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A D-STATCOM TO CONTROL POWER QUALITY ISSUES IN GRID CONNECTED WIND POWER SYSTEM

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Abstract ***—Voltage sag and voltage swell have been considered as one of the most harmful power quality problem in power system as it may significantly affect industrial production. To overcome the problem related to power quality Custom power devices, a distribution static compensator is used in this work which is one of the power-conditioning technology devices used to correct end-user problems in response to voltage sag. The fast response of the Distribution Static Compensator (DSTATCOM) makes it the efficient solution for improving power quality in distribution systems.IEEE-14 bus system is simulated using MATLAB, Simulink, and Simpower system software. It constitutes 14 bus, 5 generation, three transformers, 20 lines and 11 loads. Wind farm consisting of six 1.5-MW wind turbines is connected across the bus 8 of 14- bus system. The grid connected wind energy generation system for power quality improvement by using DSTATCOM-control scheme is simulated using SIMULINK in power system block set***

***Keywords*- DSTATCOM, Voltage sag, Voltage swell.**

I. INTRODUCTION

The causes of power quality problems are generally complex and difficult to detect when we integrate a wind turbine to the grid. The voltage of wind power generating station generally fluctuates due to nature of wind. When wind power generating station is integrated to the power grid power quality issues arises like injection of harmonics, poor power factor and distortion from pure sine wave of fundamental frequency. The need to integrate the renewable energy like wind energy into power system is to make it possible to minimize the environmental impact on conventional plant. The integration of wind energy into existing power system presents a technical challenges and that requires consideration of voltage regulation, stability, power quality problems. The power quality is an essential customer-focused measure and is greatly affected by the operation of a distribution and transmission network. The issue of power quality is of great importance to the wind turbine [1].The voltage related power-quality problems, such as sags and swells, harmonic distortions due to nonlinear loads and voltage unbalancing in electrical power distribution systems, in this paper voltage sag and swell effects when wind power integrate to the power grid is discussed.

In this paper 14-bus system is designed using MATLAB/SIMULINK software according to the IEEE Standard 14-bus system and to which a wind farm consisting of six 1.5-MW wind turbines is connected. The 9-MW wind farm is simulated by three pairs of 1.5 MW wind-turbines. Doubly–fed induction generator (DFIG) is used [2]. To overcome raised power quality issue with wind system a distribution static compensator (DSTATCOM) is used in this work which is one of the power-conditioning technology devices used to correct end-user problems in response to voltage sag. The fast response of the Distribution Static Compensator makes it the efficient solution for improving power quality in distribution systems.

II. WIND TURBINE

A wind turbine is a device that converts kinetic energy from the wind into mechanical energy. If the mechanical energy is used to produce electricity, the device may be called a wind generator or wind charger. If the mechanical energy is used to drive machinery, such as for grinding grain or pumping water, the device is called a windmill or wind pump. Developed for over a millennium, today's wind turbines are manufactured in a range of vertical and horizontal axis types. The smallest turbines are used for applications such as battery charging or auxiliary power on sailing boats; while large grid-connected arrays of turbines are becoming an increasingly large source of commercial electric power, out of the total energy generated in the country[2].

Of the total 6000 MW of energy generated in the country from renewable, around 3595 MW is from wind. While the average generation from a single turbine could range from 250 to 1000 KW, the maximum achieved in India is 2 MW. The preferred wind speed for optimum generation is around 12 m/sec (40-50 kmph) above which the turbines have to be switched off to avoid fatigue. The average height of the wind mill is 200 mt while the blades could span 80mt.

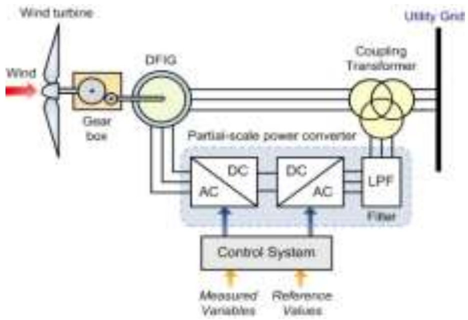

Fig 1: Block diagram of Doubly-fed induction generator

OPERATING PRINCIPAL OF DFIG:

The stator is directly connected to the AC mains, whilst the wound rotor is fed from the Power Electronics Converter via slip rings to allow DIFG to operate at a variety of speeds in response to changing wind speed. Indeed, the basic concept is to interpose a frequency converter between the variable frequency induction generator and fixed frequency grid.

