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A SVC Light Based Technique for Power Quality Improvement Of Grid Connected Wind Energy System

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Abstract: The power produced from wind energy source is always fluctuating due to variation in the wind. Thus wind power injection in to an electric grid affects the quality of power.. This paper deals the existence of the power quality problems due to the installation of wind turbine with grid. In order to eliminate these power quality problems, this paper proposes a scheme based on FACTS device called SVC light which is connected at a Point of Common Coupling. The proposed model is compared with the model that do not use any compensating device . This control scheme for the grid connected wind energy generation system is to improve the power quality and this system is simulated using MATLAB /SIMULINK in power system block set.

Keywords: Power Quality, Wind Generating System (WGS), Svc light, Statcom, Battery energy storage system (BESS).

I. INTRODUCTION

The wind power generation is asynchronous, also it is cheap. Asynchronous generators, will not contribute to regulation of grid voltage, and they are substantial absorbers of reactive power. The variations in the wind turbine and non linear load leads to large voltage fluctuations. The power quality problems can be viewed with respect to the wind generation, transmission and distribution network, such as voltage sag, swells, flickers, harmonics etc. The wind generator introduces disturbances into the distribution network... However, induction generators require reactive power for magnetization.

Some or all of which may require FACTS at the PCC to satisfy the demands. 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.

`A svc light based control technology has been proposed for improving the power quality which can technically manages the power level associates with the commercial wind turbines. The proposed Svc light control scheme for grid connected wind energy generation for power quality improvement has following objectives.

- Unity power factor at the source side.
- Reactive power support only from svc light to wind Generator and Load

11 Power Quality Problems

2.1 **Voltage fluctuations**: The voltage fluctuation problems results from the wind speed and generator torque. The voltage variation is directly related to active and reactive power variations. The voltage variation can be:

- Voltage Sag
- Voltage Swells.
- Voltage Fluctuations / Flickers

Voltage Sag

Voltage sag is considered as a decrease in rms voltage between 0.1 and 0.9 per unit (pu) at the power frequency for the durations from 0.5 cycle to 1 min. The term sag is described as decrease in voltage. The occurrence of voltage sags is generally by system faults but the energization of heavy loads, overloaded wiring and starting of large motors can also cause voltage sag.

Voltage Swells

A voltage swell is defined as an enhance in rms voltage or current between 1.1 and 1.8 pu at the power frequency for the durations from 0.5 cycle to 1 min. Voltage swells are generally connected with system error conditions, however they do not occur as frequent as voltage sags. The voltage swell can be caused by energizing a large capacitor bank, sudden load reduction, switching off a large load, open neutral connection and insulation breakdown. Voltage swells show negative effect on the performance of sensitive electronic equipment causing data errors, equipment shutdowns, and equipment damage and may lessen equipment life. It causes annoyance tripping and deprivation of electrical contacts

Voltage Fluctuations / Flickers

Voltage fluctuations/flickers are relatively small (less than 5 percent) changes in the rms line voltage. The main contributors of these changes/variations are arc furnaces, cyclo converters and other systems. They draw current with no synchronization with the line frequency. The voltage flicker results in an unnecessary pulsating torque because of the fluctuation in the speed of electric drives.

2.2. Harmonics: The existence of harmonics, results due to the operation of power electronic converters. The harmonic voltage and current should be limited to the prescribed level The calculation of total harmonic distortion (THD) describes the harmonic distortion levels that measure the complete harmonic spectrum of every individual harmonic component with magnitudes and phase angles. THD is described as the square-root of sum of squares of each individual harmonic. The following is the Voltage THD

$$V_{THD} = \frac{\sqrt{\sum_{n=2}^{\infty} V_n^2}}{V1}$$

where $V1$ represents the rms magnitude of the fundamental component and V_n is the rms magnitude of component n, where n = 2,3,.....,∞

2.3. Location of turbine in Power System: The way of connecting the wind turbine into the power system highly influences the quality of power. Thus the operation and its influence on power system depend on the structure of the adjoining power network.

