Journal of Engineering and Applied Sciences 12 (14): 3798-3802, 2017
ISSN: 1816-949X

Power Quality Enhancement in Wind Energy Conversion System using PID Based D-STATCOM

[1]A. Nabisha and [2]X. Felix Joseph
[1]Department of Electrical and Electronics Engineering,
Loyola Institute of Technology and Science, 629 302 Thovalai, India
[2]Department of Electrical and Electronics Engineering,
NICHE and Bule Hora University, Bule Hora, Ethopia

Abstract: The wind power is the fastest growing electricity resource in recent world. The incorporation of wind power with grid affects dynamic strategy of entire power system. An abnormal change in wind power is obtained by gradual motion of wind in atmosphere. Demand of reliable, quality power and increasing non-linear load is key factor for awareness of power quality in between utility and customer. Inclusion of wind power with electric grid is the major issue for various power quality problems such as reactive power, sag, swell in voltage magnitude and phase, harmonics and frequency changes. IEC 61400 specified standard guide lines and norms are followed in manufacturing of wind turbine on the basis of power quality. This issue is over come by installation of FACTS devices at point of common coupling. In this proposed scheme D-STATCOM based FACTS devices installed at PCC. To reduce the effect of various power quality issues D-STATCOM is used for providing shunt compensation. It can provide better support for various power quality problems. The performance of devices can be executed by MATLAB/SIMULINK. To enhance the performance of devices conventional PID is used with D-STATCOM. Implementing conventional controller with custom power device, increases the response of generation of compensation signal by its fine tuning of gain factor. By this PID D-STATCOM, the compensation time will considerably decrease which further lead to faster response.

Key words: D-STATCOM, power quality, PID controller, harmonics, custom power devices

INTRODUCTION

Wind is motion of air in atmosphere. Due to lack of non-renewable energy sources renewable sources play a key role to overcome the scarcity. Some of renewable sources are wind, solar, biomass and geothermal. Among that wind is a developing pollution free source. Motion of air in atmosphere fully depends on surface of earth and emission of sunlight. When the winds strike the turbine blades it generates electricity. Due to lack of storage in alternate supply the generated power by wind turbine is linked with grid network. Instability in wind speed which induces an oscillation in voltage at common point. This voltage variation leads to various power quality issues which are voltage sag, swell, flicker, harmonics, frequency changes, power factor changes. Compared to variable speed turbine, fixed speed turbine generates 12% of energy more than previous. This directs to rise in efficiency.

But in subsequent turbine, the fluctuation of wind speed transmitted as fluctuation in torque plus electrical power in grids.

Consequence is voltage fluctuation (Mohod and Aware, 2010). The grid network need to withstand during voltage fluctuation. To overcome this issue custom power devices are used. Some of the devices are D-STATCOM, SVC and UPQC. Among that SVC can rectify the issues related with voltage but not on reactive power. But device like UPQC can do superior than other but only defect is cost effective. To compare previous devices D-STATCOM can perform better over power quality issues. Further, the performance of FACTS devices can be enhanced by various conventional control techniques. Implementation of conventional control technique with custom power device raise the response time as well as utilization factor.

Power qulaity improvement

Power quality standard, issues and consequences

IEC guide lines: Standard guide lines provided for power quality measurement for wind turbine. These international standard developed by an IEC working group. Among all standards, IEC standard 61400-21 describes the standard guidelines and procedure for determining the power

Corresponding Author: A. Nabisha, Department of Electrical and Electronics Engineering,
Loyola Institute of Technology and Science, 629 302 Thovalai, India

quality characteristics of wind turbine. Some standard norms are Tsili and Papathanassiou (2009), Ammar and Joos (2014).

IEC61400-21: Wind turbine generating system, Part-21 measurement and assessment of power quality characteristics of grid connected wind turbine.

IEC61400-13: Wind turbine measuring procedure in determining the power behavior.

IEC61400-3-7: Assessment of emission limits for fluctuating load.

IEC61400-12: Wind turbine performance. The data sheet with electrical characteristics of wind turbine provide the base for the utility assessment regarding a grid connection.