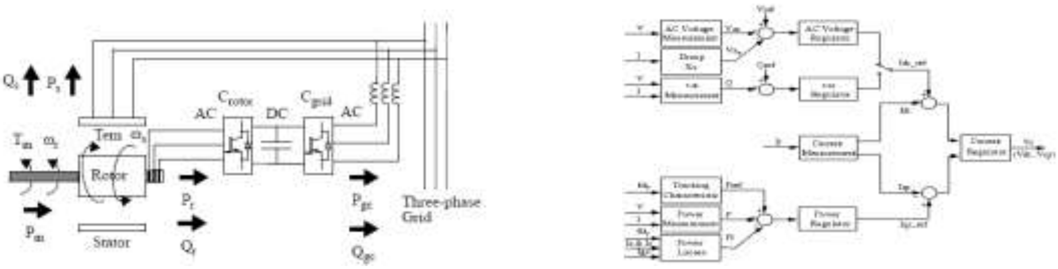

Fig 2: Power flow diagram of DFIG

When the wind turbine is operated in var regulation mode the reactive power at grid terminals is kept constant by a var regulator. The output of the voltage regulator or the var regulator is the reference d-axis current Idr_ref that must be injected in the rotor by converter rotor. The same current regulator as for the power control is used to regulate the actual Idr component of positive-sequence current to its reference value. The output of this regulator is the d- axis voltage Vdr generated by rotor. The current regulator is assisted by feed forward terms which predict Vdr. Vdr and Vqr are respectively the d-axis and q-axis of the voltage Vr.

III Major Technical Impacts of Integrating Wind Energy into the Grid

The causes of poor power Quality in grid connected renewable Wind energy system. The voltage fluctuations, reactive power compensation, poor power factor and harmonics distortion are the main aspects of power quality problems in integrating wind energy with power grid due to the inherent characteristics of these resources as shown.

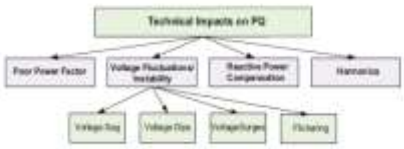

Fig 5: Technical impact on power quality

Fault ride through has come to play a role in strengthening power system security due to the increase in the integration of wind power in recent times. It requires the generators to remain connected in the likelihood of a disturbance on the network. A severe disturbance such as a fault could lead to a voltage dip and if the generators are unable to remain connected it could lead to an excessive loss of generation. This could cause stability problems and may eventually lead to cascaded tripping of other generators. The impact of the wind generation on the power system will no longer be negligible if high penetration levels are going to be reached. The extent to which wind power can be integrated into the power system without affecting the overall stable operation depends on the technology available to mitigate the possible negative impacts such as loss of generation for frequency support, voltage flicker, voltage and power variation due to the variable speed of the wind and the risk of instability due to lower degree of controllability [3].

The following are some of the power quality issues when wind is integrated to grid

- Harmonics
- Flickers
- voltage sag/dip

Voltage Sag:

Voltage sag, sometimes known as a voltage dip, is a short term reduction in the rms voltage. The IEC electro technical vocabulary, defines voltage sag as any "sudden reduction of the voltage at a point in the electrical system, followed by voltage recovery after a short period of time, from half a cycle to a few seconds". Voltage sags are characterized by their duration and depth. Duration is the length of time for which the voltage remains below a threshold. IEEE Standard defines voltage sag as a variation in the rms voltage of duration greater than ½ a cycle and less than 1 minute with a retained voltage of between 10% and 90% of nominal. This is the generally accepted definition of voltage sag. Any disturbance that persists for less than ½ cycles is considered transient phenomena while voltage variations or disturbances of duration greater than 1 minute with retained voltages of less than 90 % of nominal may be considered as either sustained under voltages or interruptions.

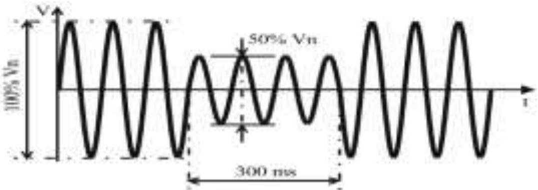

Fig 6: Voltage sag

It is said that a voltage sag has taken place in an electrical network point when the voltage in one or more phases falls suddenly beneath an established limit (generally a 90% of the normal voltage), and recovers after a short period of time (usually between 10 ms and some seconds). The maximum limit of this period is probably the most controversial issue about the voltage sag definition: some authors consider that voltage sag exists when its duration reaches 1 min, or even 3 min. The expected number of events during one year can oscillate between ten and a thousand.

