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Research Paper Engineering

Mitigation of Harmonics And Enhancement of Power Quality in A Grid Integrated Wind farm Using Statcom

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ABSTRACT

Wind Energy is one of the promising renewable energy resource used to integrate with the grid. It brings some of the technical challenges when it integrated with the grid which is power quality and voltage stability problems. In this paper a STATic synchronous COMpensator (STATCOM) with battery energy storage system for wind power application has been treated. This device was proposed as a mean to improve voltage stability and power transmission by offering reactive as well as active power compensation .For active compensation of wind power, a bank of battery energy system BESS was used in this project. The battery energy system was estimated, based upon the short term fluctuations in wind power. One of the major areas in renewable power control includes the grid connected based WECS. In this paper a grid connected wind energy conversion system using a simple PI controller is designed to resolve the problem. Finally a comparison has been made to with and without STATCOM operation from the simulation results, observing the efficiency of variation of DC link voltage variation and other parameter values.

KEYWORDS : power quality, International Electro technical commission (IEC), point of common coupling (PCC).

1. INTRODUCTION

In both the world of science and politics, most people agree upon the fact that there is a global warming issue, and that it is created by human activities. A lot of initiatives have been taken throughout the world to limit the emissions of green house gases, especially within the energy sector. To achieve these goals, technologies for new renewable energy must be developed.

Since energy is one of the key factors for a wealthy society, the technologies which offers an alternative to oil, gas and coal will be important for the future [1]. Among all the emerging renewable energy sources, like solar, tidal, wave and wind power, the latter shows the greatest potential in a short term perspective. In addition, wind power offers the most mature technology.

The demand for active power regulation and the fact that normally reactive power compensation is needed in connection with a wind farm, a STAtic synchronous COMpensator (STATCOM) with energy storage system (BESS) is proposed. The purpose of this is to include both active- and reactive compensation in the same device.

In this work, the STATCOM/BESS will be treated. The main focus will be on the converter topology for the STATCOM and its control system [2]. This will be treated theoretically and simulations. In addition, the energy storage system will be treated theoretically and simulated.

The STATCOM connected wind farm having the following objectives

- To maintain the capacitor voltage constant and also the power factor should be maintained at unity.
- To generate a constant frequency from the variable speed operation of the shaft using the traditional PI.
- To design a STATCOM controller for DC-link voltage control
- To implement the above controllers in MATLAB/SIMULINK

2. POWER QUALITY & GRID CONNECTION STANDARDS

Integrating a distributed power system into electric grid network has a list of requirement that need to be met to ensure a safe connection to grid [8]. However, to a certain degree these standards are similar and mainly based on two major international standards from Institute of Electrical and Electronics Engineer (IEEE) and International Electro technical Commission (IEC). The main and most vital requirement and limitations can be found in the standards provided by IEEE and IEC.

While some standards are developed to be specific such as

- Measurement and assessment of Power Quality Characteristics of grid connected wind turbines.
- IEEE1547.3-2007: Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems
- IEEE1547.6-2011: Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks.

These standards provide us grid connection and power quality standards in electrical distribution network.

3. POWER QUALITY ISSUES

Where a group of loads is considered, one of the main causes of poor power quality in power equipment is due to non-linear voltage-current characteristics of semiconductor devices and the increasing switching frequency. Since numerical indices of power quality deteriorate during electric power transmission and distribution, mainly due to the customers' influence, the quality of electric power cannot be fully controlled by its producer [3].

Some of the power quality issues and its consequences are

- Voltage variations
- Short and long duration voltage variations
- Voltage sags and dips
- Voltage and current distortion

The consequences of these issues are voltage variation, flicker, harmonics causes the failure of equipments that is programmable logic controller; adjustable speed drives, microprocessor based control system, flickering of light and also screen.

