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Review on Enhancement of Power Quality in the Grid Connected Wind Energy System using STATCOM

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Abstract: This paper discusses how to improve power quality for effective power transfer in a grid-integrated wind energy system. The system is a wind energy conversion system based on a renewable energy farm. The system is subjected to frequent disruptions in AC loads and renewable farm power output. As a result, there is a reactive power mismatch, which causes voltage instability and power quality issues. This gap can be closed by using a variable reactive power source, such as a static synchronous compensator. Three case scenarios of the system are tested to compare their dynamic and transient performances: (A) standalone mode, (B) grid-integrated without STATCOM mode, and (C) grid-integrated with STATCOM mode. The result will be based on the fault created on the wind system, which will be classified and controlled by STATCOM.

Keywords: Grid, Power Quality, STATCOM, Wind Turbine.

I. INTRODUCTION

Renewable resources are the most important alternative solution for electricity. Amongall these renewable sources Wind energy is one of the best alternatives. Wind energy is one of thecleanest energies as it produces no pollution. Generally, the wind farms consist of many winds turbines link with each other and generates low power but it becomes more powerful after connecting the power converters and transformer.

Wind farms generally DFIG (Doubly fed induction generator) or PMSG (Permanent magnet synchronous generator) based. Induction generators are also used due to their ability to produce useful power at varying rotor speed. While considering integration of grid with wind -farm high penetration of wind results in some ups and downs in power system. Therefore, power quality draws its mark [1].Power quality is an acronym says about the quality of voltage, current and frequency which gets deviated due to some circumstances and causes the failure in the power system. So, the picture of a perfect power supply is a smooth sinusoidal waveform of voltage and frequency within a specific tolerance due to which the equipment works properly. If any disturbance in magnitude and frequency detects then it results in the failure in power quality. From producer to consumers, in utilities and manufacturers, power quality is the key point of discussion. Maintenance and protection of sensitive equipment from generation units to consumer section is necessary as they are much more likely subjected to fail and the failure of any of these unit will interrupt the power supply as well as sometimes it leads to destruction. So, the importance of power quality and the problems associated with itcomes into picture [2].

Voltage fluctuations can result in over/under voltages which in turn can create undesirable effects like flickering of lighting devices. Voltage sag can lead to overloading problems such as intermittent lockup. On the other hand, voltage swell can damage the electrical equipment. Harmonics introduced can force losses in electrical equipment and even overheat the transformers and motors in the system. Power frequency variations mainly affects the motors and frequency sensitive devices in the system. In electrical power system most of the problem-based situations occur due to the interconnections of generators, conductors, highly rated transformer and variable nature of the loads. Hence, it is more challengeable to maintain reliable & clean power to the different uncertainties. The basic need for integration of non-conventional energy (NCE) sources such as wind energy into the grid is used to make an efficient effect on the plant. Basically, windturbines can be classified as variable speed turbine & fixed-speed turbine.

The variable speed turbines are the turbine, which operates over variable rotor speed while the fixed-speed turbines are the turbines which having its rotor speed approximately constant. The various power quality issues as per the wind

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system concernare voltage sags, voltage swells, flickers, harmonicsetc. [3]

II. PROBLEMS RELATED TOPOWER QUALITY

2.1. Power quality issues at grid side

At the grid side the power quality is the responsibility of utility. Utility should make sure that the power matches the customer requirements and should not violate the limits that are specified for the parameters which define the power quality. From the customer point of view the voltage variations and high content of harmonics in the grid power are highly undesired as they affect the performance of the end equipment. For the IIP's who have planned the wind power project, the voltage profile of evacuating substation and nearby substations is of prime concern. [4,5]

A. Voltage variation

Intermittent nature of wind power causesseveral problems and one is variation of voltage of buses in the region of high RE penetration. Wind generators mostly employed induction generators and power electronic circuits which demand reactive power for operation. Voltage sag/swell is observed where ineffective methods of reactive power management are employed. If voltage rises beyond the controllable limit, forced tripping of lines carried out, cascaded tripping may destabilise a weak power system. Generally, the power factor of evacuating substation is maintained near to unity preferably slightly lagging.

B. Voltage Transient

Fault in the power system network, capacitor switching and HVDC systems are the primary cause of voltage transients. Voltage transients are responded well by STATCOM.

2.2. Power quality issues of WTG side

In wind energy generating system the power quality primarily concerned with the quality of current waveform which is being drawn or generated by the wind turbine. Poor power quality affects the performance of the loads connected to the grid.

A. Reactive Power Consumption

Induction generators draw reactive power toproduce its working flux while generate active power at the same time. As induction generators aremost widely preferred in wind turbine generators,
collectively a wind farm demand huge amount ofreactive power.

