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Power Quality Improvement In Wind Smart Grid Using DSTATCOM And DVR

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ABSTRACT:- *In the research field of renewable energy sources wind energy conversion systems have become a focal point. The variation of wind power with the continuous variations of wind speed can cause significant power quality issues. To improve the power quality, custom power devices are used. This paper presents a novel FACTS based DSTATCOM and DVR for power quality enhancement, voltage stabilization, power factor improvement and power losses reduction of wind schemes interfaced with Smart Grid- Distribution Networks. The proposed FACTS based scheme can also be extended to distributed/dispersed renewable energy interface and utilization systems and can be easily modified for other specific stabilization and compensation requirements.*
Keywords: - *Power Quality, Wind Smart Grid, DSTATCOM, DVR*

I. INTRODUCTION

The wind power industry is one of the fastest expanding industries as a result of the rapid growth of installed capacity[1]. The wind power over the last 20-30 years has become a competitive technology for clean energy production. The increasing demand for high quality, reliable and secure electrical power system with increasing the number of distorting nonlinear loads have led to rise in power quality problems[2]. For power quality improvement, power electronic devices such as Flexible AC Transmission System (FACTS) and customizing power conditioning devices have introduced a new and emerging technology providing the power system with versatile new dynamic control capabilities[3].

Wind energy has sophisticated to a level of knowledge where it is ready to acquire a commonly accepted utility generation technology. Wind-turbine technology has experienced an impressive transformation during the last 15 years, developing from a communicate science in the 1970s to the wind turbine of the 2000s by the latest in power electronics, aerodynamics, and mechanical drive train designs. In the last five years, the world wind-turbine market has been maturing at around 30% a year, and wind power is playing an increasingly significant role in electricity generation, particularly in countries well known as Germany and Spain. Wind power is quite different from the conventional electricity generation with synchronous generators. FACTS devices are used for transmission control in general whereas customized power devices are used in distribution control. The introduction of FACTS and custom power devices named as unified power flow controller (UPFC), dynamic voltage restorer (DVR), synchronous static compensator (STATCOM), solid-state fault current limiter and solid-state transfer switch are developed for improving the system's power quality and reliability[4,5]. For example, UPFC works well for power flow control, DVR which acts as a series compensator is used for voltage sag compensation and STATCOM which is a shunt compensator is used for reactive power and voltage sag compensation[4,5]. The STATCOM, DVR, UPS and active power conditioner are only useful for compensating a particular type of power quality problems and therefore, it has become necessary to develop a new kind of Unified Series-Shunt Compensator (USSC) which can mitigate a wider range of power quality problems. Many FACTS devices used the principle of USSC had been published[4,5].

Advanced control and improved semiconductor switching of these devices have achieved a new era for power- quality mitigation. The major drawback of these devices, however, is that they are very expensive. To assess the improvement resulting from the application of FACTS devices, a basic understanding of under lying characteristics of power quality events is essential. Any variation in current, voltage or frequency that causes the failure or malfunction of equipment is the definition of a power quality problem. There has been a rapid raise of nonlinear loads in a modern electrical distribution system and examples of nonlinear loads are domestic appliances, power supplies, adjustable speed drives, rectifier equipment used in tele- communication networks etc. These power-electronic-based loads offer hugely nonlinear characteristics[7]. Because of their non-linearity nature, the loads became the major victims and the major causes of most of the power quality problems.

This paper has presented models of custom power devices, namely D-STATCOM, DVR, and applied them for effective voltage stabilization, power quality enhancement, reduction of losses and power factor improvement in distribution grid networks with the dispersed wind energy interface which are very prominent as per utilities are concerned.

II. POWER QUALITY STANDARDS, ISSUES AND ITS CONSEQUENCES

A. International Electro Technical Commission Guidelines

The IEC (International Electro Technical Commission) is the world's leading international organization in its field, and its standards are adopted as national standards by its members. In order to measure the power quality of wind turbine there are guidelines that are need to be followed. The procedure that determines the wind turbines power quality characteristics is described in the IEC standard 61400-21.

The following are the standard norms.

