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POWER QUALITY IMPROVEMENT OF GRID CONNECTED WIND ENERGY SYSTEM

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ABSTRACT

In this paper a control scheme for Battery Energy Storage System-Static Compensator is connected at a point of common coupling to mitigate the power quality issues. The STATCOM control scheme for the grid connected wind energy generation system for power quality improvement will be simulated using MATLAB/SIMULINK in power system block set. A marked reduction in the Total Harmonic Distortion is observed in source current of Wind Energy Generation System (WEGS) with the incorporation of this scheme. The development of the grid co-ordination rule and the scheme for improvement in power quality norms as per IEC-standard on the grid has been presented. The influence of wind turbine in grid system concerning power quality measurements are active power, reactive power, variation of voltage, flicker, harmonics, and electrical behaviour of switching operation. . When Wind Energy is integrated with grid, the issue of power quality arises. Awareness of power quality is highly increased in a sensitive industry.

KEYWORDS— International electro-technical commission (IEC), Power Quality (PQ), Wind Energy Generating System (WEGS), Battery Energy Storage System (BESS) ,Total harmonic distortion (THD)

INTRODUCTION

Wind power generation has gain lot of importance in recent years. The reason for increased importance is due to the latest technological advancement in wind energy conversion and an increased support from governmental institutions. The addition of wind power into the electric grid affect's the power quality. In order to address the power quality issues that arise due to the integration of wind turbine with the grid, the grid operators have imposed strict regulations requiring the wind turbines to comply power plant properties. Simplest methods of running a wind generating system are to use the generator connected to the grid system. The induction generator has advantages of robustness and cost effectiveness. However; induction generators require reactive power for magnetization. Fluctuations on the wind speed will reflect on fluctuations on the asynchronous induction generator active power, thus affecting its terminal voltage and reactive power consumption. 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. During grid disturbance, a battery energy storage system for wind energy generating system is generally required to compensate the fluctuation generated by wind turbine.

Objectives of STATCOM.

- For improvement of power factor at source side
- Minimize the effect of THD

POWER QUALITY ISSUES

A. Voltage fluctuation

The power fluctuation from wind turbine during continuous operation causes voltage fluctuation on grid. The amplitude of this fluctuation depends on grid strength, network impedance, and phase angle and power factor [3]. Because of switching operations there is a chance of voltage fluctuations.

B. Voltage Dip

It is a catastrophic drop in voltage to a value between 1 percent & 90 percent of nominal value after a short period of time. The main cause of voltage dips is due to start up of wind turbine and it causes a sudden fall of voltage [4].

C. Self Excitation of Induction generator

Wind power plants generates power by using induction asynchronous generator. The self-excitation of wind turbine generating system (WTGS) with an asynchronous generator takes place after disconnection of wind turbine generating system (WTGS) with local load. The risk of self-excitation arises especially when WTGS is equipped with compensating capacitor. The induction machine needs reactive power in order to produce active power, thus it is a common technique to compensate that reactive power with a shunt capacitor.

D. Harmonics

The harmonics distortion caused by non-linear load, saturation of magnetization of transformer and a distorted line current. To ensure the harmonic voltage within limit, each source of harmonic current can allow only a limited contribution, as per the IEC-61400-36 guideline. The total harmonic distortion of voltage is given as in (2)

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

Where V_n is nth harmonic voltage and V_1 is the fundamental frequency (50)Hz. The THD limit for 132KV is <3%.

THD of current I_{THD} is given as in (3)

$$I_{THD}==\sqrt{\sum\frac{In}{I1}100} \quad (3)$$

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%

E. Voltage Rise:

The voltage rise at the point of common coupling can be approximated as a function of maximum apparent power S_{max} of the turbine, the grid impedances R and X at the point of common coupling and the phase angle ∅ [4], given in (4)

$$\Delta u = S_{\max} \ (Rcos\emptyset - Xsin\emptyset)/U^2 \qquad (4)$$

Where Δu is Voltage rise, $S_{\max}$ is apparent power, ∅ is phase difference & U is the nominal voltage of grid. The limiting voltage rise value is <2%.

