TCSC-STATCOM Controller for the Voltage Stability Improvement of the Wind Farm Connected to the Grid

K. Amritha\textsuperscript{1}, Harika Savitry\textsuperscript{2}, Md. Shamma Parveen\textsuperscript{1}, K. Sai Soumya\textsuperscript{4} and B. Shirisha Reddy\textsuperscript{5}

\textsuperscript{1}Associate Professor, EEE Department, BVRIT Hyderabad College of Engineering for Women, Hyderabad, Telangana, INDIA
\textsuperscript{2}Student, EEE Department, BVRIT Hyderabad College of Engineering for Women, Hyderabad, Telangana, INDIA
\textsuperscript{3}Student, EEE Department, BVRIT Hyderabad College of Engineering for Women, Hyderabad, Telangana, INDIA
\textsuperscript{4}Student, EEE Department, BVRIT Hyderabad College of Engineering for Women, Hyderabad, Telangana, INDIA
\textsuperscript{5}Student, EEE Department, BVRIT Hyderabad College of Engineering for Women, Hyderabad, Telangana, INDIA

\textsuperscript{1}Corresponding Author: amritha.k@bvrithyderabad.edu.in

ABSTRACT

The project is about the improvement of voltage stability of the system which has a wind farm connected to the Grid. A combination of TCSC and STATCOM is used in the controller. The controller ensures that the system receives enough reactive power to maintain stability. The simulation model is going to be inbuilt MATLAB/SIMULINK, output voltages of the system without the controller, with each component acting separately and the collaborative control effect of TCSC and STATCOM, will be compared and studied in the simulated model to prove the efficiency of the controller.

Keywords-- Voltage Stability, TCSC, STATCOM, MATLAB/SIMULINK

I. INTRODUCTION

With the depletion of the conventional energy source, the development of recent energy sources has received more and more attention. Wind generation with its technology, advanced monetary performance, and big marketplace appeal has improved recent strength with the aid of using breakthrough. However, the connection between the grid and the irregular wind energy and the wind turbines have an enormous effect on the stable operation of the grid. Active power is supplied to the grid from the squirrel-cage asynchronous generator and the reactive power is also observed to maintain the moderate operation. If the reactive power will not match generator requirements, then the generator operation is affected and also stability of grid voltage reduces. Therefore, the balance of the grid-connected system is the current principle problem faced by wind generation grid integration. When the device is in normal operating condition, then the wind farm has to absorb a particular quantity of reactive power from the grid, then there is a decrease in voltage stability. If the fault takes place in the system to return voltage to normal we require more reactive power. To maintain safe and stable operations, the FACTS devices are widely used. Focusing on the voltage dependability issue of wind power network associated frameworks, a helpful control plan of Thyristor Controlled Series Compensator (TCSC) and Static Synchronous Compensator (STATCOM) is proposed in this investigation.

The literature survey throws light on the various methods adopted for the power quality improvements in the power systems. [1]-[3] mention the usage of STATCOM for wind energy applications while used in combination with asynchronous generators. [4] & [5] are about the progress and research opportunities available in the field of FACT devices and the application of it in the stability analysis. [6]-[7] are about the stability analysis of wind farms when connected to STATCOM with an energy storage unit. [8] is a study on the capacity of STATCOM under symmetrical faults. [9] – [10] are the analysis of the application of STATCOM on various applications. [12] – [17] are about the usage of TCSC in the mitigation of oscillations and sub synchronous reactance while used in power systems. [18] and [19] are about the improvement of the power quality because of the combined use of TCSC and STATCOM. The enhancement of power quality using STATCOM- PSS control is explained in [20]. [21] gives a steady state stability analysis of power systems during high penetration of wind speed.

A Thyristor Controlled Series Compensator (TCSC) is a fundamental FACT device which can fast alternate the reactance of the line to improve the stability of the system, so it's become a representative of the new series compensation technology in recent years. The basic TCSC scheme was introduced in 1986 by Vithayathil with others. A TCSC is a capacitive reactance compensator that includes a sequence capacitor bank shunted through a thyristor-controlled reactor to give an easily variable series capacitive reactance. During a practical TCSC application, basic compensators also are connected in series to get the required voltage ratings and operating characteristics. However, the concept of the TCSC strategy is to provide a constantly variable capacitor partially canceling the
A Static Synchronous Condenser. It's one of the members of the FACTS family. The phrases Synchronous in STATCOM mean that it may either take in or generate a reactive power compensation. The advantages of STATCOM are flexible control, less occupied area, and low loss. A STATCOM uses force-commutated devices like GTO, IGBT etc. to regulate the reactive power flow through a power network and thereby improving the steadiness of the facility network. The STATCOM is shunt device. The STATCOM is connected in shunt with the line. A Static Synchronous Compensator is likewise called a Static Synchronous Condenser. It's one of the members of the FACTS family. The phrases Synchronous in STATCOM mean that it may either take in or generate a reactive energy in synchronization with the demand to stabilize the voltage of the power network. The correlated method is proposed to enhance the system voltage stability by using STATCOM connected to the system.