Voltage variation: As a result of wind velocity and generated torque, the voltage gets varied. The voltage variation due to wind velocity is directly related with variation of real and reactive power. The common voltage variations are:

- Voltage dip
- Voltage swell
- Short interruption
- Long duration voltage variation

The flicker effect occurs by frequent variation in wind as well as the load. Voltage variation depends on strength of grid, network impedance and phase angle and power factor of wind turbine. Flicker is illustrated as fluctuation of voltage at a frequency of 10-35 Hz. It is mentioned in IEC 61400-4-15. Flicker meter is used to measure flicker in direct.

Harmonics: Power electronics converters are major source for harmonics. Harmonic voltage and current are maintained within acceptable limit at a point in which the turbine is connected with the network. To maintain the harmonic voltage within a limit each source harmonic current allows only limited input as per IEC 61400-36 guide lines.

Wind turbine location power system: Wind generating system connected with grid network influence the various power quality issues. An operation and connection point of wind turbine depends on structure of network.

Consequence of the issues: Voltage variation, flicker, harmonic induces a failure in equipment such as control in microprocessor, programmable logic controller, adjustable speed drives, flicker of light and screen. It may lead to tripping of contact, protection devices (Tsili and Papathanassiou, 2009).

MATERIALS AND METHODS

Modelling of wind turbine generating system: A D-STATCOM is a voltage source converter which is connected at point of common coupling to inject the current in to the grid network. The current is harmonic free and it maintains the phase angle in specified limit. As a result it cancels out the harmonics and it gives support to compensate the reactive power (Yaramasu and Wu, 2014). Finally it will improve the power factor as well as power quality. The grid connected wind energy system is represented in Fig. 1. It consist of wind generating system and D-STATCOM with battery energy storage system.

Wind energy generating system: In this proposed system induction generator is used. It can act both at constant and varying load condition. Naturally it has protection against short circuit condition. Kinetic energy in air is denoted as E. The following Eq. 1 is:

$$E = \frac{1}{2} m V_{wind}^2 \quad (1)$$

Where:
m = Mass of air (kg)
V_{wind} = Speed (m/sec)

Mass of air denoted as:

$$m = \rho A V_{wind} \quad (2)$$

Where:
ρ = Air density (kg/m^3)
A = Mass flow area

The power generated from the wind turbine is given as:

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

Swept area of blade: Due to non linear nature of blade only part of wind is captured by blade. It is only the extract fraction of power but not whole power. This is called power coefficient (C_p). Then, the developed power:

$$P_{wind} = C_p x \text{ wind} \quad (4)$$

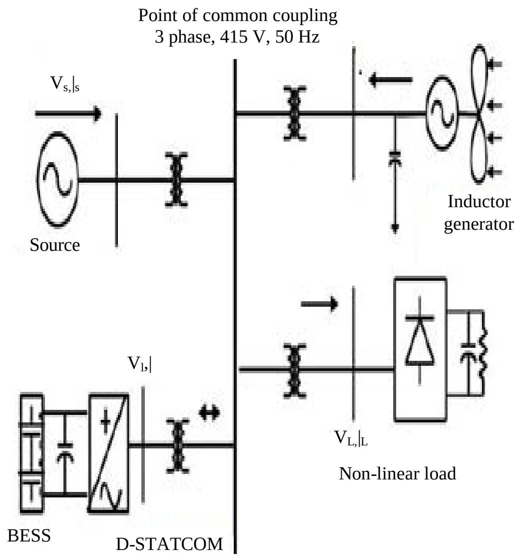

Fig. 1: Grid connected system

The coefficient is expressed as a function of tip speed as well as pitch angle (θ). The developed mechanical power in wind turbine (Singh, 2011):

$$P_{mech} = \frac{1}{2}\rho\pi R^2 V_{wind}^3 C_p \quad (5)$$

D-STATCOM-BESS System: Distribution static compensator is a voltage source converter. It provides shunt compensation. When the wind turbine connected with grid network at point of common coupling, due to fluctuation of wind the grid power quality will get affected. To overcome this issue D-STATCOM is connected at PCC. Voltage source converter injects the current in to the grid to maintain electrical parameters within its specified limit such as voltage, reactive power. Due to variation in load the harmonics will appear. The injected current from the D-STATCOM is maintained as harmonic free. It is capable of generating or absorbing the reactive power. It feed the energy from energy storage system as its input to output terminal which control independently real as well as reactive power. It has dc as a input supply and it commutates 1ϕ DC input to 3ϕ AC out supply. The Dc supply is provided by the capacitor (Bapaiah, 2013; Morales and Maun, 2003) (Fig. 2).