F. Grid Frequency

The grid frequency in India is specified in the range of 50 Hz, with 2 percent tolerance. The wind farm shall able to withstand change in frequency up to 0.5 Hz/s [5].

G. Consequences of the issues

The voltage variation, harmonics, flicker may cause the mal-function of equipment namely microprocessor based control system, programmable logic controller. It may lead to tripping of protection devices, severely affecting the power quality in the grid [4].

TEST SYSTEM DESCRIPTION

Test system shown in fig no.1. has wind generating station connected to non linear load.
The STATCOM with battery energy storage (BESS) is connected at the point of common coupling.

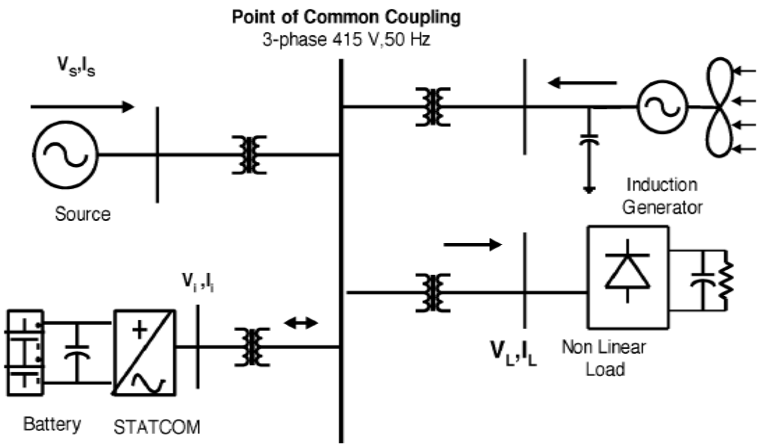

Fig.1 Grid Connected System (Test System)

A. System Overview

The STATCOM (or SSC) 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. In the paper presested, STATCOM taken DC input voltage comes from the battery energy storage system as mentioned previously. The STATCOM's output is highly controllable; it produces a set of 3-phase ac-output

Applicaiton of STATCOM in power system

1. Used for controlling voltage dynamically in transmission as well as distribution lines.
2. Used in power transmission lines for damping power oscillations.,
3. To improve transient stability
4. For controlling the voltage flicked
5. For control of Active and reactive power.

In the implemented system we are using an BESS- STATCOM advantage of the battery energy storage system (BESS) is, it can be used as an energy storage element for the purpose of voltage regulation.

PID control is used for improving the STATCOM performance in the implemented system. By individual control of gains Kp, KI and KD we can improve the performance of BESS - STATCOM

B. System Operation

STATCOM connected in parallel along with battery energy storage system in directly connected to the induction generator and to observe the effect of harmonics it is connected to to non linear load at common point of coupling to our national grid as shown in Fig. No. 3. The uses of STATCOM facilitates injection of source current, which is harmonics free and phase angle are also as designated. The advantage of introducing injection current to reduce harmonic content, improve power factor in turn improve an power quality.

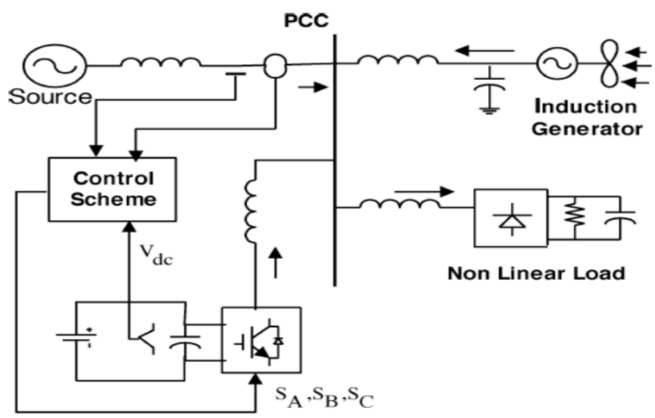

Fig.2 System Operational Scheme in grid system

CONTROL SCHEME

While implementing this paper bang-bang current controlled is used. Bang – Bang current controller uses a hysteresis current controlled method. Advantage of using this technique is , it keeps the controller and other components of control system in hysteresis boundaries. And this used for giving switching signals for STATCOM.