The study says that the huge-capacity wind farm access affects, local reactive power, and local voltage stability compensation helps to modify or increase the local voltage stability. In wind power generation systems, the series controllable compensation and asynchronous wind turbines device TCSC are used to supply electric energy to the public grid, which prevents the irregular operation of the grid-connected systems. To increase the stability of the power system the combination of TCSC and STATCOM is used. The cooperative control of TCSC and STATCOM is implemented to enhance the voltage stability of wind energy grid-connected systems while the reactive energy compensation is performed under a three-phase short-circuit fault, and wind farm and its related energy grid version is constructed in MATLAB/SIMULINK, which verifies that the cooperative control of TCSC and STATCOM can enhance device voltage balance.

### II. WIND ENERGY BACKGROUND

Wind turbines work on a basic standard: rather than utilizing power to make wind—like a fan wind turbine use the wind to make power. The wind turns the propeller-like cutting edges of a turbine around a rotor, which causes the generator to turn, which makes power. The wind is a type of sun-oriented energy brought about by a mix of three simultaneous occasions: The sun unevenly warming the air. Inconsistencies of the world's surface. Wind stream examples and rates shift enourmously across the United States and are adjusted by waterways, vegetation, and contrasts in landscape. People utilize this breeze stream, or movement energy, for some reasons: cruising, flying a kite and for creating power. The expressions "wind energy" and "wind power" both depict the cycle by which the air is utilized to create mechanical force or power. This mechanical force can be utilized for explicit assignments (like crushing grain or siphoning water) or a generator can change over this mechanical force into power. A Wind turbine converts wind energy into power makes use of the excellent from the rotor sharp ends which work like an aircraft wing or helicopter rotor cutting bounds. At the point when wind streams across the cutting end, the pneumatic stress on one side of the sharp end changes. The distinction in pneumatic stress across the different sides of the sharp edge makes both lift and drag. The power of the lift is much grounded than the drag and this does the rotor turn. The rotor is equivalent to the generator, either forthrightly or through a shaft and a change of cogwheels that speed up the turn and take into consideration many modest generators. This interpretation of streamlined power to turn off a generator makes power. The rotor match with the generator, either straightforwardly or through a shaft, and a progression of cogwheels (a gearbox) that accelerate the turn and take into account more modest generators. This interpretation of streamlined power to turn off a generator makes power.

### III. SYSTEM AND UNDER STUDY

For creating this complete Model we need:
- TCSC
- STATCOM
- Wind Turbine with the connecting system.

#### 3.1. TCSC Model

The simulation model of wind power grid-connected system with the coordinated control of TCSC and STATCOM is built using Simulink/MATLAB. The TCSC model is developed by using a three-phase voltage source block. The TCSC compensation block consists of p, CB, A, B, and C as output nodes, this output p node is connected with the TCR_Pulses node of the firing circuit.
block, the CB node of TCSC compensation block is in connection with the CB node of firing unit. 

![Figure 1: TCSC model](image)

The A, B, C nodes of the TCSC Compensation block is connected with the programmable voltage source and are grounded. Labs gate pulse is connected to the input side of labs nodes of the firing unit block and Control system block. The \( V_{tcsc} \) gate pulse is connected to the control system block and the output is displayed in the scope. The alpha and \( I_{rms} \) nodes of a control system are connected to the firing unit block. The \( Z_{ref} \) node of the control system is connected to the control system block. The Scopes block is connected in series with the main variables block. There is a powergui block.

By taking the above TCSC model as reference the below TCSC subsystem is built.

![Figure 2: TCSC simulated model](image)

In this selector Select or reorder indicated components of a multidimensional information signal. The record to every component is distinguished from an information port or this exchange.

### 3.2. STATCOM Model

A STATCOM is used for controlling the reactive power flow through a network and thus increasing the stability of the network under varying load conditions and fault conditions.
In the STATCOM model, the programmable source is connected to the resistor and inductor source with a power supply. On the other side, there is a voltage source, resistor, and the inductor are connected to the power supply and the is a voltage source, inductor and resistor are connected in series and are joined through the 3 different lines L1, L2, L3 along with the batteries.

Then from the merged point of these, all the connection is given to the A, B, C in the STATCOM and there the V_{dcP} and V_{dcM} and Neutral points are connected through the two capacitors Cp and Cm. The pulses in the STATCOM and the STATCOM controller are connected.

