International Recognized Double-Blind Peer Reviewed Research Journal
Industrial Science
ISSN 2347-5420 Impact Factor :1.5015(UIF)
Volume - 1 | Issue - 11 | June - 2015 Available online at www.lsrj.in

COMPARISON OF TWO CONTROL TECHNIQUES OF STATCOM FOR POWER QUALITY IMPROVEMENT OF GRID CONNECTED WIND ENERGY SYSTEM

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ABSTRACT:
With the increase in demand for Electricity due to increase in population and industrialization, the generation of power is really a challenge now a days. It is necessary to meet the energy needs by utilizing the renewable energy resources like wind, biomass, hydro co-generation, etc. Injection of the wind power into an electric grid affects the power quality. The main power quality issues are voltage sag, swell, flickers, harmonics etc. In this proposed scheme STATic COMpensator (STATCOM) is connected at the point of common coupling with a battery energy storage system (BESS) to mitigate the power quality issues. The battery energy storage is integrated to sustain the real power source under fluctuating wind power. Here two control schemes for STATCOM are compared: Bang-Bang current controller and Fuzzy logic controller. Bang-Bang controller is a hysteresis current controlled technique. The operation of the two STATCOM control schemes for maintaining the power quality of the grid connected wind energy system is investigated using MATLAB/SIMULINK.

KEYWORDS
STATCOM, power quality, wind generating system and BESS,Bang-Bang current controller,fuzzy logic controller.

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INTRODUCTION:

Both electric utilities and end users of electric power are increasingly concerned about the quality of power. Power quality can be defined as "any power problem manifested in voltage, current and frequency those results in failure or maloperation of the customer equipment". Injection of the wind power into an electric grid affects the power quality.

The group of devices used for mitigation of power quality problems is known by the name of Custom Power Devices (CPDs). The family of compensating devices mainly has the following members: Static Synchronous Compensator (STATCOM), Dynamic Voltage Restorer (DVR) and Unified Power Quality Conditioner (UPQC). The work analyses the performance of static compensator (STATCOM) with a battery energy storage system (BESS) connected at the point of common coupling of wind energy generating system and the existing power system to mitigate the power quality issues.

During the normal operation, wind turbine produces a continuous variable output power. The main power quality issues are voltage sag, swell, flickers, harmonics etc [3].compensator),one of the simple methods of running a wind generating system is to use the induction generator connected directly to the grid. The induction generator has inherent advantages of cost effectiveness and robustness. However, induction generators require reactive power for magnetization. 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. Here proposing a STATCOM based control technology for mitigating the power quality issues when we are integrating wind farms to the grid. In the event of increasing grid disturbance, a battery energy storage system is required to compensate the fluctuation generated by wind turbine. Here two control schemes for STATCOM is designed and compared: Bang- Bang current controller and fuzzy logic controller.

II.TOPOLOGY FOR POWER QUALITY IMPROVEMENT

The STATCOM is a three- phase voltage source inverter having the capacitance on its DC link and connected at the point of common coupling. The STATCOM injects a compensating current of variable magnitude and frequency component at the bus of common coupling [1]. Here the utility source, wind energy system and STATCOM with BESS is connected to the grid. The current controlled voltage source inverter based STATCOM injects the current into the grid in such a way that the source current (grid current) are harmonic free and they are in phase-angle with respect to source voltage. The injected current will cancel out the reactive part and harmonic part of the induction generator current and load current, thus it improves the power quality [4]. This injected current generation is by proper closing and opening of the switches of voltage source inverter of STATCOM and is different for the two control schemes proposed. For this the grid voltages are sensed and are synchronized in generating the current command for the inverter.

A. Wind Energy Generating System

In this configuration, wind energy generation is based on constant speed topologies with pitch control turbine.

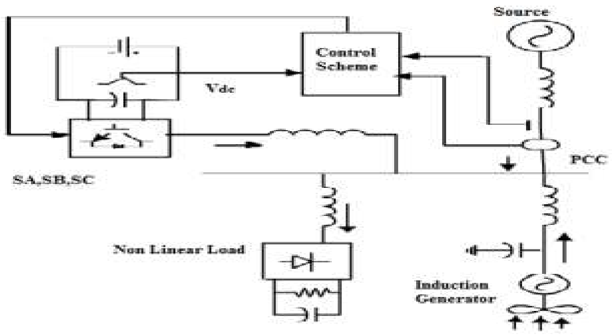


Fig.1. System operational scheme in grid system.

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. The available power of wind energy system is presented as:

Pwind = ½ ? AVwind ³ (1)

Where ? = air density (kg/m3), A = area swept out by Turbine blade (m), Vwind = wind speed (m/s).

It is not possible to extract all kinetic energy of wind. Thusextracts a fraction of the power called power coefficient 'Cp' of the wind turbine, and is given by:-

Pmech = Cp Pwind (2)

The mechanical power produced by wind turbine is givenby:-

Pmech = ½?? R²Vwind3 Cp

Where, R = Radius of the blade (m).

