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Power Quality Improvement of Wind Energy System by Using STATCOM

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Abstract — **Injection of the wind power into an electric grid affects the power quality. The influence of the wind turbine in the grid system concerning the power quality measurements are-the active power, reactive power, variation of voltage, flicker, harmonics, and electrical behavior of switching operation and these are measured according to national/international guidelines. The project 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 in power system block set. The effectiveness of the proposed scheme relives the main supply source from the reactive power demand of the load and the induction generator.**

Index Terms— Power Quality, Wind Generating System (WGS), STATCOM, BESS, IEC standard.

I. INTRODUCTION

The need to integrate the renewable energy like wind energy into power system is to minimize the environmental impact on conventional plant. The integration of wind energy into existing power system presents requires the 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 individual units can be of large capacity up to 2 MW wind turbine, feeding into distribution network, particularly with customers connected in close proximity. Today, more than 28 000 wind generating turbines are successfully operating all over the world. Fluctuations in the wind speed are transmitted as fluctuations in the mechanical torque, electrical power on the grid and leads to large voltage fluctuations. Fluctuations in network, such as voltage sag, swells, flickers, harmonics etc. The proposed STATCOM control scheme for grid connected wind energy generation for power quality improvement has following objectives.

- Maintains Unity power factor at source side.
- Supports Reactive power only from STATCOM to wind Generator and Load.
- Simple PI controller for STATCOM to achieve fast dynamic response.

The paper is organized as follows. The Section II introduces the power quality standards, issues and its consequences of wind turbine and the grid coordination rule

II.POWER QUALITY ISSUE AND IMPROVEMENT

A. Power quality standards, issues and its consequences

1. *International electro technical commission guidelines:*

Some guidelines of measurements and norms are specified under IEC 61400 standard which determines the power quality of wind turbines.

The standard norms are specified.

i. IEC 61400-21: Measuring the power quality characteristic of grid connected wind turbine.
ii. IEC 61400-13: Wind Turbine—measuring procedure in determining the power behavior.
iii. IEC 61400-3-7: Measures the emission limits for fluctuating load and IEC 61400-12: Wind Turbine performance.

2. *Harmonics:*

It is due to the operation of power electronic converters. Harmonic voltage and current should be in limited as per the IEC-61400-36 guideline. The rapid switching gives a large reduction in lower order harmonic current and higher order harmonics are filtered out by using filters.

3. *Voltage variation:*

This is due to the fluctuations in the wind turbine due to 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 flicker issue describes dynamic variations in the network caused by wind turbine or by varying loads. Amplitude of voltage fluctuations depends on grid strength, network impedance, phase angle and power factor of wind turbine.

During voltage variations frequency is in the range 10–35 Hz. The IEC 61400-4-15 specifies a flicker meter that can be used to measure flicker directly.

4. 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.

5. *Self excitation of wind turbine generating system:*

The self-excitation of wind turbine generating system (WTGS arises a risk equipped with commutating capacitor. It provides the reactive power compensation to the induction generator.

The disadvantages of self-excitation are the safety aspect and balance between real and reactive power.

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6. *Consequences of the issues:*
Voltage variations, voltage flicker, harmonics causes the malfunctions of equipments. It leads to tripping of protection devices, damaging the sensitive equipments. Overall it degrades the power quality in the grid.

B. Grid Coordination

When you submit your final version, after your paper has been accepted, prepare it in two-column format, including figures and tables.

1. *Voltage rise (u)*
The voltage rise at the point of common coupling can be approximated as a function of maximum apparent power Smax of the turbine, the grid impedances R and X at the point of common coupling and the phase angle , given
in Eq. 1.

$$= \frac{smax\ (RcosΦ - XsinΦ)}{2} \quad \textbf{(1)}$$

Where —voltage rise,
smax —max. apparent power,
Φ—phase difference,
U—nominal voltage of grid.

The Limiting voltage rise value is <2 %

2. *Voltage dips (d)*
The voltage dips is due to startup of wind turbine and it causes a sudden reduction of voltage. It is the relative % voltage change due to switching operation of wind turbine. The decrease of nominal voltage change is given in Eq. 2.

D = Ku sn/sk **(2)**

Where d is relative voltage change, sn is rated apparent power,
sk is short circuit apparent power, and Ku is sudden voltage reduction factor.
The acceptable voltage dips limiting value is <3%.

3. *Flicker*
The measurements are made for maximum number of specified switching operation of wind turbine with 10-min period and 2-h period are specified, as given in Eq. 3.

P = c (ψk) sn/sk **(3)** Where P —Long term flicker.

c (ψk) —Flicker coefficient

The Limiting Value for flicker coefficient is about ≤ 0.4, for average time of 2 h.

4. *Harmonic*
The harmonic distortion is assessed for variable speed turbine with a electronic power converter at the point ofcommon connection. The total harmonic voltage distortion of voltage is given as in Eq. 4.

$$V_{THD} = \sqrt{\sum_{h=2}^{40} \frac{V_n^2}{V_1}} 100 \quad (4)$$

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 Eq. 5

$$I_{THD} = \sqrt{\sum_{h=2}^{40} \frac{I_n}{I_1}} 100 \quad (5)$$

where *I*n is the nth harmonic current and *I*1is the fundamental frequency (50) Hz.
The THD of current and limit for 132 KV is <2.5%.