The V_{abc}_B1 and labc_B1 gate pulses are connected to the STATCOM Controller with reference to the V_{dcPN}.

Externally the Signals and Scopes are connected to the STATCOM scope and the powergui is externally connected. Then the complete circuit is run and tested. By taking the above STATCOM model as reference the below STATCOM subsystem is built.

The zig zag transformers are used to here which helps to completely eliminate the harmonics. It also provides grounding to the transformer and helps to avoid the fault current.
The 3-phase voltage source is connected to the transformer on the left side of the transformer the n2 is connected to the resistor and the resistor is grounded. And the a, b, c nodes are connected to the A, B, C of the RLC series block. These are again connected to the battery with wind turbines A, B, C, and trip 1 is connected to trip. The wind turbine m is connected to the P and Q junctions and finally, they are connected to the two diodes and from one diode it is connected to the display.

![Wind Turbine connected to the Grid](image)

**Figure 5:** Wind Turbine connected to the Grid 1

### IV. WIND TURBINE WHEN CONNECTED TO BOTH TCSC AND STATCOM

The powergui set simulation type, simulation parameters, and preferences are placed. The Three-phase source, Three-phase voltage source in series with RL branch, Three-phase VI measurements, Ideal three-phase voltage, and current measurements are connected. The output of the voltage s and currents are stated as per unit in volts and amperes. A three-phase transformer block performs a three-phase transformer operation with the help of three single-phase transformers.

![Wind Turbine and STATCOM](image)

**Figure 6**

The winding connection to 'Yn' is provided to access the neutral point of the Wye. The Three-phase PI section line block models a three-phase cable with one PI section. This block is made up of one set of RL series-connected between the input and output terminals and two sets of shunt capacitance combined at both ends of the line. RLC elements are computed using hyperbolic corrections yielding a particular...
representation within the positive- and zero-sequence at a specified frequency only.

To obtain an extended frequency response, we connect several PI section blocks into the scope, and from the other diode, it is cascade or uses a Distributed Parameter line. Three-Phase fault implements a fault (short-circuit) between any phase and therefore the ground. When the external switching time mode is chosen, a Simulink logical signal is employed to regulate the fault operation.

At the point when TCSC works in the steady impedance mode, it utilizes voltage and current calculation for computing the TCSC impedance. The reference impedance by implication decides the force level. The terminating circuit utilizes three single-stage PLL units for synchronization with the line current. For synchronization line current is used, as opposed to line voltage since the TCSC voltage can shift generally during the activity. Simulink model of TCSC with transmission line is introduced and related waveforms are dissected.

An open circle MATLAB/re-enactment model of TCSC gadget on transmission line additionally investigated with waveform. TCSC normally interfaces in arrangement with line and permits changing impedance of transmission path and by this change to impact power streams. Control is quick, effective, and increment cut-off points of communicated power.

The stair generator connected to the control system generates a signal changing at specified times. Output is kept at zero until the first specified transition time.

During consistent state activity, the STATCOM control keeps the basic segment of the VSC voltage in stage with the reference voltage. On the off chance that the voltage created by the VSC is higher (or lower) than the reference voltage, the STATCOM produces (or retains) receptive force. The measure of receptive force relies upon the VSC voltage greatness and on the transformer spillage reactances. The crucial part of VSC voltage is constrained by differing DC transport voltage. To fluctuate the DC voltage, and along these lines the responsive force, the VSC voltage point (alpha) which is regularly held near zero is briefly stage moved. This VSC voltage slack or lead delivers an impermanent progression of dynamic force which brings about an increment or reduction of capacitor voltages.

The turbine of model 7 block is connected to two models of TCSC and STATCOM which are internally built subsystems this implements a model of a variable speed pitch controlled wind turbine using a synchronous generator. This controls the distortions in the turbine and stabilizes the voltage which is mainly required and also gives the actual output of our project.

V. RESULT AND OUTPUTS

When TCSC, STATCOM and fault are not connected to Wind Turbine

![Figure 7: When TCSC, STATCOM and fault are not connected](image-url)
Figure 7 shows the output when the circuit is designed without TCSC - STATCOM devices. The output voltage generated by the wind turbine contains a lot of distortion. A fault is introduced into the circuit at 3 sec.

![Figure 8: When a fault is introduced](image)

Figure 9 and 10 show the outputs voltage and currents of the system when TCSC and STATCOM are used separately. Even though the waveform voltage waveform looks sinusoidal, the current waveform contains distortions in it.

![Figure 9: Output of TCSC](image)

![Figure 10: Output of STATCOM](image)
VI. CONCLUSION

The graphs in fig.11 show that when TCSC and STATCOM are used simultaneously, the voltage and current waveforms are completely free from distortions.

