Power Quality Improvement For Grid Connected Wind Energy System Using Svc Light

B.v.v. l kala bharathi
EEE student
SVECW, Bhimavaram, India

S.Dileep kumar varma
Department of Electrical & Electronics
SVECW, Bhimavaram, India

Abstract

The generated power from renewable energy source is always fluctuating due to environmental conditions. Integrating these renewable sources to grids to any considerable degree can expose the system to issues that need attention lest the functionality of the grid be impaired. In the same way wind power injection in to an electric grid affects the power quality due to the fluctuation nature of the wind.

This project shows the existence of the power quality problems due to the installation of wind turbine with grid. In order to mitigate these power quality problems, this project proposes a scheme based on FACTS device called SVC light which is connected at a PCC. The proposed model is compared with the model that do not use any compensating device .Performance of the system with BESS under load variations and Fault ride through capability of the svc light is also analysed.This control scheme for the grid connected wind energy generation system to improve power quality is simulated using MATLAB or SIMULINK in power system block set.

Keywords—Power Quality, Wind Generating System (WGS), Svc light, Statcom, Fault ride through capability, Battery energy storage system (BESS)

1.Introduction

The dominating kind of wind power generation is asynchronous, this since it is robust and cost effective. Induction generators, however, do not contribute to regulation of grid voltage, and they are substantial absorbers of reactive power.

. In the fixed-speed wind turbine operation, all the fluctuations in the wind speed are transmitted as fluctuations in the mechanical torque, electrical power on the grid and leads to large voltage fluctuations. The power quality issues can be viewed with respect to the wind generation, transmission and distribution network, such as voltage sag, swells, flickers, harmonics etc. However the wind generator introduces disturbances into the distribution network... However, induction generators require reactive power for magnetization. *Grid Codes* are issued by grid companies, spelling out the rules that apply for anyone who wishes to connect a wind farm to the grid. Main requirements involve:

- Reactive power supply
- Fault ride-through capability
- Voltage control
- Power quality control (flicker, harmonics)
- Frequency control,

some or all of which may require FACTS at the PCC to satisfy the demands [ref 2]

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.

2. Power quality issues and its Consequences

A. Power quality issues

1) **Voltage Variations**: The voltage variation issue results from the wind velocity and generator torque. 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. Thus the power fluctuation from wind turbine occurs during continuous operation. The amplitude of voltage fluctuation depends on grid strength, network impedance, and phase-angle and power factor of the wind turbines. It is defined as a fluctuation of voltage in a frequency 10–35 Hz. The IEC 61400-4-15 specifies a flicker meter that can be used to measure flicker directly.[ref 1]

2. **Harmonics**: The harmonic results due to the operation of power electronic converters. The harmonic voltage and current should be limited to the acceptable level at the point of wind turbine connection to the network. 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 rapid switching gives large reduction in lower order harmonic current compared to the line commutated converter, but the output current will have high frequency current and can be easily filter-out.

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

4. **Fault ride-through capability***:* Regarding fault ride-through, the e.on 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.

5. Absorption of Reactive power*:* Induction generators require reactive power for magnetization. Induction generators, however, do not contribute to regulation of grid voltage, and they are substantial absorbers of reactive power When the generated active power of an induction generator is varied due to wind, absorbed reactive power and terminal voltage of an induction generator can be significantly affected.

B. Consequences of the Issues

The voltage variation, flicker, harmonics causes the malfunction of equipment's 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, stoppage of sensitive equipment's like personal computer, programmable logic control system and may stop the process and even can damage of sensitive equipment's. Thus it degrades the power quality in the grid.

3. Topology for 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 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 command for the inverter. The proposed grid connected system is implemented for power quality improvement at point of common coupling (PCC), as shown in Fig. 2. The grid connected system in Fig. 2, The consists of wind energy generation system.[ref 5]

A. Wind generation system

In this configuration, wind generations are based on constant speed topologies with pitch control turbine. 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.

