Power Quality Improvement in Grid Connected Wind Energy System

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Abstract: Wind power is one of the optimistic source of energy generation among all the renewable energy sources. Hence for effectively exploiting wind energy sources it must be connected to electric grid. Wind power inculcation into grid affects power quality because of its fluctuating nature. The concerned power quality issues are voltage sag, voltage swell, active power, flicker, reactive power, harmonics, voltage interruption and power quality depends upon performance of switching devices. In this proposed system, simulation model of grid connected wind energy system with uncompensated and compensated is simulated. In this system STATCOM is designed and it is capable to maintain the voltage stability in grid and reduce the harmonic components from voltage. To overcome the power quality issues of grid connected wind energy generating system, STATCOM control scheme with linear & non linear load is simulated using MATLAB/SIMULINK. The results of this sustainable and renewable model are to meet the power demand and for promoting green energy systems.

Index Terms: Power quality, wind generating system, STATCOM.

INTRODUCTION

Now a day’s energy demand is increasing rapidly, due to the growth in population and economic development in the world leading to increase in environmental impact on conventional plants. Hence renewable energy resources must be employed in order to meet the energy demand and have communal development and prolong growth. In recent years, among the other renewable energy sources, wind energy is gaining ever increasing attention as a clean, safe and economical resource. Thus to exploit wind power effectively its grid connection is necessary so as to realize its potential to significantly mitigate present day problems like energy demand along with atmospheric pollution. But amalgamation of wind power to grid introduces power quality issues, which predominantly consist of voltage regulation and reactive power compensation. The power quality is a crucial customer focused measure and is of prominent importance to the wind turbine.

Voltage dips are one of the most occurring power quality problems. Off course, for an industry an outage is worse, than a voltage dip, but voltage dips occur more often and cause severe problems and economical losses. Utilities often focus on disturbances from end-user equipment as the main power quality problems. This is correct for many disturbances, flicker, harmonics, etc, but voltage dips mainly have their origin in the higher voltage levels. Faults due to lightning, is one of the most common causes to voltage dips on overhead lines. If the economical losses due to voltage dips are significant, mitigation actions can be profitable for the customer and even in some cases for the utility. Since there is no standard solution which will work for every site, each mitigation action must be carefully planned and evaluated. There are different ways to mitigate voltage dips, swell and interruptions in transmission and distribution systems. At present, a wide range of very flexible controllers, which capitalize on newly available power electronics components, are emerging for custom power applications. STATCOM is often used in transmission system. When it is used in distribution system, it is called STATCOM. STATCOM is a key FACTS controller and it utilizes power electronics to solve many power quality problems commonly faced by distribution systems. Potential applications of STATCOM include power factor correction, voltage regulation, load balancing and harmonic reduction. Comparing with the SVC, the STATCOM has quicker response time and compact structure. It is expected that the STATCOM will replace the roles of SVC in nearly future. STATCOM is different in both structure and function, while the choice of control strategy is related to the main-circuit structure and main function of compensators, so STATCOM adopt different control strategy. At present, the use of STATCOM is wide and its strategy is mature, compared to other FACTS devices.

POWER QUALITY PROBLEMS

The ideal power supply system is nothing but the ideal power quality means to supply electric energy with ideal and constant supply frequency with pure sinusoidal waveform of a described voltage with minimum disturbances. Power quality issues are getting increasingly important day by day to utility grid and end user consumers. The various power quality problems are voltage sag, swell, interruption, voltage unbalance, flicker, and harmonics etc which are discussed briefly.

1. Voltage Sag

It is defined as decrease in voltage between 10 to 90% of its nominal rms voltage at the rated power frequency i.e. 50Hz. Voltage sag consequences are tripping of motor or causes its controller to malfunction, namely programmable logic controller, microprocessor based control system, adjustable speed drives that may lead to a process stoppage.
2. Voltage Swell

Voltage swell is an increase in RMS voltage in range of 10% to 80% for duration greater than half cycle and less than 1 minute. A swell can occur due to a single line-to-ground fault on the system which can result temporary voltage rise on the other unfaulted phases. Swells can also be caused by switching off a large load or switching on a large capacitor bank.

3. Voltage Unbalance

Voltage imbalance is deviation in the magnitude and phase of one or more of the phases, of a three phase supply, with respect to the magnitude of the other phase and the normal phase angle. Voltage imbalance can cause temperature rise in motors and can even cause a large motor to trip.

4. Harmonics

It is a sinusoidal component of a periodic wave having a frequency that is an integral multiple of the fundamental frequency. A non-linear element in power systems such as power electronic devices, static power converters, arc dis-charge devices etc creates harmonics in system. Harmonics cause communication interference, heating, and malfunction of equipments.

Consequences of the Issues

The voltage variation, sag, swell, and harmonics causes mal-functioning of electronics equipments namely microprocessor based system, programmable logic controller, adjustable speed drives etc. Due to all this problems it may cause trip-ping of contractors, protection devices, also stoppage of sensitive equipments like computer, programmable logic control system and may be damage the sensitive equipments. Due to all this problems the whole system will be derated.

TOPOLOGY FOR POWER QUALITY IMPROVEMENT

The STATCOM based current control voltage source inverter injects the current into the grid in such a way that the source current are harmonic free and their phase-angle with respect to source voltage has a desired value. The injected current will cancel out the reactive part and harmonic part of the load and induction generator current, thus it improves the power factor and the power quality. To accomplish these goals, the grid voltages are sensed and are synchronized in generating the current command for the inverter. The proposed grid connected system is implemented for power quality improvement at point of common coupling.