1) *IEC 61400-21: Measurement and Assessment of power quality characteristic of grid connected wind turbine*
2) *IEC 61400-13: Wind Turbine measuring procedure in determining the power behavior.*
3) *IEC 61400-3-7: Assessment of emission limits for fluctuating load IEC 61400-12: Wind Turbine performance.*

B. Voltage Variation

This is due to the fluctuations in the wind turbine caused by wind. The voltage variation is directly related to real and reactive power variations. The voltage variation is commonly classified as under:

- Voltage Sag/Voltage Dips.
- Voltage Swells.
- Short Interruptions.
- Long duration voltage variation.

The voltage variation issue describes the variations that occur dynamically in the network which are caused by either wind turbine or by load variations. Thus during continuous operation the power fluctuation occurs from the wind turbine. The factors that affect the amplitude of voltage fluctuation are network impedance, phase angle, power factor and grid strength of the wind turbines. The voltage fluctuation occurs at a frequency of 10–35 Hz. To measure the variation directly a flicker meter is specified in the IEC 61400-4-15.

C. Harmonics

The occurrence of harmonics is because of the operation of the power electronics converters. The harmonics voltage and current should be within the limits as mentioned in the IEC-61400-36 guideline. The rapid switching results in a huge reduction of lower order harmonics current when compared to the line commutated converter, whereas the output current can have high frequency and filtering can be done easily.

D. Wind Turbine Location in Power System

It is located where the power quality is highly influenced. Its operation and its influence on the power system depend on the structure of the network.

E. Self Excitation of Wind Turbine Generating System

The self-excitation of wind turbine generating system (WTGS) raises a risk equipped with commutating capacitor. The compensation of the reactive power is provided by the capacitor that is connected to induction generator. By balancing the system voltage and frequency can be determined. The main disadvantages of self-excitation are the safety issues and real and reactive power balancing.

F. Consequences of the Issues

The malfunctioning of the equipments such as programmable logic controller, flickering of light and screen, microprocessor based control system, adjustable speed drives etc is caused by the voltage variation, harmonics, flicker. This results in tripping of contractors, protection devices and stoppage of sensitive equipments like programmable logic control system, personal computer, etc. It may even stop the process and damage the sensitive equipments. Thus the degradation of the power quality occurs in the grid.

III. TOPOLOGY FOR POWER QUALITY IMPROVEMENT

The STATCOM is a three-phase voltage source inverter having the capacitance on its DC link and connected at the point of common coupling. The STATCOM injects a compensating current of variable magnitude and frequency component at the bus of common coupling into the grid. This will cancel out the reactive part and harmonic part of the load and induction generator current, thus improving the power factor and the power quality. The grid voltages are sensed and are synchronized in generating the current in order to achieve these goals. In the proposed one the grid connected system is implemented at point of common coupling (PCC) for power quality improvement, as depicted in Fig.1. The figure consists of battery energy storage system with STATCOM and wind energy generation system.

A. Wind Energy Generating System

Wind generations are based on constant speed topologies with pitch control turbine in this configuration. The induction generator does not require a separate field circuit, it can accept constant and variable loads, and has natural protection against short circuit hence it is used in the proposed scheme. The equation (1) presents the available power of wind energy system.

$$P_{wind} = \frac{1}{2}\rho A V_{wind}^3 \quad (1)$$

Where ρ (kg/m) is the air density and A(m2) is the area swept out by turbine blade, V_{wind} is the wind speed in m/s. It is not possible to

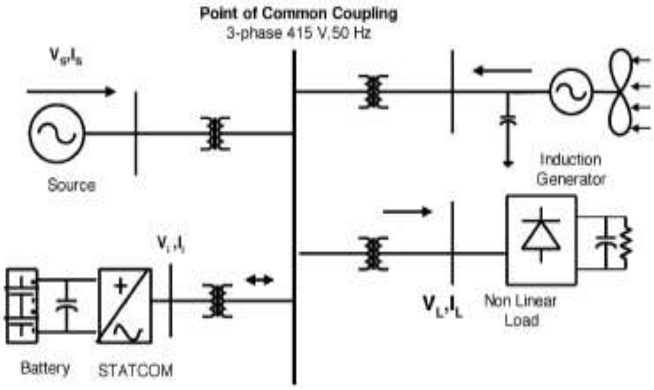

Fig.1. Grid connected system for power quality improvement.