Voltage swells:

Voltage Swell is defined by IEEE as the increase in the RMS voltage level to 110% - 180% of nominal, at the power frequency for durations of ½ cycles to one (1) minute. It is classified as a short duration voltage variation phenomena, which is one of the general categories of power quality problems. A swell is defined as an increase to between 1.1 and 1.8 p.u. in rms voltage at the network fundamental frequency with duration from 0.5 cycles to one minute. The term momentary overvoltage is also used as a synonym for swell. Switching off a large inductive load or energizing a large capacitor bank is typical system maneuvers that cause swells. Although not as common as voltage sags, swells are also usually associated to system faults. The severity of a voltage swell during a fault condition is a function of the fault location, system impedance, and grounding. The end threshold is usually set 1 - 2% of the reference voltage below the start threshold. In other words, the duration of a voltage swell is measured from when one phase rises above 110% of the reference voltage until all three phases have again fallen below 108% - 109% of the reference voltage. If the event persists longer than 1 min it will be re-classified as an overvoltage. Main causes of voltage swells include energizing of capacitor banks, shutdown of large loads, unbalanced faults, transients, and power frequency surges. The effects of voltage. swells are largely the same as for voltage dips.

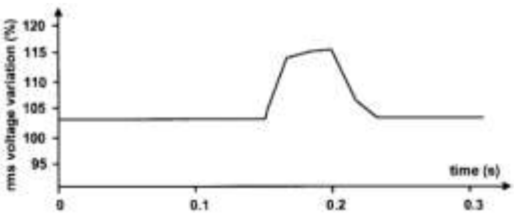

Fig 7: Voltage swells

Voltage swells are usually associated with system fault conditions - just like voltage sags but are much less common. This is particularly true for ungrounded or floating delta systems, where the sudden change in ground reference result in a voltage rise on the ungrounded phases. In the case of a voltage swell due to a single line-to-ground (SLG) fault on the system, the result is a temporary voltage rise on the un faulted phases, which last for the duration of the fault.

IV Distribution Static Compensator:

A DSTATCOM is a shunt connected device which is used in an AC distribution system where, reactive current compensation and load balancing are necessary. The building block of a DSTATCOM is a voltage source converter (VSC) consisting of self-commutating semiconductor valves and a capacitor on the DC bus [4].

Basic Principle

The D-STATCOM is similar to Transmission STATCOM in that it uses a VSV of the required rating. The D-STATCOM is viewed as a variable current source determined by a control functions. A fixed capacitor/filter can be used in parallel with DSTATCOM to increase dynamic rating in the capacitive range. And by connecting energy storage device such as SMES super con-ducting magnetic energy storage) on the DC side it is possible to exchange real power with the network for a limited time (during large voltage sag).

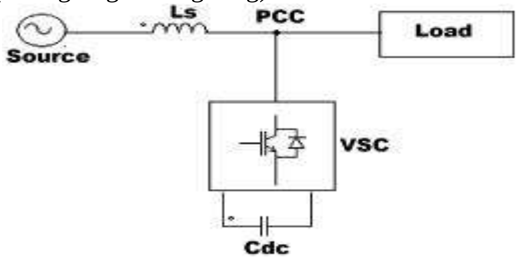

Fig 8: Basic structure of D-STATCOM.

Configuration

A D-STATCOM (Distribution Static Compensator), which is schematically depicted in Figure5.1, 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 reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control of active and reactive power exchanges between the D-STATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power.

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.

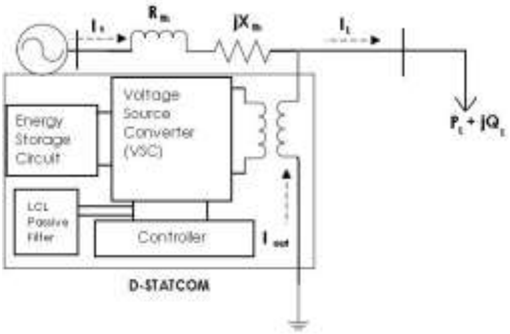

Fig 9: DSTATCOM configuration

A. Reasons for Choosing DSTATCOM in Integration of Wind Mill:

Capacitors are usually connected to fixed speed wind turbines to enhance the system voltage because they are a sink of reactive power. Mechanically switched fixed shunt capacitors can enhance the system's voltage stability limit, but is not very sensitive to voltage changes. Also, voltage regulated by the wind generators equipped with only fixed capacitors can become higher than the voltage limit of 1.05 pu. Hence, a fixed capacitor cannot serve as the only source of reactive power compensation.

The output of the wind power plants and the total load vary continuously throughout the day. Reactive power compensation is required to maintain normal voltage levels in the power system. Reactive power imbalances, which can seriously affect the power system, can be minimized by reactive power compensation devices such as the DSTATCOM. The DSTATCOM can also contribute to the low voltage ride through requirement because it can operate at full capacity even at lower voltages.