1. Wind Energy Generating System

The induction generator is used in the proposed scheme because of its simplicity, it does not require a separate field circuit, it can accept constant and variable loads, and has natural protection against short circuit. The available power of wind energy system is given by,

\[ P_{\text{wind}} = \frac{1}{2} \rho A V^3 \text{wind} \]

Where, \( \rho \) (kg/m) is the air density, A (m) is the area swept out by turbine blade, Vwind is the wind speed in meters. It is not possible to extract all kinetic energy of wind, thus it extract a fraction of power in wind, called power coefficient \( C_p \) of the wind turbine.

\[ P_{\text{mech}} = C_p P_{\text{wind}} \]

Where, \( C_p \) is the power coefficient, depends on type and operating condition of wind turbine. This coefficient can be express as a function of tip speed ratio \( \lambda \) and pitch angle \( \theta \). The mechanical power produce by wind turbine is given by,

\[ P_{\text{mech}} = \frac{1}{2} \rho IR^2 V^3 \text{wind} C_p \]

2. STATCOM – Static Synchronous Compensator

The STATCOM is a shunt-connected reactive power compensation device that is capable of generating and/or absorbing reactive power and in which the output can be varied to control the specific parameters of an electric power system. It is in general a solid-state switching converter capable of generating or absorbing independently controllable real and reactive power at its output terminals when it is fed from an energy source or energy-storage device at its input terminals. Specifically, the STATCOM considered in this chapter is a voltage-
source converter that, from a given input of dc voltage, produces a set of 3-phase ac-output voltages, each in phase with and coupled to the corresponding ac system voltage through a relatively small reactance (which is provided by either an interface reactor or the leakage inductance of a coupling transformer). The dc voltage is provided by an energy-storage capacitor. A STATCOM can improve power-system performance in such areas as the following:

a. The power-oscillation damping in power transmission systems.
b. The dynamic voltage control in transmission and distribution systems.
c. The transient stability.
d. The voltage flicker control

3. System Operation

The shunt connected STATCOM is connected with the interface of the induction generator and non-linear load at the PCC in the grid system. The STATCOM compensator output is varied according to the controlled strategy, so as to maintain the power quality norms in the grid system. The current control strategy is included in the control scheme that defines the functional operation of the STATCOM compensator in the power system. A single STATCOM using insulated gate bipolar transistor is proposed to have a reactive power support, to the induction generator and to the nonlinear load in the grid system. The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes:

1. Voltage regulation and compensation of reactive power;
2. Correction of power factor; and
3. Elimination of current harmonics

4. Schematic Diagram of STATCOM

A STATCOM (Static Compensator), which is consists of a two-level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer. The VSC converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactivity of the coupling transformer. Suitable adjustment of the phase and magnitude of the STATCOM output voltages allows effective control of active and reactive power exchanges between the STATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power

5. Voltage Source Converter (VSC)

A voltage-source converter is a power electronic device that connected in shunt or parallel to the system. It can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. The VSC used to either completely replace the voltage or is the difference between the nominal voltage and the actual. It also converts the DC voltage across storage devices into a set of three phase AC output voltages. In addition, STATCOM is also capable to generate or absorbs reactive power. If the output voltage of the VSC is greater than AC bus terminal voltages, STATCOM is said to be in capacitive mode. So, it will compensate the reactive power through AC system and regulates missing voltages. These voltages are in phase and coupled with the AC system through the reactivity of coupling transformers. Suitable adjustment of the phase and magnitude of the STATCOM output voltages allows effective control of active and reactive power exchanges between D-STATCOM and AC system. In addition, the converter is normally based on some kind of energy storage, which will supply the converter with a DC voltage.

SIMULATION RESULTS

With STATCOM

During the operation induction generator draws reactive power from the grid for its magnetization. Non linear load distorts the grid current waveform and also increase the harmonic component. Due to this, grid current is not in phase with the grid voltage and its wave shape is also different from sine wave which is shown in fig 5. Hence the power factor is not unity. Reactive power requirement of induction generator and load is supplied by the grid. This waveform shows the load side (i.e) wind side voltage and current waveforms, the STATCOM will acts for a particular interval of time 0.15 to 3 seconds.

Fig.4 Schematic diagram of STATCOM

Fig.5 Load side voltage and current waveforms
The below waveform shows the statcom which acts in current conduction mode, for a three phases A, B and C shown in fig 6.

Without STATCOM

STATCOM OFF condition and in ON condition grid current is 1800 out of phase with voltage, which signifies that the excess power after feeding the non linear load is fed back to the source which is shown in fig 7

Because of the absence of STACOM, and the presence of non linear load the harmonics wave form can be produced for a particular interval of time 0.15 sec to 3 sec. For this the STATCOM drawn no current, at the same time the remaining excess current fed back to the working of induction motor for synchronization as shown in below figure 8.

CONCLUSION

This paper presents the STATCOM-based control Scheme for reactive power compensation and harmonic reduction in grid connected wind generating system feeding non linear load. The control system for the STATCOM is simulated using MATLAB/SIMULINK. The Simulation results shows the grid voltage and current are in-phase, making the power factor unity, which implies that the reactive power demand of Induction generator and load is no longer. The control scheme has a capability to cancel out the harmonic parts of the load current. It maintains the source voltage and current in-phase and support the reactive power demand for the wind generator and load at PCC in the grid system, thus it gives an opportunity to enhance the utilization factor of transmission line.

REFERENCES


Fig.6 Current feed by STATCOM

Fig.7 Load side voltage and current waveforms

Fig.8 before STATCOM