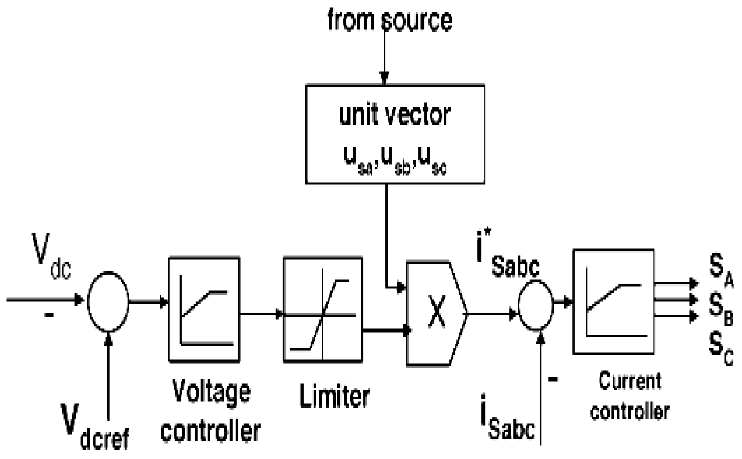

Fig.3. Control System

Source phase Voltages V_{sa} , V_{sb} ,V_{sc} and is expressed, as sample template V_{sm} , sampled peak voltage , as in (5)

$$Vsm = \left\{ \frac{2}{3} \left(V_{sa}^2 + V_{sb}^2 + V_{sc}^2\right) \right\}^{1/2} \qquad (5)$$

The in-phase unit vector are obtained from AC source -phase voltage and RMS value of unit vector u_{sa} u_{sb} u_{sc} as show in (6)

$$u_{sa} = \frac{Vsa}{Vsm} \qquad u_{sb} = \frac{Vsb}{Vsm} \qquad u_{sc} = \frac{Vsc}{Vsm} \qquad (6)$$

The in-phase generated reference currents are derived using in-phase generated reference currents are derived using in-phase unit voltage template as, in (7).

$$i_{Sa}^* = I.u_{sa} \qquad i_{Sb}^* = I.u_{sb} \qquad i_{Sc}^* = I.u_{sc} \qquad (7)$$

The reference current is generated as in (7) and current flowing in line is detected by current sensors and subtracted for obtaining a current error for a hysteresis based bang-bang controller. Thus the ON/OFF switching signals for IGBT of STATCOM . The switching function S_A for phase 'a' is expressed as (8).

$$i_{sa} < (i_{Sa}^* - HB) \quad S_A \rightarrow 0$$
$$i_{sa} > (i_{Sa}^* - HB) \quad \rightarrow S_A = 1 \qquad (8)$$

where HB is a hysteresis current-band, similarly the switching function S_B , S_C can be derived for phases "b" and "c".

SYSTEM SIMULATION AND ITS PERFORMANCE

The system is simulated in MATAB/SIMULINK power system block-set. A library model of wind generating system, inverter and load is utilized for simulating the system for power quality improvement. The system performance is simulated .The system parameter for given system is given in Table I.

Table I
System Parameters

Sr. No	Parameters	Rating
1	Grid Voltage(Source)	3 phase ,415 v, 50 Hz
2	Induction Generator	3.35Kva, 415V, 50Hz,P=4, Speed =1440 rpm Rs=0.01Ω Rr=0.015 Ω, Ls=0.06H , Lr=0.06H
3	Inverter Parameters	DC link voltage = 800v Dc link Capacitance=100µF Switching Frequency=2KHz
4	IGBT Rating	Collector voltage=1200V Forward current =50A Gate Voltage=20v Power Dissipation=310W
5	Load Parameters	Non-Linear Load 25Kw

SIMULATION RESULTS AND ANALYSIS

CASE 1: Test system without STATCOM

In this case, the source is directly connected to non linear load with wind farm . Fig 4 shows the source voltage and current waveforms for case1.In this case the whole system is running without STATCOM and additional load is switched at step time of t=0.8sec. It is observed from Fig 4 that the source current of the grid is distorted due to the effects of nonlinear load.