2.4.Fault ride-through capability*:* Regarding fault ride-through, the grid code stipulates that the wind turbine generator (WTG) must stay connected for a close-up 3-phase fault in the transmission system that is cleared within normal protection operating times (150 ms). Mechanical power output during and after the fault has been cleared must not be significantly reduced. The WTG must remain stable throughout, which calls for fast re-magnetization of the WTG when the grid voltage returns after the fault.

2.5. Absorption of Reactive power*:* Asynchronous generators require reactive power for magnetization. Indu*ct*ion generators, does not contribute to regulation of grid voltage, and they are absorbers of reactive power When the active power generated from induction generator is varied due to wind, absorbed reactive power and terminal voltage of an induction generator can be significantly affected.

II. RESULT OF THE POWER QUALITY PROBLEMS

The voltage variations and harmonics badly affect equipments namely microprocessor based control system, programmable logic controller; adjustable speed drives, flickering of light and screen. It may leads to tripping of contractors, tripping of protection devices, shut down of sensitive equipments like personal computer, programmable logic control system and even can damage of sensitive equipments. Hence it degrades the power quality in the grid.

IV. POWER QUALITY IMPROVEMENT

SVC LIGHT based current control voltage source inverter injects the current into the grid in such a way that the source current are harmonic free and their phase-angle with respect to source voltage has a desired value. The injected current will cancel out the reactive part and harmonic part of the load thus it improves the power quality. Hence the grid voltages are sensed and are synchronized in generating the current command for the inverter. The proposed grid connected system is implemented for power quality improvement at point of common coupling (PCC).

4.1 Wind generation system

The available power of wind energy system is presented as under in (4.1).

$$P_{wind} = \frac{1}{2}\rho A V_{wind}^3 \qquad (4.1)$$

where ρ(kg/m^3) is the air density and A (m^2) is the area swept out by turbine blade, V_{wind} is the wind speed in m/s. It is not possible to extract all kinetic energy of wind, thus it extract a fraction of power in wind, called power coefficient *Cp* of the wind turbine, and is given in (4.2).

$$P_{mech} = C_p P_{wind} \qquad (4.2)$$

where *Cp* is the power coefficient, depends on type and operating condition of wind turbine. This coefficient can be expressed as a function of tip speed ratio λ and pitch angle θ. The mechanical power produce by wind turbine is given in (4.3)

$$P_{mech} = \frac{1}{2}\rho\pi R^2 V_{wind}^3 C_p \qquad (4.3)$$

where R is the radius of the blade (m).

4.2 SVC LIGHT

SVC Light is a STATCOM type of device, based on VSC (Voltage Source Converter) technology and equipped with IGBTs (Insulated Gate Bipolar Transistor) as semiconductors.

4.3 Voltage source converter

The function of a VSC is a fully controllable voltage source matching the system voltage in phase and frequency, and with amplitude which can be continuously and rapidly controlled, so as to be used as the tool for reactive power control . In the system, the VSC is connected to the system bus via a small reactor. With the VSC voltage and the bus voltage denoted U2 and U1 respectively, it can be shown that the output of the VSC can be expressed as follows

$$P = \frac{U_1 U_2 \sin\alpha}{x}$$

$$Q = \frac{U_1 U_2 \cos\alpha}{x} - \frac{U_1^2}{x}$$

Where:

P:Active power of the VSC

Q:Reactive power of the VSC

U1: Bus voltage
U2: VSC voltage
α: Phase difference between the voltages
X: Reactance of the coupling reactor.

It can be seen that by choosing zero phase shift between the bus voltage and the VSC voltage (α =0), the VSC will act as a purely reactive element. (In reality, a small phase shift is allowed, in order to make up for the VSC losses.) It is further seen that if U2 › U1, the VSC will act as a generator of reactive power, i.e. it will have a capacitive character. If U2 ‹ U1, the VSC will act as an absorber of reactive power, i.e.it will have an inductive character.