V SIMULATED MODEL

Single Line Diagram 14 Bus System:

The DG is connected used in the improvement of voltage profile of the system has been applied to a standard IEEE 14 bus test system. The system consists of 14 bus, 5 generation, three transformers, and 20 branches. The system consists 11 loads. Four transformers data include the tap setting with transmission data. The transmission data include the resistance, reactance & Suseptance [8].

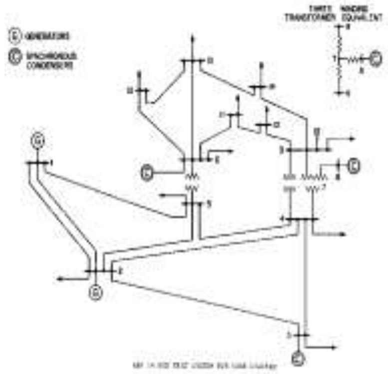

Fig 10: Single line diagram of 14 bus system.

Simulated Model:

IEEE 14 bus system is designed and simulated using MATLAB/SIMULINK software to which a wind farm consisting of six 1.5-MW wind turbines is connected. The 9-MW wind farm is simulated by three pairs of 1.5 MW wind-turbines. Here we doubly –fed induction generator (DFIG) is used. Wind turbine has a protection system monitoring voltage, current and machine speed. In the case of renewable energy, DSTATCOM device is advantageous when integrated with wind farms. As wind farms become a larger part of the total generation and as the penetration levels increase, issues related to integration such as transients, stability, and voltage control are becoming increasingly important [9]. For wind generation applications, DSTATCOM configuration controls the voltage sag and swell which in turn improves the reactive power compensation When The load increases simulated model is as shown below in fig,

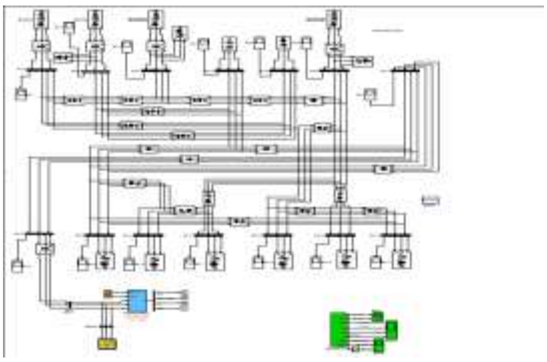

Fig 11: Simulated model with DSTATCOM

Cases Analyzed

- 14 bus system model.
- Wind power system without DSTATCOM.
- Wind power system with DSTATCOM.
- After 3-phase fault without DSTATCOM and WPG.
- After 3-phase fault with STATCOM.
- After 3 phase fault with WPG and DSTATCOM.

The response of the IEEE 14 bus system in case of without WPG is as shown below.

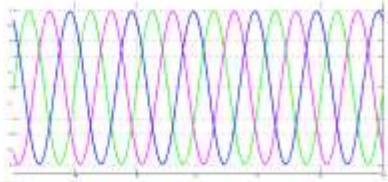

Fig 11: Output of 14 bus system without wind

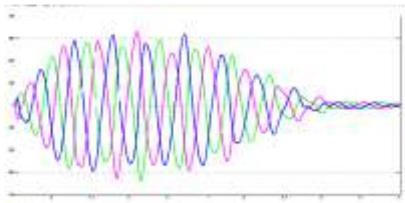

Fig 12 : Wind power system without DSTATCOM

Fig 13 wind system with DSTATCOM

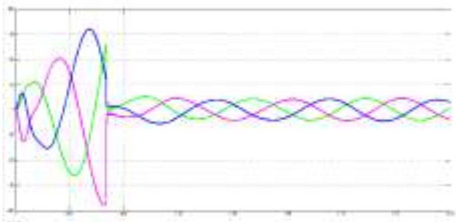

Fig 14: After 3-phase fault with WPS

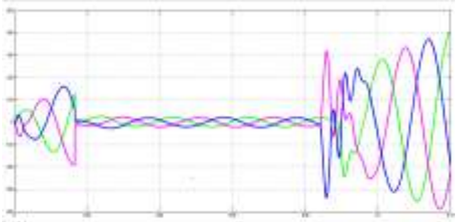

Fig 15: After 3 phase fault with WPS and DSTATCOM

VI CONCLUSION

IEEE 14-bus system is designed with the help of MATLAB/SIMULINK software. While integrating the wind mill the various power quality issues arise, which is solved by compensating device DSTATCOM is shown in the simulated waveform. DSTATCOM is used to mitigate voltage instability during swell and sag.

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