Indian J.Sci.Res. 17(2): 220-224, 2018

ISSN: 0976-2876 (Print)
ISSN: 2250-0138(Online)

MODELLING AND CONTROL OF THREE AND FOUR LEG INVERTER IN WIND ENERGY SYSTEM FOR GRID POWER QUALITY ENHANCEMENT

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Abstract- In this paper Modelling and Control of Three and Four Leg Inverter in Wind Energy System for Grid Power Quality Enhancement. Static Compensator (STATCOM) is connected at a point of common coupling with a battery energy storage system (BESS) to resolve the power quality difficulties. The battery energy storage used to preserve constant real power from varying wind power. The produced power can be stored in the batteries at low power demand hours. The grouping of battery storage with wind energy generation system will combine the output by captivating or inserting reactive power and permit the real power flow required by the load. In the grid new renewable resources is added to extract more power. Injection of wind power into the grid affects the power quality resulting in poor performance of the system. Wind energy is considered to be a very promising alternative for power generation because of its alternative for power generation because of its tremendous environmental, social, and economic benefits. In general voltage & frequency must be kept as stable as possible. This stability can be obtained by using FACTS devices. Recently voltage-source or current-source inverter based various FACTS devices have been used for flexible power flow control, secure loading and damping of power system oscillation.The FACTS Device (STATCOM) control scheme for the grid connected wind energy generation system to improve the power quality is simulated using MATLAB/SIMULINK.

Keywords: Wind power, Distribution Network, Induction Generator, STATCOM, Reactive Power, Harmonics, and Power Quality, 3 leg and 4 leg converter.

I.Introduction

To have sustainable growth and social progress, it is necessary to meet the energy need by utilizing the renewable energy resources like wind, biomass, hydro, co-generation, etc. In sustainable energy system, energy conservation and the use of renewable source are the key paradigm. 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 [1]. The integration of wind energy into existing power system presents 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 [2]. There has been an extensive growth and quick development in the exploitation of wind energy in recent years. The individual units can be of large capacity up to 2 MW, feeding into distribution network, particularly with customers connected in close proximity [3]. Today, more than 28 000 wind generating turbines are successfully operating all over the world. In the fixed-speed wind turbine operation, all the fluctuation in the wind speed are transmitted as fluctuations in the mechanical torque, electrical power on the grid and leads to large voltage fluctuations. The power quality issues can be viewed with respect to the wind generation, transmission and distribution network, such as voltage sag, swells, flickers, harmonics etc. However the wind generator introduces disturbances into the distribution network.

One of the simple methods of running a wind generating system is to use the induction generator connected directly to the grid system. The induction generator has inherent advantages of cost effectiveness and robustness. However; induction generators require reactive power for magnetization. When the generated active power of an induction generator is varied due to wind, absorbed reactive power and terminal voltage of an induction generator can be significantly affected. A proper control scheme in wind energy generation system is required under normal operating condition to allow the proper control over the active power production. In the event of increasing grid disturbance, a battery energy storage system for wind energy generating system is generally required to compensate the fluctuation generated by wind turbine. In recent years power electronic converters are widely used in industrial as well as domestic applications for the control of power flow for automation and energy efficiency. Most of the time these converters draw harmonic current and reactive power from AC source and causes the power quality problems [9]. STATCOM is most effective for harmonic compensation. Different types, such as shunt and series active power filters are used effectively [2].

Recently Active Conditioners such as STATCOM is used to overcome these problems and also compensating the ha rmonics and suppressing the reactive power simultaneous ly due to fluctuating loads. To overcomes the above disadvantages; STATCOM is best suited for reactive power compensation and harmonic reduction. It is based on a controllable voltage source converter (VSC). In normal operating system we need a control circuit for the active power production. For reducing the disturbance we use a battery storage system. This compensates the disturbance generated by wind turbine. A STATCOM has been proposed for improving the power quality. This STATCOM technically manages the power level associated with the commercial wind turbines. This system produces a proper voltage level having power quality improvements. This system provides energy

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saving and uninterruptible power [5]. The wind energy system is used to charge the battery as and when the wind power is available. The voltage source inverter is controlled by using the current control mode.

The proposed system with battery storage has the following objectives:

• Unity power factor and power quality at point of common coupling bus.

• Real and reactive power support only from wind generator and batteries to load.

• Self operation in case of grid failure. The utility companies can view the current, voltage and power of each system simultaneously by using the online smart metes. The utility can measure power generation of each system simultaneously.