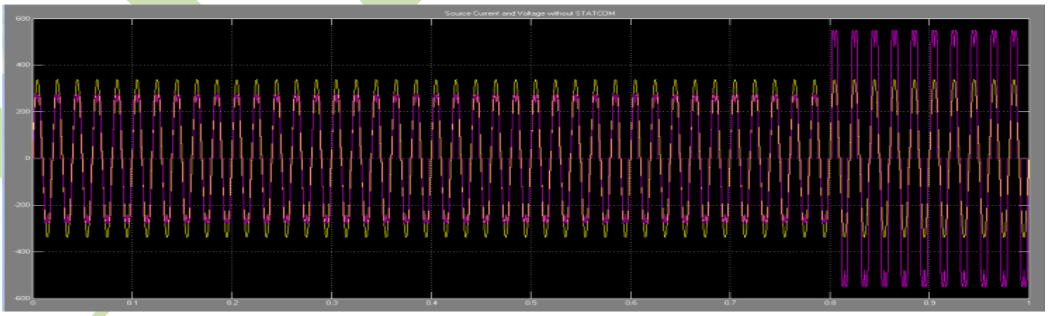

Fig.4 Source voltage and current waveforms without STATCOM

CASE 2: Test system with STATCOM

This system is operating with STATCOM. In previous case the load is increased at 0.8s as seen in the fig.4. This additional demand is fulfil by STATCOM compensator. Thus, STATCOM can regulate the available real power from source. The result of current and voltage are shown in fig no. 5

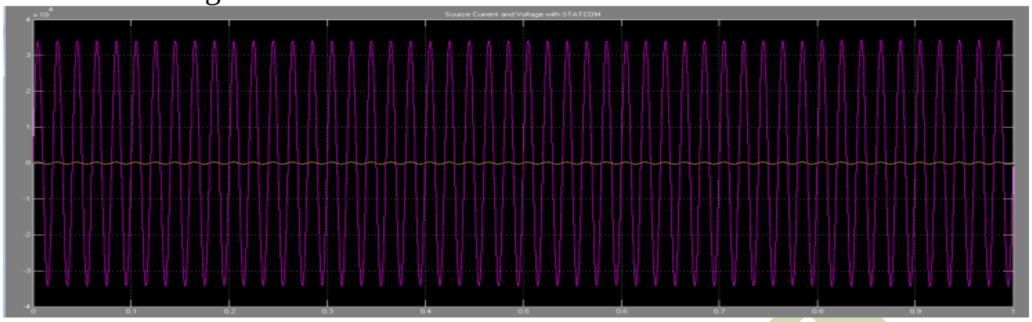

Fig.5 Source Current and Voltage with STATCOM

CASE 3: Wind farm connected to grid with STATCOM

Here, the STATCOM is connected to the grid at 0.7s.The source voltage and current waveforms for this case are shown in Fig 6. It is observed from Fig 6 that when the STATCOM controller is switched ON at 0.7s, without change in any other load condition parameters, it starts to compensate the harmonics effect.

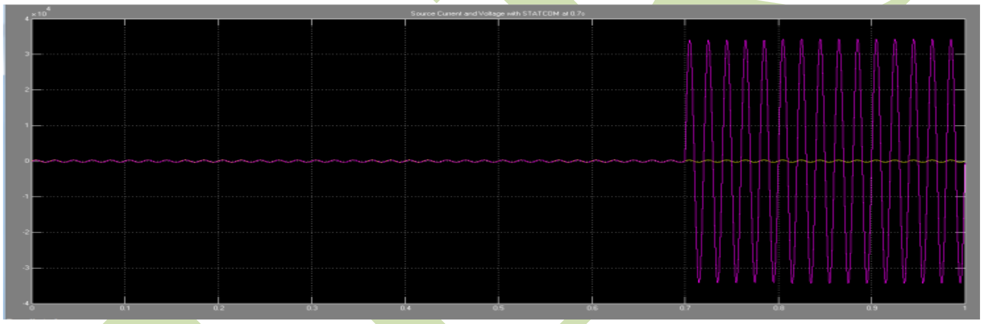

Fig.6 Source Current and Voltage with STATCOM at t=0.7 sec

From the Fig 7, it is observed that the source current waveform is distorted due to the integration of wind generating system with the grid. Fig 7 presents the Fast Fourier transform (FFT) analysis for grid connected wind energy system without STATCOM. It is been found that THD without STATCOM is 30.89%.