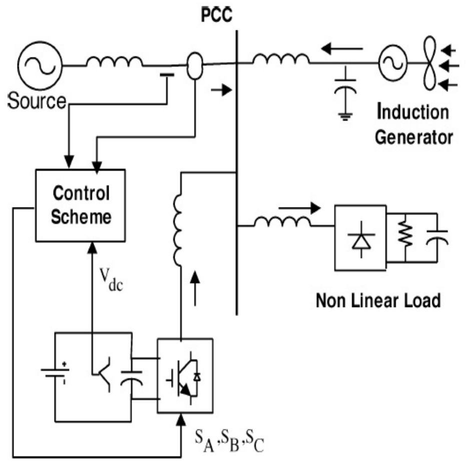


Fig.1.Grid connected system for power quality [ref1]

The available power of wind energy System is presented as under in Eq 1.

$$p_{wind}=(1/2)\rho A v^3_{wind} \quad (1)$$

Where ρ (kg/m) is the air density and A (m) is the area swept out by turbine blade, V_{wind} is the wind speed in mtr/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 Eq2.

$$P_{mech}=c_p.p_{wind} \quad (2)$$

Where *Cp* is the power coefficient, depends on type and operating condition of wind turbine. This coefficient can be express as a function of tip speed ratio α and pitch angle β . The mechanical power produces by wind turbine is given in Eq.3

$$P_{mech}= (1/2)\rho\Pi R^2 v^3_{wind}\, c_p \quad (3)$$

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

B. 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.

It is worth pointing out that the SVC Light is capable of yielding a high reactive input to the grid more or less unimpeded by possible low grid voltages, and with a high dynamic response. This is highly useful to improve the fault ride-through capability of a wind farm, where otherwise the returning voltage upon fault clearing would be depressed.

.

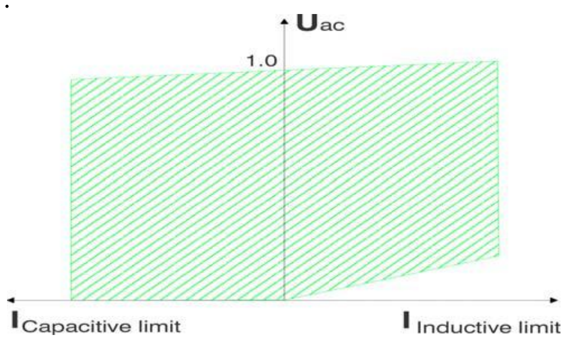


Fig.2 SVC Light voltage/current characteristics [ref 2]

1). *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 (Fig4.]. In the system, the VSC is connected to the system bus via a small reactor. With the VSC voltage and the bus voltage denoted U_2 and U_1 respectively, it can be shown that the output of the VSC can be expressed as follows:

$$P = \frac{U_1U_2 \sin\alpha}{X}$$

$$Q = \frac{U_1U_2 \cos\alpha}{X} - \frac{U_1^2}{X}$$

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.

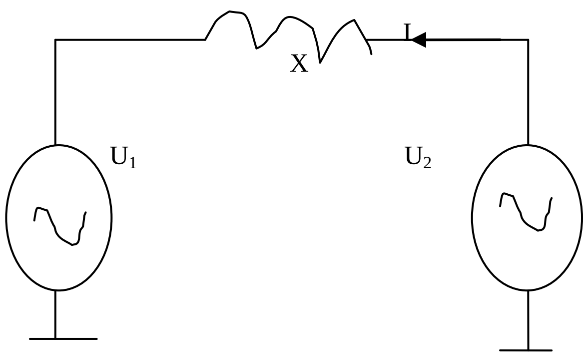
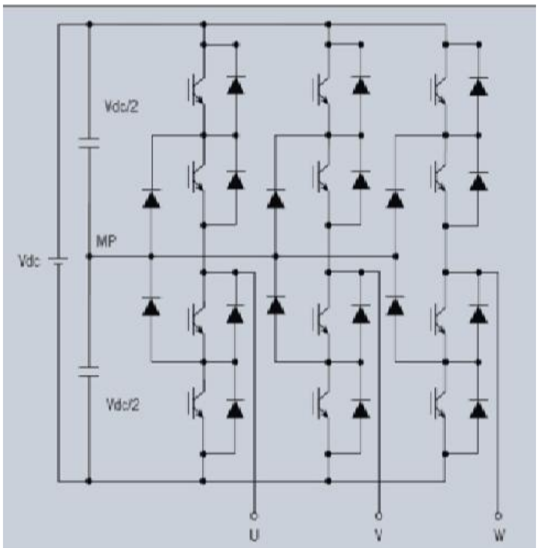