REFERENCES

[1] Xiang, Z., Xie, D., & Gong, J., et al. (2008). Dynamic characteristics analysis of STATCOM for reactive compensation in wind farm. *Autom. Electr. Power Syst.*, 32(9), 92–95.

[2] Qi, L., Langston, J., & Steurer, M. (2009). Applying a STATCOM for stability improvement to an existing wind farm with fixed-speed induction generators. *IEEE Power and Energy Society General Meeting-Conversion and
Delivery of Electrical Energy in the 21st Century, Pittsburgh, Pennsylvania, pp. 1–6.
[3] Wei, Q. & Harley, R.G. (2007). Power quality and dynamic performance improvement of wind farms using a STATCOM. IEEE Power Electronics Specialists Conf., Orlando, FL, USA, pp. 1832–1838.
[4] Huang, L., Guo, J., & Bu, G., et al. (2012). Research progress and prospect of FACTS coordinated control. Power Syst. Prot. Control, 40(5), 138–147.
[5] Zhu, T., Duan, R., & Wang, Z. (2015). Research on different types of single FACTS element improving dynamic stability Western Yunnan power grid. Power Syst. Prot. Control, 43(20), 65–70.
[6] Hossain, M.J., Pota, H.R., & Ramos, R.A. (2012). Improved low-voltage-ride-through capability of fixed speed wind turbines using decentralized control of STATCOM with energy storage system. IET Gener. Transm. Distrib., 6(8), 719–730.
[7] Arulampalam, A., Barnes, M., & Jenkins, N. (2006). Power quality and stability improvement of a wind farm using STATCOM supported with hybrid battery energy storage. IEEE Proc., Gener. Transm. Distrib., 153(6), 719–730.
[8] Yao, J., Zhou, T., & Chen, Z. (2016). Studies on STATCOM capacity configuration for FSIG-based wind farm under symmetrical grid fault. Trans. China Electrotech. Soc., 31(1), 45–54.
[9] Zhou, X., Zhang, S., & Ma, Y. (2009). Research and analysis of static synchronous compensator principle and performance. Mach. Des. Manuf., 12, 76–78.
[10] Yao, G., Fang, R., & Li, D., et al. (2015). DC capacitor voltage balancing control of cascaded static synchronous compensator. Power Syst. Prot. Control, 43(18), 23–30.
[11] Wei, W., Liu, W., & Song, Q., et al. (2005). Research on fast dynamic control of static synchronous compensator using cascade multilevel inverters. Proc. CSEE, 25(3), 23–28.
[12] Varma, R.K., Semsedini, Y., & Addy, S. (2007). Mitigation of subsynchronous oscillations in a series compensated wind farm with thyristor controlled series capacitor (TCSC). In: Power Systems Conf.: Advanced Protection Control Communication and Distributed Resources, Clemson, pp. 331–337.
[13] Wu, S., Jiang, W., & Li, Y., et al. (2000). Analog test on system dynamic control of TCSC. Power Syst. Technol., 24(3), 3–8.
[14] Luo, Y., Yang, R., & Liu, C., et al. (2014). Control strategy of TCSC for stability improvement in power systems integrated with large scale wind farms. Electr. Meas. Instrum., 51(4), 35.
[15] Bai, F., He, P., & Zhang, P., et al. (2011). Simulation research on suppressing synchronous resonance of power system by TCSC. J. Dalian Univ. Technol., 51(S1), 65–68.
[16] Li, S., Yu, L., & Dong, W. (2016). Analysis of reliability non-coherence of power systems with TCSC. Power Syst. Prot. Control, 44(14), 1–7.
[17] Zheng, Y., Li, H., & Wu, T. (2014). Impedance characteristics of TCSC and its conduction angle for subsynchronous resonance mitigation. Power Syst. Prot. Control, 42(16), 27–32.
[18] Cheng, Z.-x., Wu, X.-b., & Dai, X-g. (2013). Simulation analysis of The improvement of system's stability by the joint compensation of SVC and TCSC. Lab. Res. Explor., 32(09), 76–80.
[19] Ning, K.E., Jianshe, S.U., & Chen, C. (2004). Simulation study of TCSC and SVC to improve transient stability of transmission system. Autom. Electr. Power Syst., 28(1), 20–23.
[20] Kuang, H., Zhang, S., & Zeng, L., et al. (2015). Stability and power quality improvement of wind power integrated system using STATCOM-PSS control. J. Power Supply, 13(3), 100–106+133.
[21] Vittal, E., O'Malley, M., & Keane, A. (2010). A steady-state voltage stability analysis of power systems with high penetration of wind. IEEE Trans. Power Syst., 25(1), 433–442.