4. PROPOSED CONTROL SCHEME

The control principle investigated here compromises a system with disconnected STATCOM and DC/DC-converter control. This in order to omit the change of reference for the STATCOM-controller. The power controller is needed to be slower than the DC-bus controller, so the latter voltage can be kept steady [3]. Also, there is a need to introduce an upper- and lower voltage limit for the super capacitor to avoid instabilities in the DC/DC-converter.

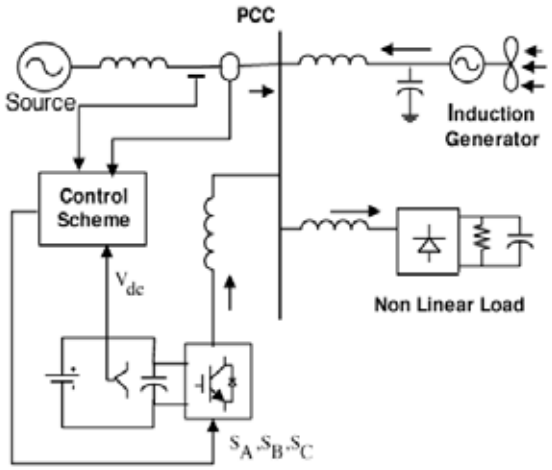


Figure 1: block diagram of grid connected wind energy system along with STATCOM –BESS

4.1 OPERATING PRINCIPLE

The electrical grid and wind energy system are interconnected at the point of common coupling to ensure the power injection to grid. The continuous power injection in to the distribution network is possible by the help of STATCOM and battery energy storage system. STATCOM gives stability to the system and voltage control and BESS provide continuous power supply to the grid, among the natural and wind energy fluctuations conditions. This total phenomenon gives power quality throughout the system and fulfills the IEC standards further characteristics with and without STATCOM operations are stated in the results section.

4.2 BATTERY ENERGY STORAGE SYSTEM-STATCOM

Battery energy storage system (BESS) is connected with a Static Compensator (STATCOM) to moderate the power quality issue and to improve voltage stability. The BESS is incorporated to maintain the real power source in fluctuating wind power.

In fig 2 the principle of the system is shown, here presented with a 2-level converter.

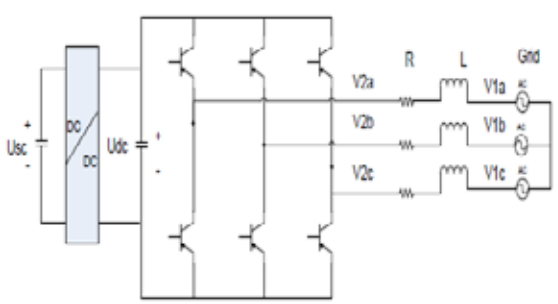


Figure 2: STATCOM with BESS

Energy function of a typical battery is given by [6]:

$$E(t) = E_o + \int V(t).i(t)$$

Where, E_o represents the initial battery voltage level. The main advantage of BESS over other energy devices is its high energy density.

5. SIMULATION RESULTS AND ANALYSIS

5.1 PERFORMANCE OF STATCOM UNDER LOAD VARIATIONS

The wind energy generating system is coupled with grid have the nonlinear load. The characteristics of the system is measured by exchanging the STATCOM at time t=0.7s and how the STATCOM reacts to the step change of order for increment in extra load at 1.0 s is indicated in the simulation. The controller begins to moderate for reactive demand and also harmonic current.

S.No	Parameters	Ratings
1.	Grid Voltage	3-Phase,415V,50Hz
2.	Induction Motor/ Generator	3.35KVA,415V,50Hz,P=4, Speed=1440rpm,Rs=0.01Ω, Rr=0.015Ω,Ls=0.06H,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

Table 1: System Parameters

Total dynamic performance is likewise completed by step change in the load current, when connected at 1.0 s. This extra demand is satisfy by STATCOM compensator. Hence, STATCOM can manage the accessible real power transfer from the source. The consequence of source current, load current is demonstrated in Fig 3.a individually. While the consequence of injected current from STATCOM is demonstrated in Fig.3.b and the current generated from wind generator at PCC are indicated in Fig 3.d