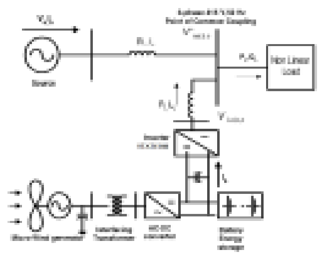

Fig.1 Scheme of wind generator with battery storage [6].

The most used unit to compensate for reactive power in the power systems are either synchronous condensers or shunt capacitors, the latter either with mechanical switches or with thyristor switch, as in Static VAR Compensator (SVC). The disadvantage of using shunt Capacitor is that the reactive power supplied is proportional to the square of the voltage. Consequently, the reactive power supplied from the capacitors decreases rapidly when the voltage decreases [3] .To overcomes the above disadvantages; STATCOM is best suited for reactive power compensation and harmonic reduction. It is based on a controllable voltage source converter (VSC). The paper study demonstrates the power quality problem due to installation of wind turbine with the grid. In this proposed scheme STATIC COMPENSATOR (STATCOM) is connected at a point of common coupling with a battery energy storage system (BESS) to mitigate the power quality issues. The battery energy storage is integrated to sustain the real power source under fluctuating wind power. The STATCOM control scheme for the grid connected wind energy generation system for power quality improvement is simulated using MATLAB/SIMULINK.

II. Static Synchronous Compensator (Statcom)

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, which is a voltage-source converter which when fed 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 based control technology has been proposed for improving the power quality which can technically manages the power level associates with the commercial wind turbines. A STATCOM can improve power-system Performance like:

1. The dynamic voltage control in transmission and distribution systems,

2. The power-oscillation damping in power- transmission systems,

3. The transient stability,

4. The voltage flicker control, and

5. The control of not only reactive power but also (if needed) active power in the connected line, requiring a dc energy source.

A STATCOM is analogous to an ideal synchronous machine, which generates a balanced set of three sinusoidal voltages at the fundamental frequency with controllable amplitude and phase angle. This ideal machine has no inertia, is practically instantaneous, does not significantly alter the existing system impedance, and can internally generate reactive (both Capacitive and inductive) power.

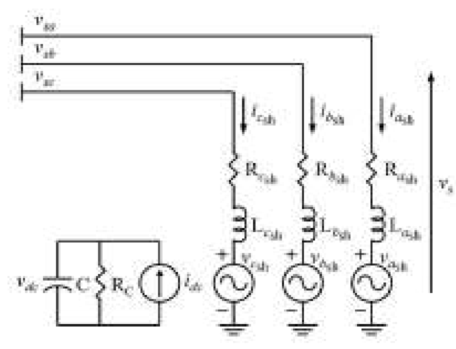

Fig. 2 Equivalent circuit of STATCOM

Fig.2. shows the equivalent circuit of the STATCOM connected to the power system. The reactive power supplied by the STATCOM is either inductive or capacitive depending upon the relative magnitude of fundamental component of vs with respect to vm. If |v

m| > |vs|, the VSI draws reactive power from the ac bus whereas if |v m| < |vs|, it supplies reactive power to the ac system

III Power Quality Issues

A. Voltage Variation:

The voltage variation issue results from the wind velocity and generator torque. 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 flicker issue describes dynamic variations in the network caused by wind turbine or by varying loads. Thus the power fluctuation from wind turbine occurs during continuous operation. The amplitude of voltage fluctuation depends on grid strength, network impedance, and phase-angle and power factor of the wind turbines. It is defined as a fluctuation of voltage in a frequency 10–35 Hz.

B. Harmonics:

The harmonic results due to the operation of power electronic converters. The harmonic voltage and current should be limited to the acceptable level at the point of wind turbine connection to the network. To ensure the harmonic voltage within limit, each source of harmonic current can allow only a limited contribution. The rapid switching gives a large reduction in lower order harmonic current com- pared to the line commutated converter, but the output current will have high frequency current and can be easily filter out. The harmonic distortion is assessed for variable speed turbine with a electronic power converter at the point of common connection [9]. The total harmonic voltage distortion of voltage is given as in (1)

$$V_{\mathrm{THD}} = \sqrt{\sum_{h=2}^{40} \frac{V_n^2}{V_1} 100} \quad (1)$$

Where Vn is the nth harmonic voltage and V1 is the fundamental frequency (50) Hz. The THD limit for 132 KV is <3 %.THD of current ITHD is given as in (2)

$$I_{\mathrm{THD}} = \sqrt{\sum \frac{I_n}{I_1} 100} \quad (2)$$

Where In is the nth harmonic current and I1 is the fundamental frequency (50) Hz. The THD of current and limit for 132 KV is <2.5%.