As the wind speed is not constant, the use of electronic power conversion devices in wind turbine generators become inevitable to achieve a rotor speed for maximum extraction of energy from wind. The operation of power electronic devices also requires reactive power. To avoid voltage stability problem either STATCOM or capacitor arrangement is used to supply this demand of reactive power.

B. Current Harmonics Generation

Capacitors are used as an essential part of the wind turbine generators for supplying reactive power demand. Capacitor switching may cause large voltage transient. The frequency and amplitude of such transient are enormous, particularly when back-to-back switching is involved, for instance capacitor bank switching. The over voltages may damage the insulation, Moreover, electronic equipment such as controllers are very sensitive to these transients, may produce incorrect commands. In addition, lightning strikes will cause an overvoltage in the electrical system of wind turbine.

2.3. Electrical Noise

It is high frequency signals which are being transmitted at both the side of the grid system. Thesecauses degradation of telecommunication equipment in form of radio interference. The figure shows its diagrammatic representation which having frequency signal with high magnitude. As per the utility side corona is one of the important noise examples, which emits hissing noise which irritatesthe customer.

2.4. Voltage Unbalance

Voltage unbalance is referred as the deviation of phase voltage. Most of the time motors tolerate unbalance of voltage of 2%. The unbalance voltage greater than 2% causes overheating of transformer, generators and the site equipment.

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2.5. Flicker

It is most commonly found issue in wind system which is rapid and continuous change in the voltage magnitude. Its magnitude is about 0.95 to 1.05 of thenormal voltage. At the time of normal operating condition wind turbines delivers continuous power at the output side, but due to changes in speed of wind turbine it results into the voltage fluctuation. The sources of voltage (V) flicker are intermittent loads, starting of motor, arc furnaces which effects on both utility and end users in the form of irritation

and light flickering. The power conditioning element used for this is Static VAR system.[7]

III. CONCEPT OF HARMONIC

3.1. Harmonic Distortion

The term harmonic distortion is defined as the periodic deviation of voltage or current sine wave from a smooth sinusoidal shape. It is occurredwhen the frequencies of the multiple integers of thefundamental frequency are added to the pure sinusoidal waveform of voltage or current. It istherefore said that, the integer multiples of the fundamental frequency are called harmonics. Sototal harmonics distortion (THD) is the measure of all the waveform values that are distorted. [8,9]

3.2. Sources of harmonic distortion

At the generation end, power electronics converters are responsible for the generation of harmonics. At the receiving end, non-linear loads are responsible for the generation of harmonics. Theexample of different nonlinear load includes computer, arc furnace, television, mercury lamps, arc welders, battery charger, variable speed drive, medical diagnostics equipment and fluorescent lamps. Other reasons i.e., transformer saturation, resonance phenomena, light dimmers, switch mode power supply (SMPS) are the cause of generation ofharmonics

3.3. Effects of harmonics distortion

Harmonics distortion leads to the damage to the transmission as well as distribution network and also to the consumer equipment. Harmonics distortion results in the overload operation of the electric motor, misbehaved operations of fuses, faulty operation of circuit breaker, tripping of variable speed drives, incorrect power measurement,overheating of motors and transformers, damage to the electrical equipment power factor correction capacitors etc.

3.4. Mitigation of harmonics distortion Application of active conditioners, input

chokes, passive filters, isolation transformers and FACTS devices like STATCOM, DVR, SVC (built-in power factor correction capability) will result in harmonics mitigation.[10]

METHODOLOGY FOR POWERQUALITY IMPROVEMENT

The STATCOM based current control voltage source inverter injects the current into the grid will cancel out the reactive part and harmonic part of the load and induction generator current, thusit improves the power factor and the power quality. To accomplish these goals, the grid voltages are sensed and are synchronized in generating the current. The proposed grid connected system is implemented for power quality improvement at point of common coupling (PCC), for grid connected system.[11]

4.1. Wind energy generating system

In this configuration, wind generations arebased on constant speed topologies with pitch control turbine The generator is used in the proposedscheme because of its simplicity, it does not requirea separate field circuit, it can accept constant and variable loads, and has natural protection against short circuit.

4.2. STATCOM (Static Synchronouscompensator)

Basic configuration STATCOM acronym stands for Static Synchronous Compensator. It is coming under FACTS family which is capable of generating and/or absorbing reactive power. Theoutput current of the STATCOM can be controlled independently of the AC system voltage.

The main role of STATCOM is to stabilizethe wind plant after disturbance. A STATCOM consists of a voltage source converter (VSI- two level), a dc voltage source acts as an energy storagedevice, a coupling transformer connected with AC supply system in shunt and control devices as shownin fig (1).