Extract all kinetic energy of wind, thus it extract a fraction of power in wind, called power coefficient Cp of the wind turbine, and is given in (2).

$$P_{mech} = C_p P_{wind} \quad (2)$$

where Cp denotes the power coefficient which depends on the type and the operating condition of wind turbine. This coefficient can be expressed as a function of pitch angle θ and tip speed ratio λ. The mechanical power produced by the wind turbine is given in equation 3

$$P_{mech} = \frac{1}{2}\rho\pi R^2 V_{wind}^3 C_p \quad (3)$$

where R is the radius of the blade (m).

B. BESS-STATCOM

The STATCOM (or Static Synchronous compensator) 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 system. In general it is solid state switching converter device which is capable of generating or absorbing independently controllable real and reactive power at its output terminals when it is fed from an energy source at its input terminals. Basically, the STATCOM considered in this is a voltage-source converter from a given input of dc voltage produces a set of 3-phase ac-output voltages, each in phase with and coupled to the subsequent ac system voltage through leakage reactance. For the voltage regulation in STATCOM, the battery energy storage system (BESS) is used as an energy storage element. The BESS naturally maintains dc capacitor voltage constant and it is best for STATCOM since it rapidly injects or absorbs reactive power to stabilize the grid system. It also controls the power fluctuations occurs distribution and transmission system with very fast response by charging and discharging of DC link capacitor. The battery is connected in parallel to the dc capacitor of STATCOM .The STATCOM is a three-phase voltage source inverter having the capacitance on its DC link and connected at the point of common coupling.

C. System Operation

In the grid system STATCOM with battery energy storage is connected in shunt with the induction generator interface and nonlinear load at the PCC.

To maintain the power quality norms in the grid system, the STATCOM compensator output is varied according to the controlled strategy. The current control strategy defines the functional operation of the STATCOM

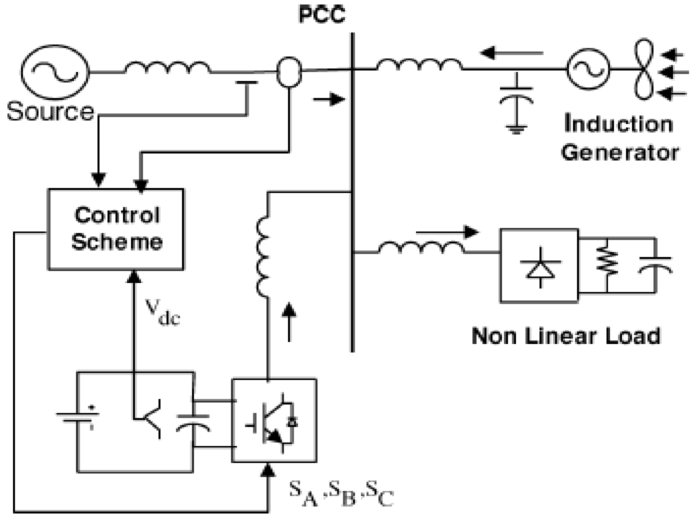

Fig. 2. System operational scheme in grid system.

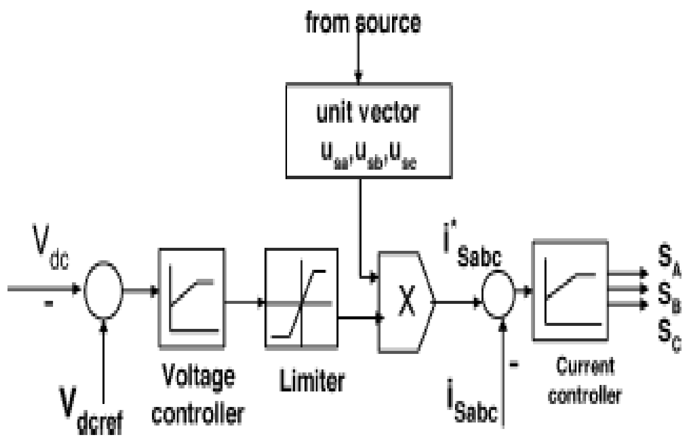

Fig. 3. Control system scheme.