C. *Reactive Power:*

Traditional wind turbine is equipped with induction generator. Induction Generator is preferred because they are inexpensive, rugged and requires little maintenance. Unfortunately induction generators require reactive power from the grid to operate. The interactions between wind turbine and power system network are important aspect of wind generation system. When wind turbine is equipped with an induction generator and fixed capacitor are used for reactive compensation then the risk of self excitation may occur during off grid operation. Thus the sensitive equipments may be subjected to over/under voltage, over/under frequency operation and other disadvantage of safety aspect. The effective control of reactive power can improve the power quality and stabilize the grid. The suggested control technique is capable of controlling reactive power to zero value at point of common connection (PCC).

IV. Reference Current Generation For STATCOM

Reference current for the STATCOM is generated based on instantaneous reactive power theory [7][10]. A STATCOM injects the compensation current which is a sum of reactive component current of IG, non-linear load and harmonic component current of non-linear load. P-Q theory gives a generalized definition of instantaneous reactive power, which is valid for sinusoidal or non sinusoidal, balanced or unbalanced, three-phase power systems with or without zero sequence currents and/or voltages.

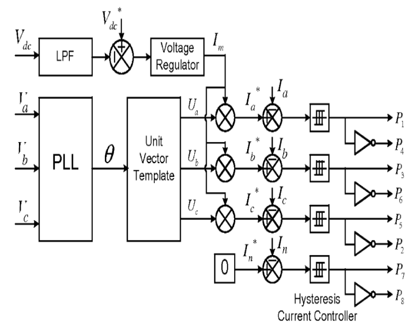

Fig.3. Block diagram representation of grid-interfacing inverter control.

The control diagram of grid- interfacing inverter for a 3-phase 3-wire system is shown in Fig. 3. While performing the power management operation, the inverter is actively controlled in such a way that it always draws/ supplies fundamental active power from/ to the grid. If the load connected to the PCC is non-linear or unbalanced or the combination of both, the given control approach also compensates the harmonics, unbalance, and neutral current. The duty ratio of inverter switches are varied in a power cycle such that the combination of load and inverter injected power appears as balanced resistive load to the grid. The regulation of dc-link voltage carries the information regarding the exchange of active power in between renewable source and grid. Thus the output of dc-link voltage regulator results in an active current (Im).

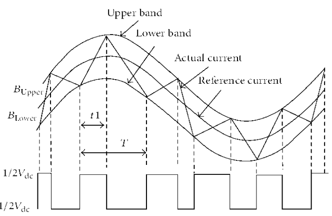

Fig.5. Hysteresis current Modulation

With the hysteresis control, limit bands are set on either side of a signal representing the desired output waveform [6]. The inverter switches are operated as the generated signals within limits. The control circuit generates the sine reference signal wave of desired magnitude and frequency, and it is compared with the actual signal. As the signal exceeds a prescribed hysteresis band, the upper switch in the half bridge is turned OFF and the lower switch is turned ON. As the signal crosses the lower limit, the lower switch is turned OFF and the upper switch is turned ON. The actual signal wave is thus forced to track the sine reference wave within the hysteresis band limits.

V. Matlab Modeleing And Simulation Results

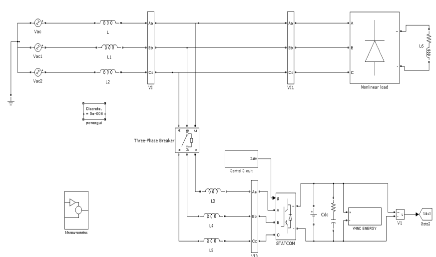

Fig.5 shows the Matlab/simulink model of 3-leg converter with wind energy system

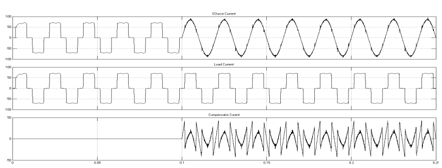

Fig.6 simulated wave forms of proposed system single phase source current, load current and compensator current