Fig 3 .VSC: a controllable voltage source

From (4) and (5) 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.

2. Converter valve: A VSC of three-level configuration is built up as in fig. 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.



[Ref 3]

Fig. 4 3-level VSC configuration

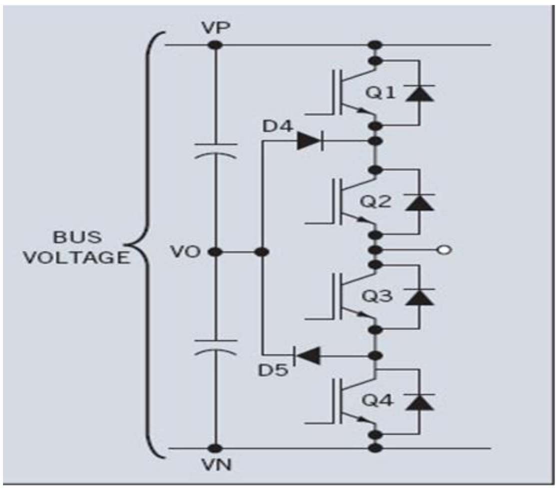


Fig. 5 single leg of VSC
[ref 3]

IGBT	Vout = Vp	Vout = V0	Vout = Vn
Q1	On	Off	Off
Q2	On	On	Off
Q3	Off	On	On
Q4	Off	Off	On

[Ref 4]

3.Valve assembly*:* For SVC Light the IGBT has been chosen as the most appropriate power device. IGBT allows connecting in series, thanks to low delay times for turn-on and turn-off. It has low switching losses and can thus be used at high switching frequencies. Nowadays, devices are available with both high power handling capability and high reliability, making them suitable for high power converters. Thus, by series connecting IGBTs, VSC ratings of more than 100 MVA are achieved without any need for paralleling devices. In the converter, there are four IGBT valves and two diode\valves in each phase leg. The valves are built up by stacked devices with interposing coolers and an external pressure applied to each stack (Fig. 5).

4. 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.

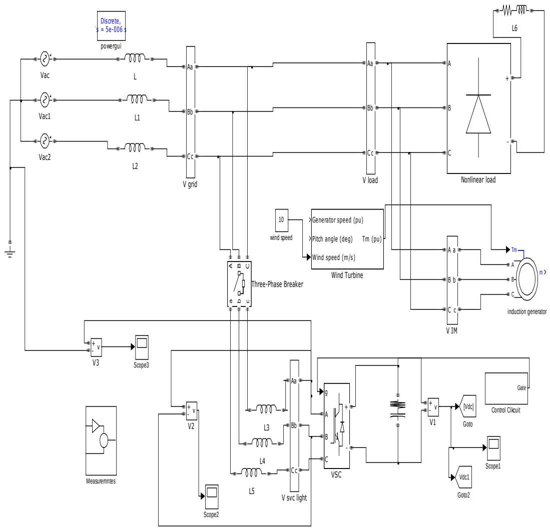


Fig 6. simulink diagram of proposed scheme

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

Table .1

S.N	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	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

5. Control scheme

The control algorithm needs the measurements of several variables such as three-phase source current i_{sabc}, DC voltage v_{dc}, inverter current i_{iabc} with the help of sensor. The current control block, receives an input of reference current i^*_{Sabc} and actual current i_{Sabc} are subtracted so as to activate the operation of STATCOM in current control mode.