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The VSC converts dc voltage from energy storage device to three phase AC suitable for grid application. The VSC used here is IGBT type. This output voltage AC from STATCOM is in phase withthe supply voltage and connected to the PCC through the reactance of the coupling transformer. For controlling the overall STATCOM operation, control signals are given to the VSC of the transformer. This helps in active and reactive powercontrol. STATCOM supplies reactive power (capacitive STATCOM) when system voltage is lowand absorbs reactive power (inductive STATCOM) when system voltage is high. Fig. (1) shows the one-line diagram of the STATCOM. [12]

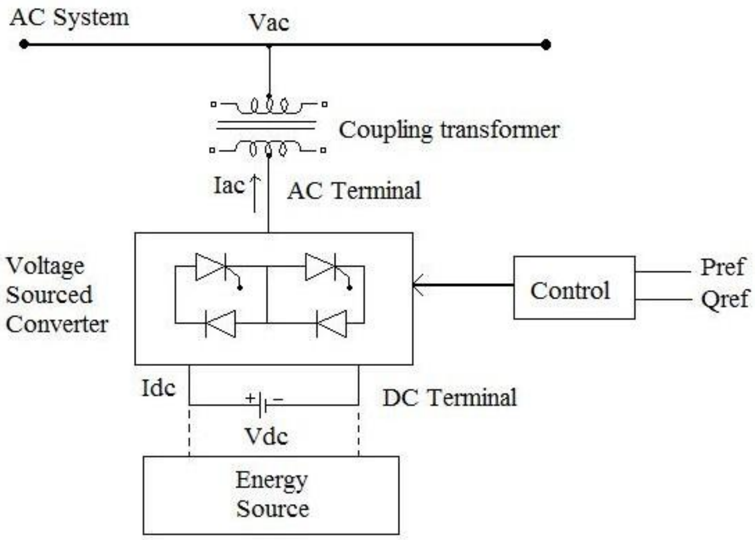

Fig. 1 Basic Configuration of STATCOM [12]

The real and reactive power injected by theSTATCOM is given by the following equations

$$P = \frac{V_1 V_2 sin\delta}{X}$$

$$Q = \frac{V_1 (V_1 - V_2 cos\delta)}{X}$$

Where, δ= phase angle of V1 w.r.t V2. V1 isthe supply voltage and V2 is the generated voltage by VSC of STATCOM which is in phase with V1 (for steady state operation) i.e., δ=0, due to this realpower flowing is P=0. From this, two conditions arise.

i. V2 < V1, Q is flowing from V1 to V2
i.e. (STATCOM is absorbing reactive vars)

ii. V2 > V1, Q is flowing from V1 to V2Thus, the total amount of reactive vars is,