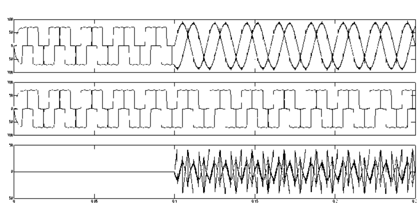

Fig.7 simulated wave forms of proposed system three phase source current, load current and compensator current

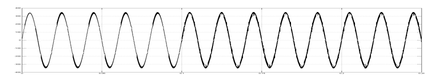

Fig.8 shows the power factor of 3-leg converter

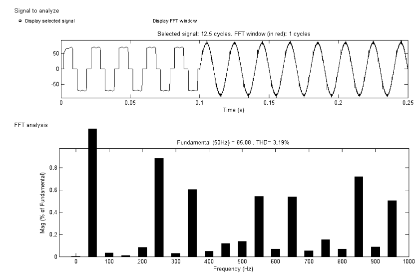

Fig.9 shows the FFT Analysis of 3-leg converter total harmonic distortion value is 3.19%

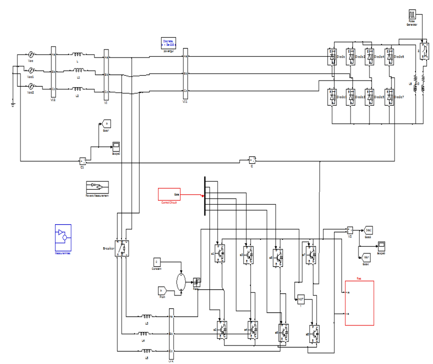

Fig.10 shows the Matlab/simulink model of 4-leg converter

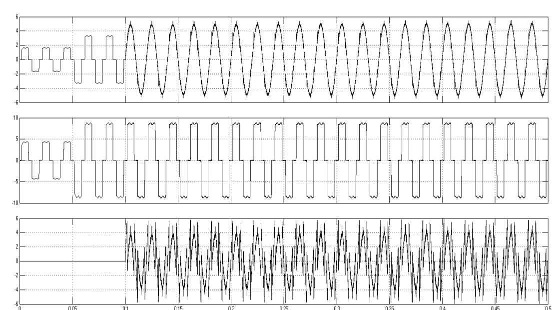

Fig.11 simulated wave forms of 4-leg converter single phase source current, load current and compensator current

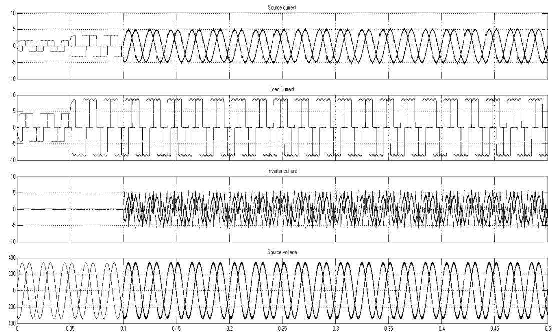

Fig.12 simulated wave forms of 4-leg converter three phase source current, load current, compensator current and neutral current

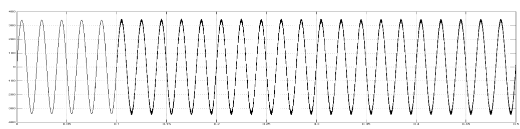

Fig.13 shows the power factor of 4-leg converter

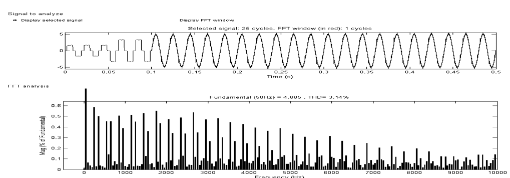

Fig.14 shows the FFT Analysis of 4-leg converter total harmonic distortion value is 3.14%

VI. Conclusion

This paper presented Grid Power Quality Improvement in Wind Energy Systems using 3 leg and 4 leg converter. The hysteresis current controller is used to generate the switching signal for inverter in such a way that it will cancel the harmonic current in the system. This scheme improves power factor and also make harmonic free source current in the distributed network at the point of common connection. The wind power exchange is regulated across the dc bus having energy storage and is made available under the steady state condition. This also makes real power flow at instantaneous demand of the load. Rapid injection or absorption of reactive/real power flow in the power system can be made possible through battery energy storage and static compensator. Battery energy storage provides rapid response and enhances the performance under the fluctuation of wind turbine output and improves the voltage stability of the system.

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