Control scheme: The shunt connected compensator D-STATCOM with energy storage system connected with wind energy generating system and non linear load at point of common coupling (Fig. 3).

The D-STATCOM is combination of insulated bipolar transistor with capacitor which is providing reactive power compensation at common point to avoid power quality problem (Arulampalam *et al*., 2003). The control schememainly depends on current control which is used to operate the voltage source converter in better way to provide a reactive power support. According to the gain function of conventional controller, the pulse width modulated signal will be generated to operate the converter according to the firing angle (Barua, 2011).

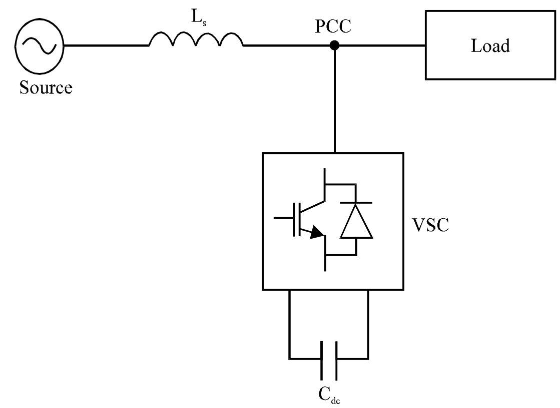

Fig. 2: Distribution static compensator

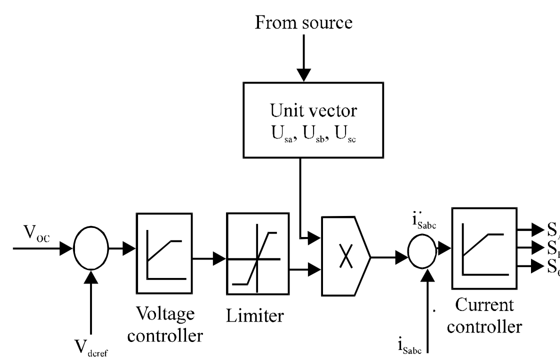

Fig. 3: PID control scheme

RESULTS AND DISCUSSION

The proposed system demonstrates about D-STATCOM based PID controller which is simulated in Matlab/Simulink. System parameters of given proposed system is mentioned in Table 1.

The performance of wind turbine isanalyzed in proposed system is to overcome various power quality issues that occur in power system network. The identified issues are voltage sag and swell, reactive power problem, harmonics and power factor maintenance. At normal operating condition the required voltage from the wind turbine is represented in Fig. 4. During an occurrence of voltage sag 10 and 90% of nominal voltage

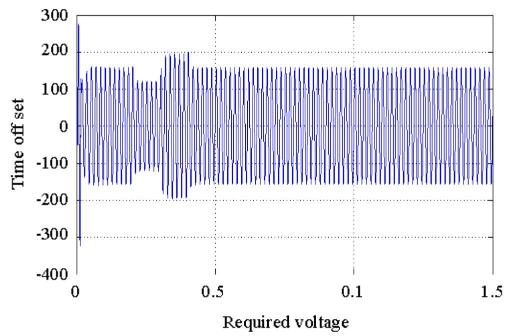

Fig. 4: Required voltage on sag condition

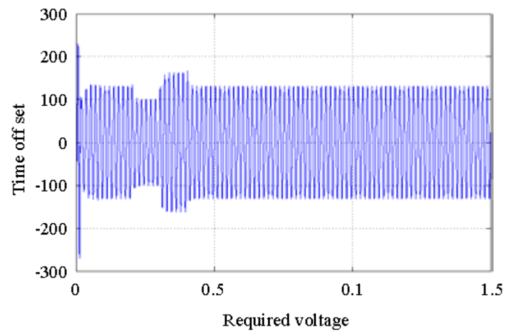

Fig. 5: Generated voltage on sag condition

Table 1: Simulation parameters

Parameters	Ratings
Grid voltage	3 Phase, 415 V, 50 Hz
Induction generator	3.35 KVA, 415 V, 50 Hz, P = 4, Speed = 1440 rpm
Line series inductance	0.05 mH
Inverter parameters	DC Link Voltage = 800 V, DC link capacitance = 100 μF, Switching frequency = 2k Hz
IGBT rating	Collector voltage = 1200 V, Forward current = 50 A, Gate voltage = 20 V, Power dissipation = 310 W
Load parameter	Non-linear load = 25 kW

will decrease. Main reason for voltage dip is overload and short circuit. At same operating condition of wind turbine the generated voltage is denoted in Fig. 5.