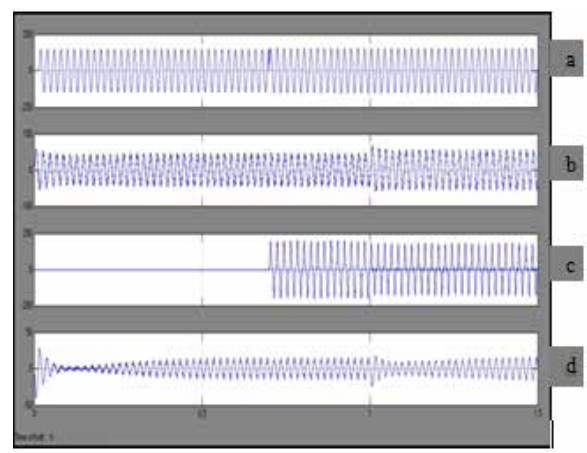


Figure 3: Current at A. PCC B Load Current. C. Injected Current of Inverter D. wind generating system.

The DC link voltage controls the source current in the grid system, as a result the DC link voltage is kept up consistent over the capacitor as indicated in Fig.4.a The current through the dc link capacitor viewing the charge and discharge operation as indicated in figure 4..b

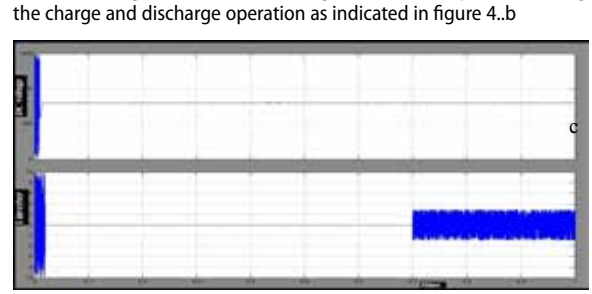
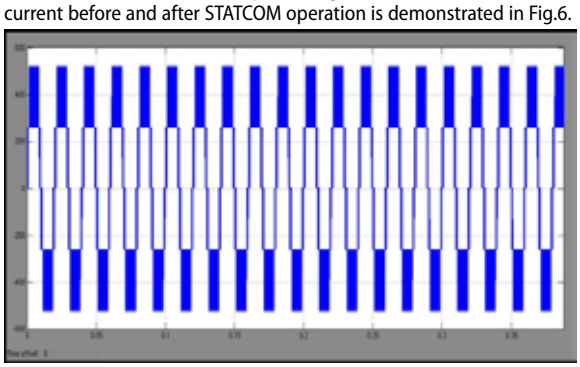


Figure 4: (a) DC link. Voltage (b) Capacitor Current Vs time

6. POWER QUALITY IMPROVEMENT

It is noticed that the grid is influenced y source current because of the impacts of nonlinear load and wind generator, subsequently clarity of waveform may be missing on both sides on the system characteristics. The inverter voltage at output during STATCOM operation with the load variations are demonstrated in Fig 5. The dynamic load does

have an influence on the output voltage of the inverter. The source current before and after STATCOM operation is demonstrated in Fig.6.



Time(S)
Figure 5: output voltage of STATCOM

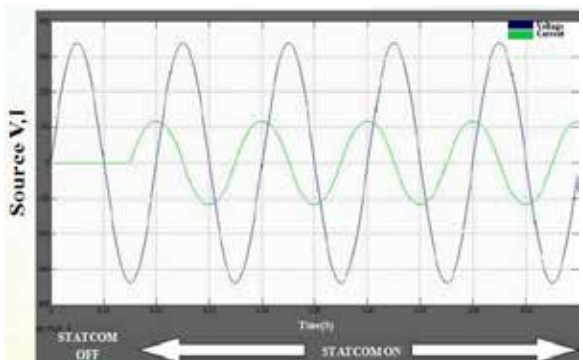


Figure 6: supply Voltage and Currents during ON-OFF state of STATCOM at PCC.