1. *Grid Frequency*
The grid frequency in India is specified in the range of 47.5–51.5 Hz, for wind farm connection

III. TOPOLOGY FOR POWER QUALITY 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, 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.

The proposed grid connected system is implemented for power quality improvement at point of common coupling (PCC), for grid connected system in Fig. 1

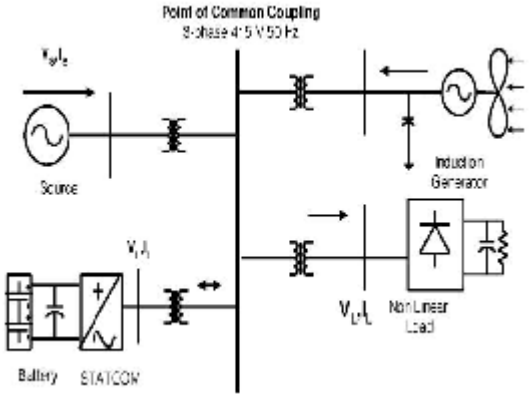

Fig.1. Grid connected system for power quality improvement.

A. 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.

B. STATCOM – STATIC SYNCHRONOUS COMPENSATOR

The Static Synchronous Compensator (STATCOM) is a shunt device of the Flexible AC Transmission Systems (FACTS) family using power electronics to control power flow and improve transient stability on power grids . The STATCOM regulates voltage at its terminal by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, the STATCOM generates reactive power (STATCOM)

A STATCOM can improve power-system performance in such areas as the following:

1. The dynamic voltage control in Transmission and

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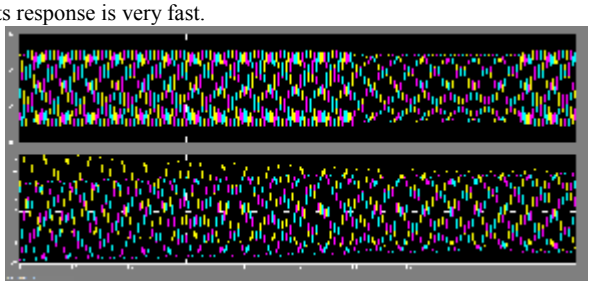
distribution systems;

2. The power-oscillation damping in power transmission systems;
3. The transient stability;
4. The voltage flicker control; and
5. It also controls real power in line when it is needed.

Advantages

1) It occupies small areas.
2) It replaces the large passive banks and circuit elements by compact converters.
3) Reduces site work and time.
4) Its response is very fast.



IV. SYSTEM PERFORMANCE

The proposed control scheme is simulated using SIMULINK in power system block set. The system parameter for given system is given Table I.

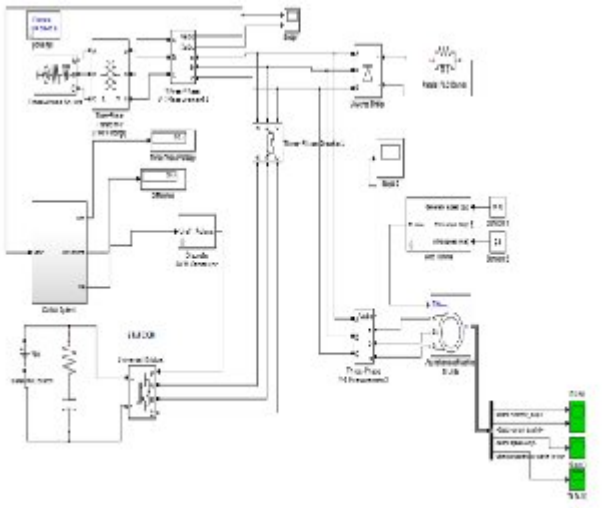
	Parameters	Ratings
1	Grid Voltage	3-Phase, 415V,50Hz
2	Induction motor/generator	3.35KVA, 415V,Hz,P=4, Speed=1440rpm,Rr=0.01Ω, Rs=0.015Ω,Ls=Lr=0.06H
3	Line series inductance	0.05mH
4	Inverter Parameters	DC Link Voltage=800V, DC Link capacitance=100μF, Switching Frequency=2kHz
5	IGBT rating	Collector Voltage=1200V, Forward Current=50A,Gate Voltage=20V,Power Dissipation=310w
6	Load Parameter	Non-Linear Load=25kw

CONCLUSION.

The paper presents the STATCOM-based control scheme for power quality improvement in grid connected wind generating system and with non linear load. The power quality issues and its consequences on the consumer and electric utility are presented. The operation of the control system developed for the STATCOM-BESS in MATLAB/SIMULINK for maintaining the power quality is simulated.

FIG 3. SIMULATION

Fig.2. 3phase output current and voltage of grid



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