4.4 Converter valve: One side of the VSC is connected to a capacitor bank, which acts as a DC voltage source. The converter produces a variable AC voltage at its output by connecting the positive pole, the neutral, or the negative pole of the capacitor bank directly to any of the converter outputs By use of Pulse Width Modulation (PWM), an AC voltage of nearly sinusoidal shape can be produced without any considerable need for harmonic filtering.

V. CONTROL SCHEME

5.1 Generation of reference current: In three-phase balance system, the RMS voltage source amplitude is calculated at the sampling frequency from the source phase voltage (Vsa,Vsb,vsc) and is expressed, as sample template *Vsm*, sampled peak voltage, as in (9)

$$Vs_{max} = \{(2/3)\,(V^2_{sa}+V^2_{sb}+V^2_{sc})\}^{1/2} \qquad (9)$$

The in-phase unit vectors are obtained from AC source—phase voltage and the RMS value of unit vector as shown in (10).

$$u_{sa} = V_{sa}/Vs_{max},\ u_{sb} = V_{sb}/Vs_{max},\ u_{sc} = V_{sc}/Vs_{max} \qquad \textbf{(10)}$$

The in-phase generated reference currents are derived using in-phase unit voltage template as, in (11)

$$i^*_{sa} = I.\, u_{sa}\ ,\ i^*_{sb} = I.\, u_{sb},\ i^*sc = I.\, u_{sc} \quad (11)$$

where **I** is proportional to magnitude of filtered source voltage for respective phases. This ensures that the source current is controlled to be sinusoidal. The unit vectors implement the important function in the grid connection for the synchronization for SVC LIGHT.

5.2. Current Controller

Bang-Bang current controller is implemented in the current control scheme. The reference current is generated and actual current are detected by current sensors and are subtracted for obtaining a current error for a hysteresis based bang-bang controller. Thus the ON/OFF switching signals for IGBT of STATCOM are derived from hysteresis controller

V1. OPERATION OF THE SYSTEM

The shunt connected STATCOM with battery energy storage is connected with the interface of the induction generator and non-linear load at the PCC in the grid system. The STATCOM compensator output is varied according to the controlled strategy, so as to maintain the power quality norms in the grid system.