A 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).

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

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

$$u_{sa} = V_{sa}/Vs_{max}, u_{sb} = V_{sb}/Vs_{max}, u_{sc}=V_{sc}/Vs_{max}$$

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

B. Current Controller

Bang-Bang current controller is implemented in the current control scheme. The reference current is generated as in (10) 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 [19].The switching function for phase 'a' is expressed as (12).

$$Isa<(isa^*-HB)\text{->}S_A=0$$
$$Isa>(isa^*-HB)\text{->}S_A=1 \quad (12)$$

where HB is a hysteresis current-band.

6. Performance of the system

Performance of the system is measured by switching the SVC LIGHT at time t=1.2sec.then the three phase injected current into the grid from STATCOM will cancel out the distortion caused by the nonlinear load and wind generator. The IGBT based three-phase inverter is connected to grid through the transformer. The generation of switching signals from reference current is simulated within hysteresis band of 0.08.

A. Power quality improvement

1.Unity power factor: The source current with and without STATCOM operation is shown in Fig. 9. This shows that the unity power factor is maintained for the source power when the STATCOM is in operation.

*2.***Reactive power support:** Reactive power is generated by the SVC LIGHT and reduces the burden at the Grid side. Generation of reactive power before and after the svc light is oN.

3.Reduction of Harmonic distortion:
The fig 10. Shows how THD is improved and is with in the considerable limits

