault through reactive power compensation offered by the STATCOM. The GA based response of the controller, namely, real and reactive power, speed of the rotor, wind speed and pitch angle with respect to time during three phase faults are shown in figure...
4. The results show that the performance of STATCOM to improve the stability of power system is effective. Oscillations are damped so as to maintain the rated voltage at PCC and improve the active power output of the wind turbine.

**Table 1. Parameters of DFIG**

| Parameters          | Value     |
|---------------------|-----------|
| Rated power         | 2MW       |
| Rated voltage       | 0.69 kV   |
| Stator resistance   | 0.007 p.u.|
| Rotor resistance    | 0.005 p.u.|
| Stator inductance   | 0.171 p.u.|
| Rotor inductance    | 0.156 p.u.|
| DC link voltage     | 1.2 kV    |

**Figure 3.** MATLAB_SIMULINK output for $Q_{STATCOM}$ during three phase fault
Figure 4. MATLAB_SIMULINK output for Real power, reactive power, rotor speed, wind speed, and pitch angle of the wind farm during 3 phase fault

It can be seen that the active and reactive powers are stabilized faster with less oscillations. Fault is induced at t=10sec and the rotor speed is shown in per unit for fault clearance time t= 12 s. The simulation time is 20s which is enough to investigate the transient behavior of rotor speed. During fault, the STATCOM has the capacity to control the reactive power transfer at its terminal. Hence it achieves voltage regulation.

6. Conclusion

The power system stability enhancement of a Multi-machine benchmark power system by STATCOM is discussed. The Simulation results demonstrated that with the proposed GA based STATCOM controller, the transient stability of the wind farm under three-phase symmetrical fault conditions had improved. In the proposed scheme, during and after the fault condition, the voltage deviations are reduced and oscillations of the active power are damped. Therefore, the Genetic Algorithm based STATCOM controller is effective in optimizing the power flow even during fault conditions.

References

[1] TangT, Ping J, HiaboH, Chuan Q, Feng W 2013 Optimized Control of DFIG Based Wind Generation using Sensitivity Analysis Particle Swarm Optimization., IEEE Trans. Smart Grid., 4 (1), pp. 509-520.

[2] Ayyarao S.L. Tummala, Hemanth K, Alluri R, Ramanarao P. V 2018 Optimal Control of DFIG Wind Energy System in Multi-machine Power System using Advanced Differential Evolution., IETE Journal of Research., 66(1), pp. 91-102 DOI: 10.1080/03772063.2018.1466732.

[3] Rakesh kushwah., Mandakini Gupta 2016 Modelling & Simulation of SVC and STATCOM For Enhancement of Power System Transient Stability Using Matlab, International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT).pp.4041-4045 DOI: 10.1109/ICEEOT.2016.7755473

[4] Karami. A, Mahmoodi Galougahi K 2019 Improvement in Power System Transient Stability by using STATCOM and Neural Networks., Electrical Engineering-Springer.,101, pp.19–33https://doi.org/10.1007/s00202-019-00753-5.

[5] Gupta Vipin Patel., Varun Kumar, Dilip Kumar 2018 Coordination of SVC and PSS for Stability Enhancement of DFIG-Based Offshore Wind Farm Connected to a Multi-Machine System, International Journal of Advance Research and Development, 3(4), pp. 227-237.

[6] Hemeida, M. G, Hegazy Rezk, Mohamed M, Hamada 2017 A comprehensive comparison of STATCOM versus SVC-Based Fuzzy Controller for Stability Improvement of Wind Farm Connected to Multi-Machine Power System, Electrical Engineering-Springer.100, pp. 935–951 DOI: 10.1007/s00202-017-0559-6.

[7] Talha Ahmed Taj, Hany M. Hasanien, Abdul Rahman I. Alolah, Syed M. Muyeen 2015 Transient Stability Enhancement of Grid connected Wind Farm Using an Adaptive Neuro-Fuzzy Controlled – Flywheel Energy Storage System, IET Renew. Power Generation, 9(7), 792–800.

[8] Ketan G. Damor, Dipesh M. Patel, Vinesh Agrawal., Hirenkumar G. Patel 2014 Improving Power System Transient Stability by using Facts Devices. International Journal of Engineering Research & Technology, 3(7).