During voltage sag condition to avoid power quality issue occurrences, compensation signal provided by voltage source converter is represented in Fig. 6. During normal operating situation the required voltage from the wind turbine is represented in Fig. 7.

The generated voltage is high compared to required voltage at voltage swell condition. Voltage swell is opposite to sag condition. From the simulation result the generated voltage is 310 V. At voltage swell the required voltage is lower than generated. It is represented in Fig. 8 and 9.

At voltage swell condition the required voltage is fewer. To overcome this power quality problem the compensation signal provided by converter based D-STATCOM with PID controller is present in Fig. 9.

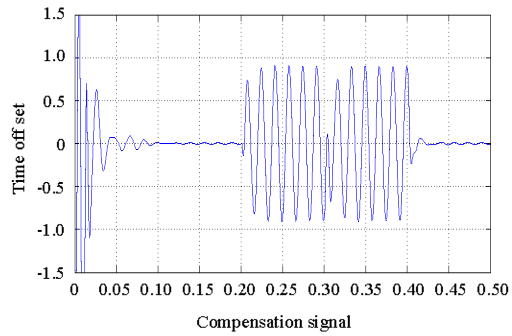

Fig. 6: Output of DSTATCOM based PID on voltage sag condition

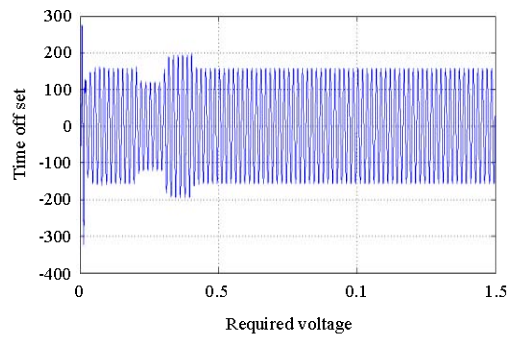

Fig. 7: Required voltage on swell condition

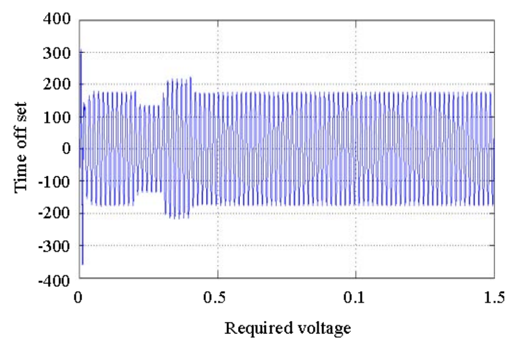

Fig. 8: Generated voltage on swell condition

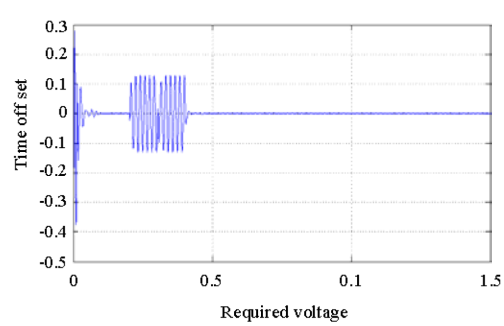

Fig. 9: Output of DSTATCOM based PID on voltage swell condition

CONCLUSION

This study clearly demonstrates the various power quality problems (Morales and Maun, 2003; Sunil and Loganathan, 2012) in wind energy conversion system. In this proposed method D-STATCOM based FACTS device is implemented to recover various power quality issues. The operation of D-STATCOM is controlled by conventional PID controller. In grid connected wind energy conversion system, the compensation provided by converter eliminates various power quality issues such as voltage fluctuation, reactive power problem and harmonics. The result is executed by Matlab/Simulink Initially without controller the compensation provided by FACTS devices were not satisfied. While using the conventional controller the response of the system increased high. The compensation within duration t = 0.5 sec. The PID with D-STATCOM enhance the response time.

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