VII Simulation Results Of SVC Light

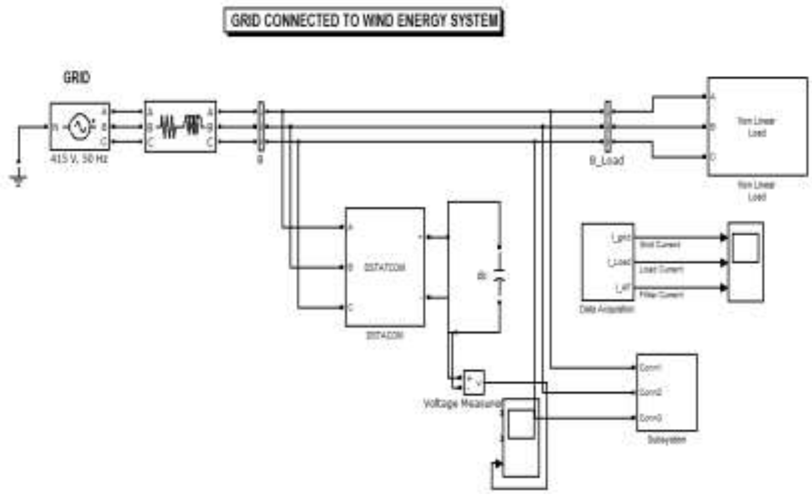

Fig 7 A Simulink model of SVC Light

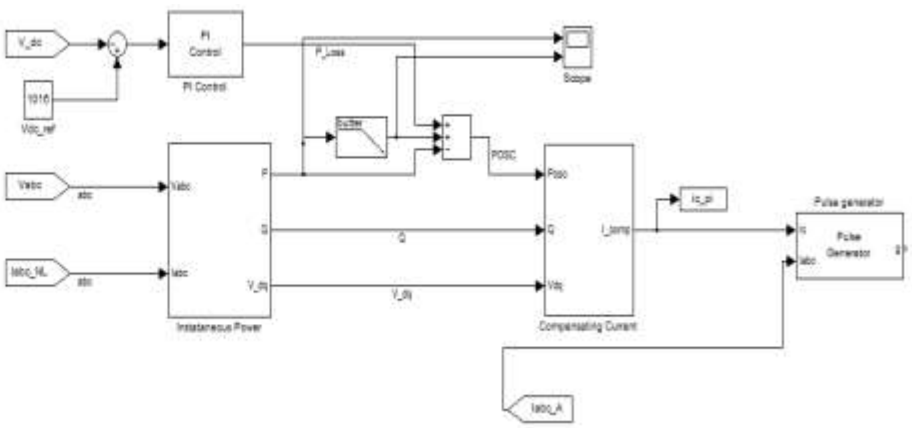

Fig 7. B Simulink model of control scheme for SVC Light

In this section the simulation results of SVC Light are shown. The developed model of a SVC Light and its control scheme in MATLAB/SIMULINK environment are shown in Fig. 7A and Fig. 7B respectively. Due to the non-linear load connected to the system, harmonics are produced in load current waveform as shown in Fig. 7.2. At 0.2 sec, SVC Light is put in operation for compensating current harmonics. As soon as the SVC Light is turned ON, the feedback PI controller acts immediately forcing the DC link voltage to settle down at reference value, here 1016V. At the same time, the SVC Light also starts compensating the current harmonics generated by non-linear load. The SVC Light injects a current Fig.7.4 in such a way that the source current becomes sinusoidal. The improved source current profile can be noticed from Fig. 7.3.The Fig. 7.1 and Fig. 7.2 show that the load voltage and current remain unaffected throughout the operation.