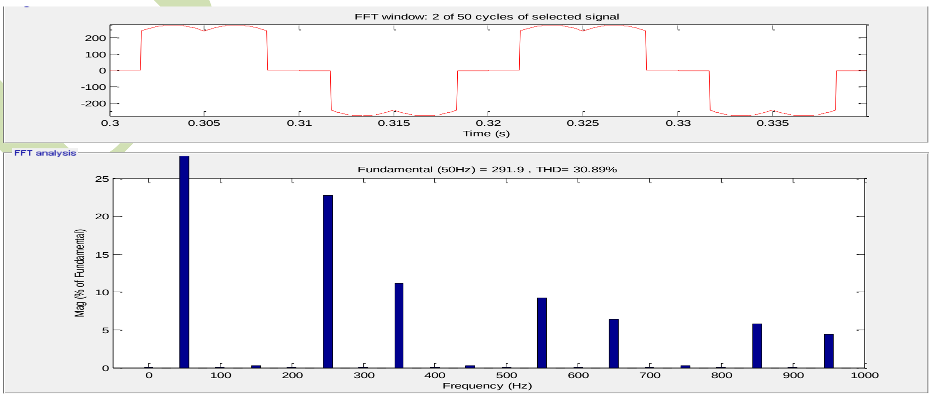

Fig.7 FFT analysis of source current for the test system without STATCOM

Fig.No. 8 shows Fast Fourier Transfor (FFT) evaluation for grid connected wind energy system with STATCOM. It is been found that, by usage of STATCOM THD is 0.51% which is within the limits imposed by the standards. Thus it can be concluded that performance of the controller designed for STATCOM is as at par with international standards.

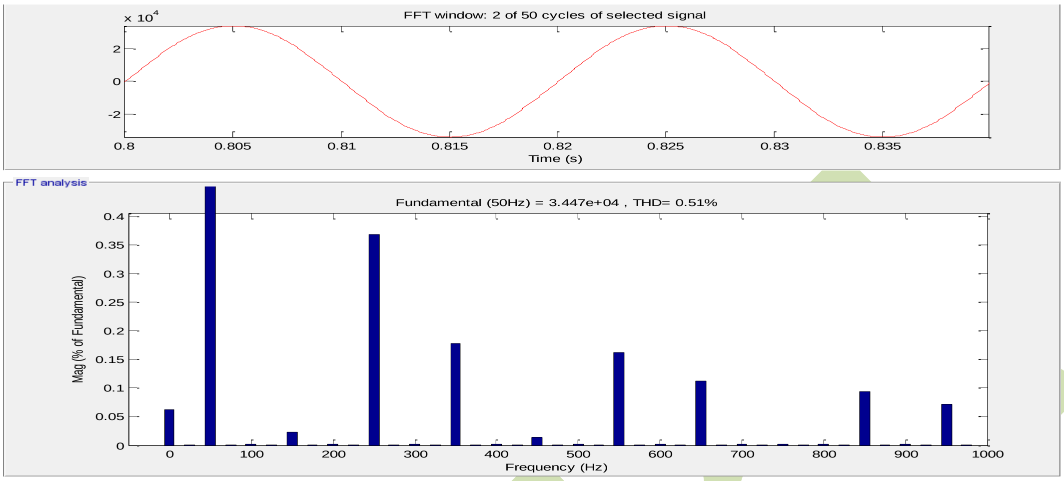

Fig.8 FFT analysis of Source current for the test system with STATCOM

CONCLUSION

Study presented in this paper, is to investigate the effect of wind of wind generation interconnection to national grid is addressed and simulated using powerful tool MATLAB/Simulink. A test system simulated here was having non linear load and STATCOM is connected to improve the performance of the system. The STATCOM is connected to point of common coupling (PCC) and same is been simulated. It was observed from the simulation results that the THD in the source current waveform has been greatly reduced from 30.89% to 0.51% with the use of STATCOM.

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