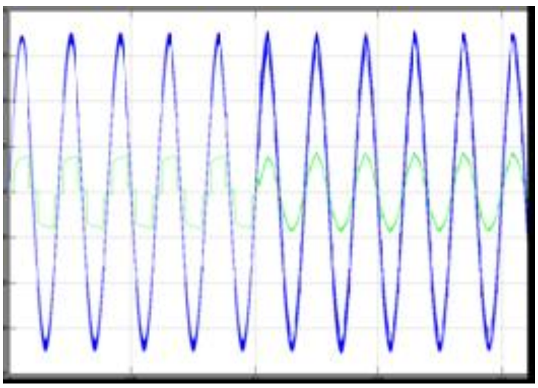


Fig 9 supply voltage and current at PCC

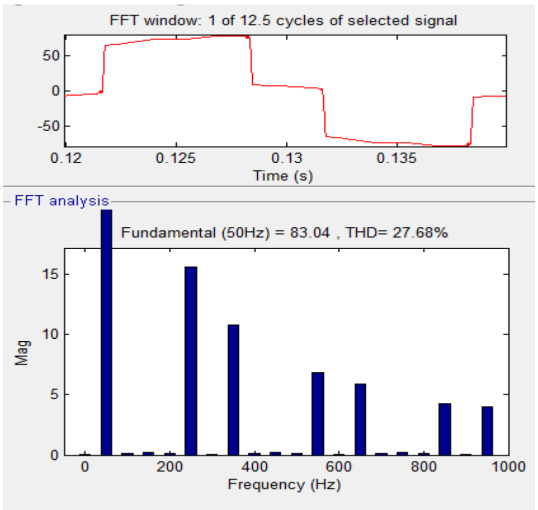


Fig 10.FFT of source current without SVC LIGHT

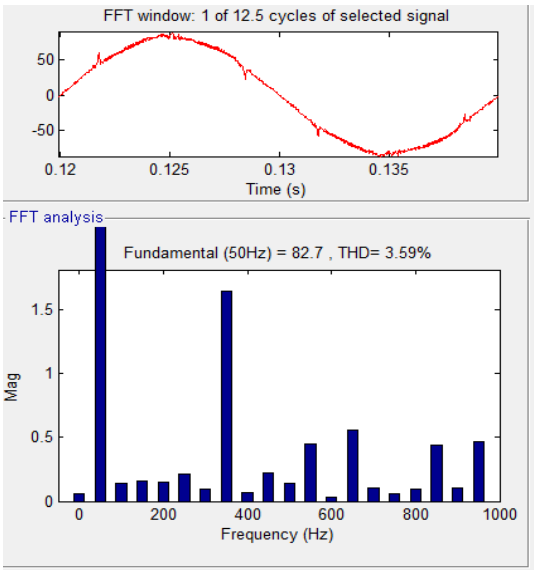


Fig 11.FFT of source current with SVC LIGHT

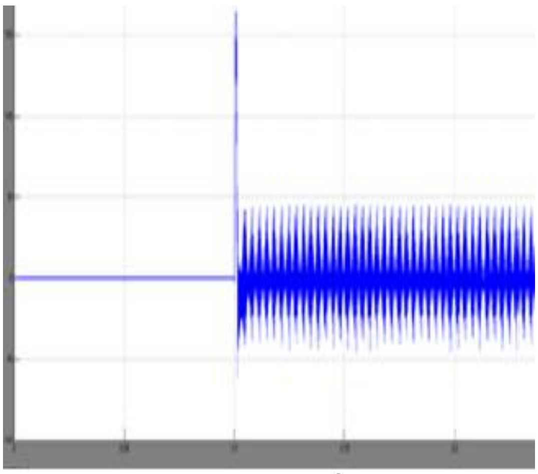


Fig 12 .Current through capacitor

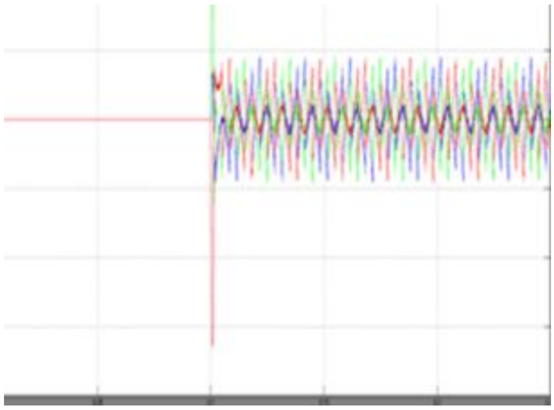


Fig.13 Three phase injected inverter current

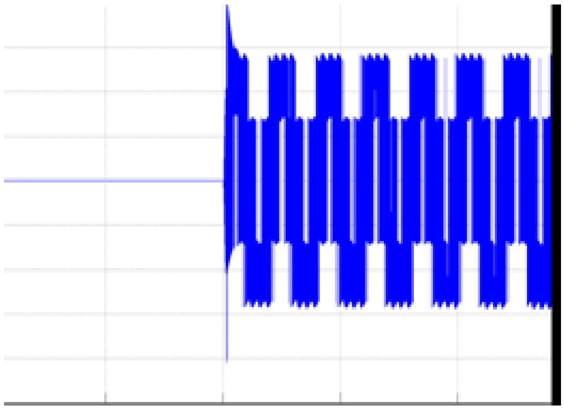


Fig 14. Svc light output voltage

Fig 15. DC link voltage

*B.*Performance of the system with BESS under load variations:

The response of the SVC LIGHT to a step change command for increase in additional load at time t=1.4sec is shown in fig 16.