Compensator which is included in the control scheme in the power system. A single STATCOM with insulated gate bipolar transistor is proposed for the reactive power support to the induction generator and also to the nonlinear load in the grid system. Fig. 2 shows the main block diagram of the system operational scheme.

D. Dynamic Voltage Restorer

Among the power quality problems (sags, swells, harmonics etc.) voltage sags are the most severe disturbances. In order to overcome these problems the concept of custom power devices is introduced recently. One of these devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks. DVR is a recently proposed series connected with solid state device that injects voltage into the system in order to regulate the load side voltage. It is normally installed in a distribution system between the supply and the critical load feeder at the point of common coupling (PCC). Other than voltage sags and swells compensation, DVR can also be added with other features like: line voltage harmonics compensation, reduction of transients in voltage and fault current limitations [9]. DVR consists of rectifier, energy storage device, PWM inverter, filter, and injection transformer.

The block diagram of DVR is shown in Fig. 4.

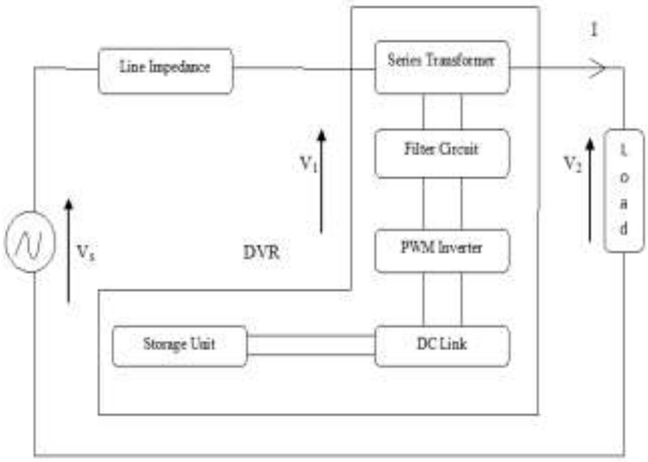

Fig. 4 Block diagram of DVR

A. Rectifier

The process of converting AC supply into DC supply is known as rectification. A device which is used for rectification is known as rectifier. The AC voltage cannot be stored directly in a storage device. Hence, the rectifier circuit is used in the DVR.

B. Energy Storage Device

Energy storage device stores the converted DC voltage from the rectifier. It is very important device in the DVR. The energy storage device is DC capacity, batteries, super-capacitor, super conducting magnetic energy storage and flywheels.

C. PWM inverter

The DC supply from the storage device is passed to the PWM inverter. The PWM inverter generates the voltage with required magnitude and frequency. It converts the DC voltage into AC voltage. The PWM inverter is connected between the energy storage device and filter circuit.

D. Filter

Filter circuit is used to remove the unwanted noise signals or harmonics in the generated voltage from the PWM inverter. The LC filter is used in the DVR to improve the quality of power.

E. Injection Transformer

The injection transformer is connected with the transmission line in series. When the voltage level is decreased in the transmission line then the transformer inject the voltage with required magnitude and frequency. The supply to the transformer is given from the filter circuit.

IV. CONCLUSION

Recent trends in power distribution system shows that penetration level of DG in the grid has increased considerably. End user appliances are becoming more sensitive to Power Quality Condition. FACTS based DSTATCOM and DVR for power quality enhancement, voltage stabilization, power factor improvement and power losses reduction of wind schemes interfaced with Smart Grid- Distribution Networks are insuring quality of power supply by mitigating voltage dips caused by faults and load fluctuation DVR which acts as a series compensator is used for voltage sag compensation and STATCOM which is a shunt compensator is used for reactive power and voltage sag compensation.

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