$$Q = \frac{1 (V1 - V2)}{X}$$

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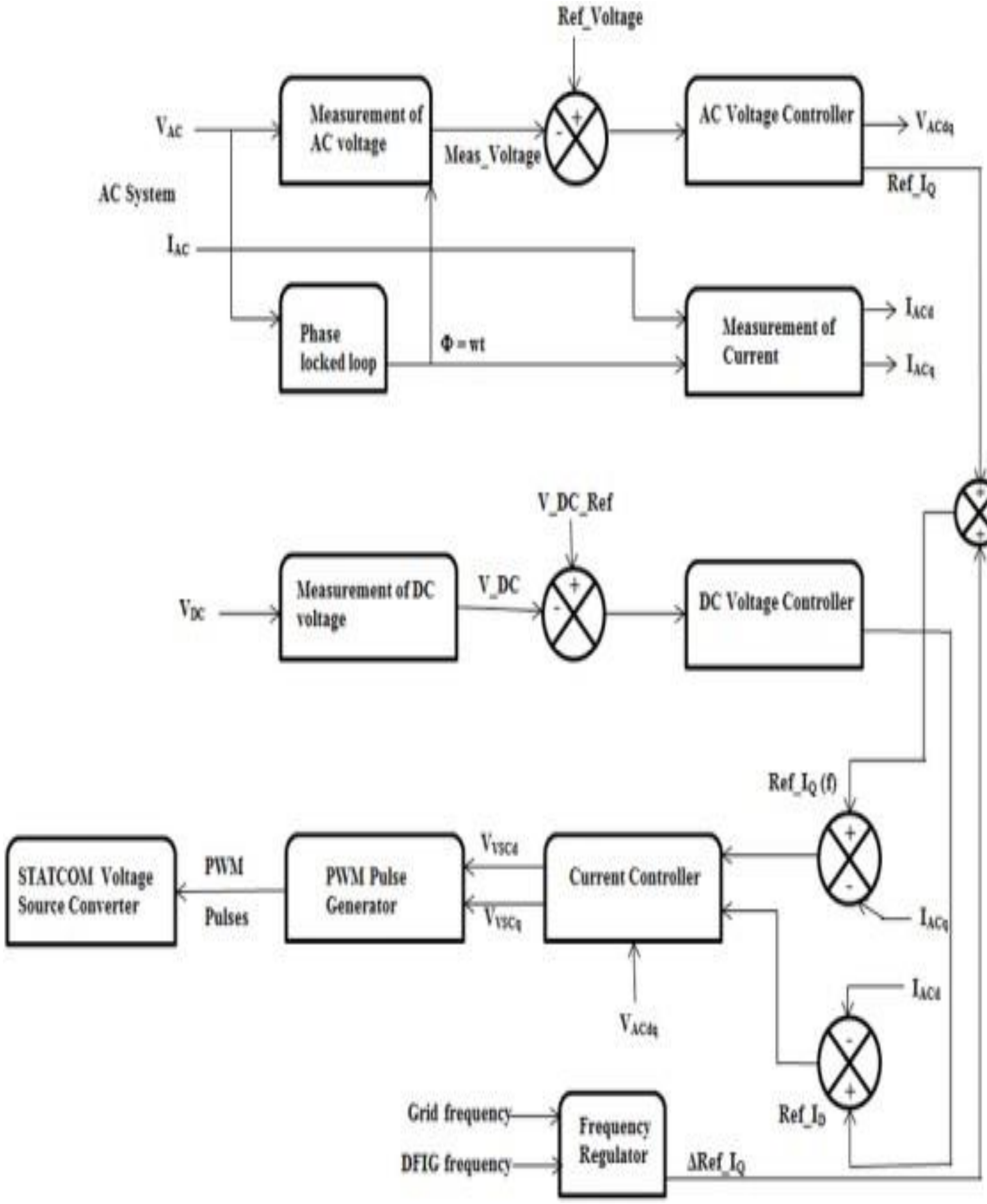

Fig. 2 Block Diagram of STATCOM Controller[13]

Fig. (2) shows the control strategy is adopted for STATCOM. It consists of a PLL circuit which generates the reference angle θ_{PLL} for park's transformation circuits (abc-dq) and synchronises the IGBT (thyristor) voltage with the voltage of the grid. The PCC voltage (V_1) is compared with the reference value (V_{ref}) and the difference is applied to the AC voltage regulator block to generate the reference reactive current (I_{qref}). The inner current regulation loop compares the injected and absorb reactive q-current (I_q) with the reference value (I_{qref}) to produce desired control signal which is again fed to the AC voltage regulator and produces signal V_{2d}. Similarly, dc voltage of capacitor (V_{dc}) is compared with the reference value (V_{dcref}) and that output is given to a DC voltage regulator block to generate the reference reactive current (I_{dref}). Again, the inner current loop compares the reactive d- current (I_d) with reference value (I_{dref}) to produce desired phase angle and the whole signal outputs is fed to the AC voltage regulator and produces signal

V_{2q}. The signals are now fed to the PWM modulator which generates necessary control signal for VSC of STATCOM. The control strategy of STATCOM can be presented mathematically [13].

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$$Iqref = (V\,ref - V1) + (Kp + Kis)$$

$$Idref = (Vdc\,ref - Vdc) + (Ksp + Kis)$$

ADVANTAGES OF STATCOM

1. It occupies a small footprint, for it replacespassive banks of circuit elements bycompact electronic converters.
2. It offers modular, factory-built equipment,thereby reducing site work and commissioning time.
3. It uses encapsulated electronic converters, thereby minimizing its environmental impact. [14-16]

IV. APPLICATION OF STATCOM

1. STATCOM is installed to support electrical networks that have a poor power factor and often poor voltage regulation.
2. The most common use of STATCOM is for voltage stability.
3. A STATCOM is a voltage source converter(VSC) based device, with the voltage source behind a reactor.
4. The voltage source is created from a DC capacitor and therefore a STATCOM has very little active power capability. [14-16]

CONCLUSION

In this paper is presented the power qualityparameters which deal with the system stability. It ismainly focused on how distortion is related to the increasing of nonlinear load. The whole system design of wind power plant is done here. STATCOM based controller is used in the wind farm to improve the power quality of the system. The major parameter i.e., THD calculation is done using FFT analysis at PCC in both conditions (withSTATCOM and without STATCOM). It shows thatwith STATCOM the harmonics are reduced which leads to restoring the sinusoidal waveform at point of common coupling (PCC). Overall, we can conclude that the use of STATCOM improves the power quality.

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