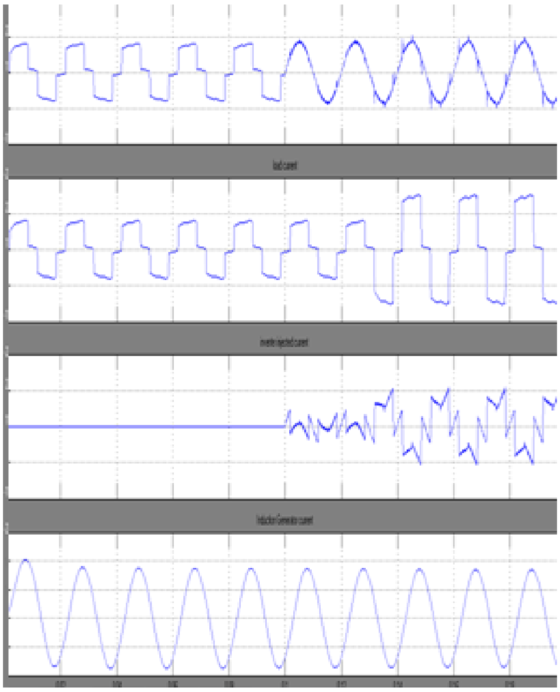


Fig 11.(a) source current. (b) Load current. (c) Inverter current. (d) Induction generator current.

C) **Fault ride through capability of SVC LIGHT**

Svc light fastly injects reactive power **upon** Fault clearing and hence grid voltage returns to its normal value upon fault clearing. Here fault occurs at time t=0.08sec.this fault is cleared by SVC LIGHT when it comes to on condition.

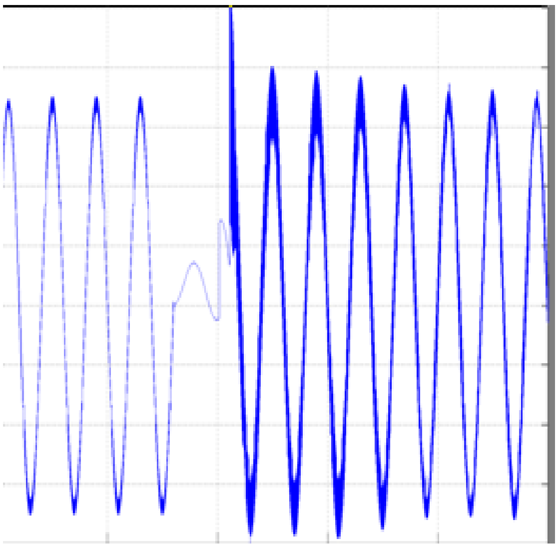


Fig 12 shows how the voltage at PCC is returned to its normal value when svc light is ON at timee t=1.4sec.

7. Conclusion

In this paper we present the FACTS device (SVC LIGHT) -based control scheme for power quality improvement in grid connected wind generating system and with nonlinear 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 SVC LIGHT in MATLAB/SIMULINK for maintaining the power quality is to be simulated. It has a capability to cancel out the harmonic parts 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 using BESS and it has Fault ride through capability thus it gives an opportunity to enhance the utilization factor of transmission line. Thus the proposed scheme in the grid connected system fulfills the power quality.

REFERENCES

[1]. "A STATCOM-Control Scheme for Grid Connected Wind Energy System for Power Quality Improvement" Sharad W. Mohod, *Member, IEEE,* and Mohan V.

[2]. "FACTS for Grid Integration of Wind Power"Rolf Grünbaum, *Member, IEEE*

[3]. A Study of Wind Farm Stabilization Using DFIG or STATCOM Considering Grid RequirementsK. E Okedu* *Department of Electrical/Electronic Engineering, University of Port Harcourt, Nigeria.*

[4]. Yuvraj v "Improving grid power quality with FACTS device on integration of wind energy system"IEEE Trans.on E 2011

[5]. Rolf Grunbaum"FACTS for Grid integration of Wind power"IEEE power tech 2005

[6]. Belkacem mahdad "contribution to the improvement of power quality using Multi Hybrid model based wind shunt FACTS" 2011 IEEE Trans.

[7]. K. S. Hook, Y. Liu, and S.Atcitty "Mitigation of the wind generation integration related power quality issues by energy storage,|| *EPQU J.*, vol. XII, no. 2, 2006.

[8]. "Analysis of Harmonic Distortion in Non-linear Loads" **Anne Ko** Department of Electrical Power Engineering Mandalay Technological University, Mandalay, Myanmar