This indicates the unity power factor to be maintained in support of the source power while the STATCOM is in operating condition. The current waveform with and without the STATCOM action is investigated. The Fourier analysis of this waveform is shown and the THD of the source current by PCC with no STATCOM is 0.40 %, as demonstrated in Fig.7.

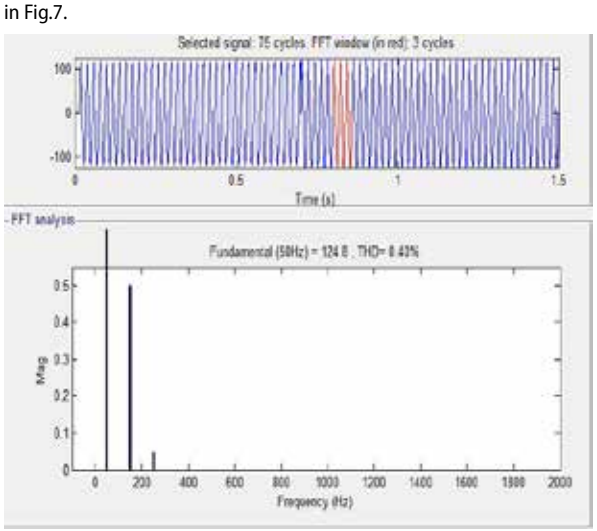


Figure 7: (a) Current at Source. (b) Source current Fourier analysis

The power quality enhancement is seen at point of common coupling, once the state of controller is maintained at ON position. The STATCOM is put within the function at 0.7 s along with waveform of source current with STATCOM is demonstrated in Figure.8 along with FFT. It is demonstrated that the THD has been enhanced significantly and within the IEC norms and standards.

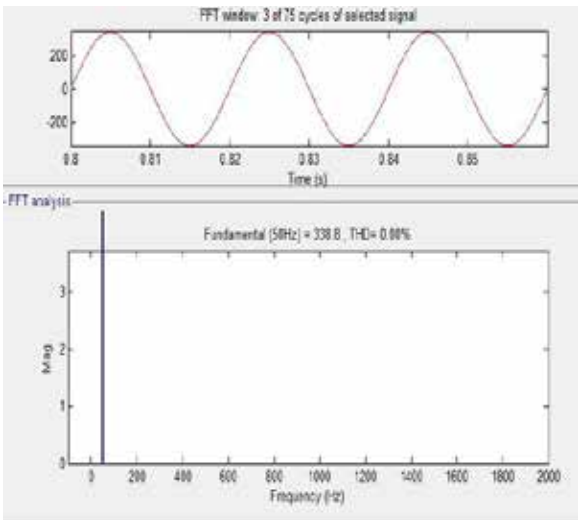


Figure 8: (a) Current at Source. (b) Source current Fourier analysis

The above tests by proposed system have not only power quality enhancement feature as well as having solution for sustain capability to support the load by the energy storage with help of batteries

7. CONCLUSION

This paper introduced the STATCOM-based control plan for power quality enhancement in grid integrated wind generating farm and with non linear load under the fluctuating conditions. The power quality issues and its outcomes on the electric utility and consumers are exhibited. The operation of the control scheme is designed with the parallel connection of STATCOM and BESS in MATLAB/SIMULINK for keeping up the power quality as stable throughout the system. The control scheme has an ability to block the load current harmonics. It keeps up the source voltage and current in equilibrium state and payback the amount of reactive power for the grid associated with distribution system and load at PCC. Accordingly it gave a chance to improve the utility factor of transmission system. The grid connected wind energy conversion system and STATCOM with BESS have demonstrated the exceptional execution. Accordingly the proposed plan in the grid connected wind energy conversion system satisfied the power quality standards and norms according to the IEC standard 61400-21.

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