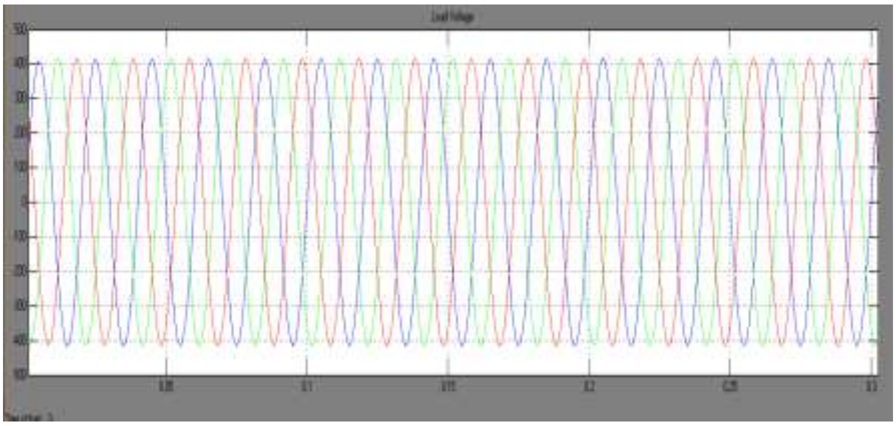

Fig 7.1 Three phase load voltage

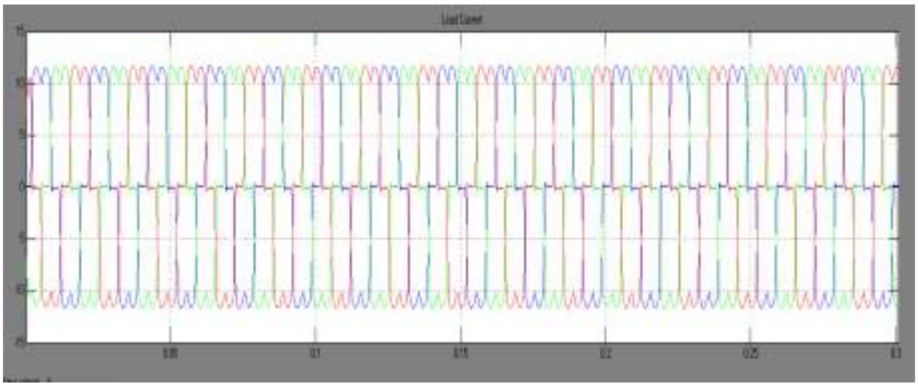

Fig. 7.2: Load current

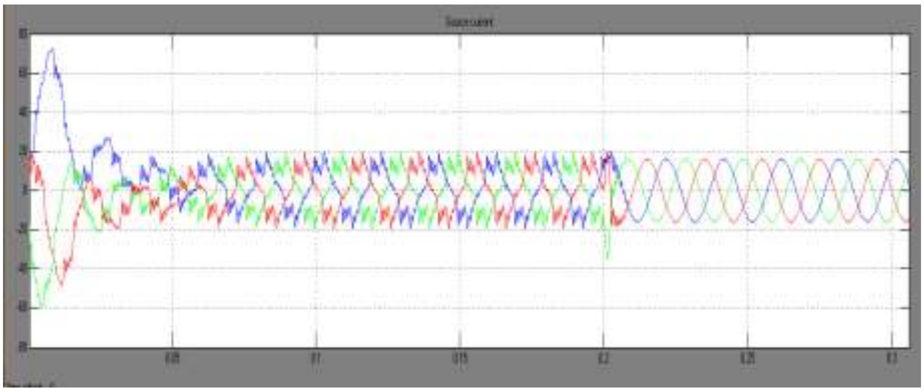

Fig. 7.3: Source current before and after compensation

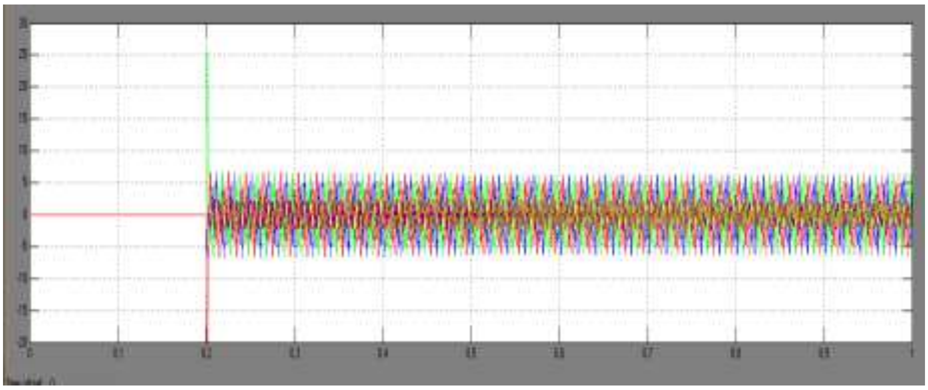

Fig. 7.4: Compensation current

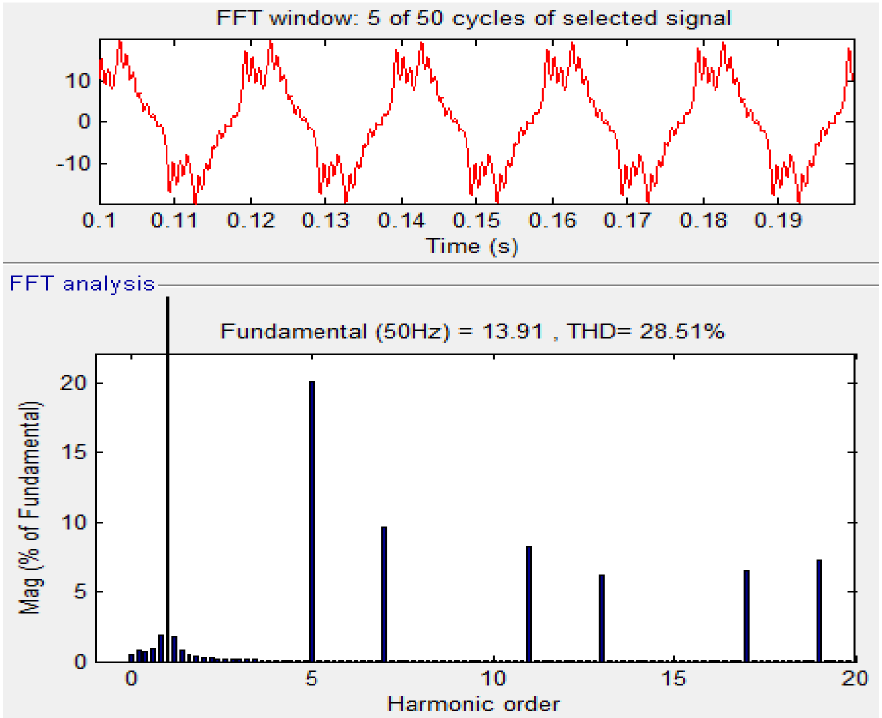

Fig. 7.5: Source current THD before compensation

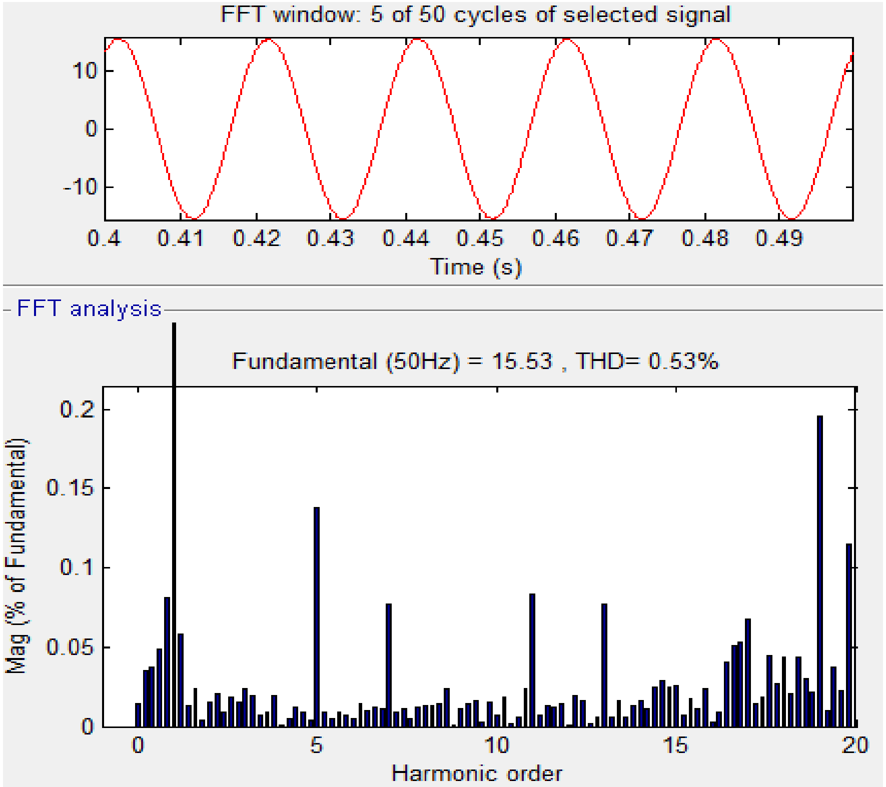

Fig. 7.6: Source current THD (with SVC Light)

The harmonic spectrums of source current before and after compensation are shown in Fig. 7.5 and 7.6 respectively. The source current before compensation has Total harmonic distortion (THD) of 28.51%.With shunt inverter in operation there is a considerable reduction in THD at source side current, from 28.51% to 0.53%. where SVC light is connected Shunt inverter is able to prevent the penetration of current harmonics from the load side to the source side.

III. CONCLUSION

In this paper, SVC LIGHT based control scheme for improvement of power quality in grid connected wind generating system and with nonlinear load is discussed. The power quality problems and its results on the consumer and electric utility are presented. The operation of the control system is developed for the SVC LIGHT in MATLAB/SIMULINK for maintaining the power quality. It has a capability to cancel out the harmonics of the load current. It maintains the source voltage and current in-phase and support the reactive power demand for the wind generator and load at PCC in the grid system .Thus the scheme here in the grid connected system fulfills the power quality.

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