B. BESS-STATCOM

The battery energy storage system (BESS) is used as an energy storage element for the purpose of voltageregulation [1].

The BESS will naturally maintain dc capacitor voltage Constant and is best suited in STATCOM since it rapidly injects or absorbs reactive power to stabilize the grid system. When power fluctuation occurs in the system, the BESS is used to level the power fluctuation by charging and discharging operation. The battery is connected in parallel to the dc capacitor of STATCOM.

C. System Operation

The shunt connected STATCOM with battery energy storage is connected at the interface of the induction generator and non-linear load at the PCC [4]. The Fig.1 represents system operational scheme in grid system. The STATCOM output is varied according to the control strategy, so as to maintain the power quality norms in the grid system. The current control strategies for STATCOM are the Bang-Bang controller and fuzzy logic controller. A single STATCOM using insulated gate bipolar transistors is proposed to have a reactive power support to the induction generator and to the nonlinear load in the grid system.

D. Control Scheme

The first control scheme approach is based on injecting the currents into the grid using "bang-bang controller" [1].The controller uses a hysteresis current controlled technique as shown in Fig 2. Using such a technique, the controller keeps the control system variable between the boundaries of hysteresis area and gives correct switching signals for STATCOM operation. The current controller block receives reference current and actual current as inputs and are subtracted so as to activate the operation of STATCOM in current control mode [5].

The second control scheme is fuzzy logic controller.

The inputs to the controller 'change in grid voltage (?V)' and 'change in grid current (?I)' and is represented as membership functions of the controller .The output is correct switching signals for IGBTs of STATCOM (?U).

E. Grid Synchronisation:

In the three-phase balance system, the RMS source
Voltage amplitude is calculated from the source phase
Voltages (Vsa, Vsb, Vsc) and is expressed as sample template (sampled peak voltage),V sm :

$$V_{sm} = \sqrt{\{(2/3)(V_{sa}^2+V_{sb}^2+V_{sc}^2)\}} \qquad (4)$$

The in-phase unit vectors are obtained from source voltage in each phases and the RMS value of unit vector is shown below.

$$U_{sa} = V_{sa}/V_{sm}$$
$$U_{sb} = V_{sb}/V_{sm} \qquad (5)$$
$$U_{sc} = V_{sc}/V_{sm}$$

The in-phase reference currents generated are derived using in-phase unit voltage template as shown below.

$$i_{sa}^* = I^* U_{sa},\ i_{sb}^* = I^* U_{sb},\ i_{sc}^* = I^* U_{sc} \qquad (6)$$

Where 'I' is proportional to magnitude of filtered source voltage for respective phases. This ensures that the source current is controlled to be sinusoidal [6].

F. Bang-Bang Current Controller

It is implemented in the current control scheme. The reference current is generated as in equation (6) 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 IGBTs of STATCOM are derived from hysteresis controller [1] .The switching function SA for phase 'a' is expressed as:

$$(i_{sa} - i_{sa}^*) < HB = S_A = 1 \qquad (7)$$

$$(i_{sa} - i_{sa}^*) > HB = S_A = 0$$

Compared to this is same for phases 'b' and 'c'.

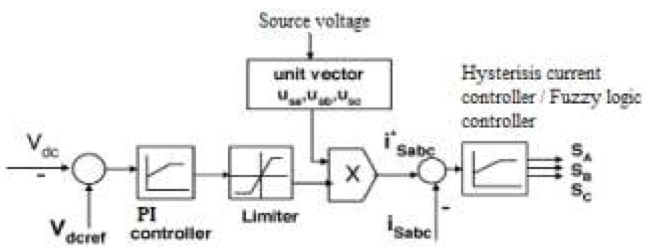


Fig.2. Control Scheme

G. Fuzzy Logic Controller:

In a fuzzy logic controller, the control action is determined from the evaluation of a set of simple linguistic rules. The development of the rules requires a thorough understanding of the process to be controlled, but it does not require a mathematical model of the system. The objectives include excellent rejection of input supply variations both in utility and in wind generating system and load transients. Expert knowledge can also be participated with ease that is significant when the rules developed are intuitively inappropriate [7]. The rule base developed is reliable since it is complete and generated sophistically without using extrapolation.

In this paper, fuzzy control is used to control the Firing angle for the switches of the VSI of STATCOM. In this design, the fuzzy logic based STATCOM has two inputs 'change in voltage(ΔV)' and 'change in current(?I)' and one control output(?U).

Firstly the input values will be converting to fuzzy variables. This is called fuzzification. After this, fuzzy inputs enter to rule base or interface engine and the outputs are sent to defuzzification to calculate the final outputs. These processes are demonstrated in Fig. 3. Here seven fuzzy subsets have been used for two inputs. These are: PB (positive big), PM (positive medium), PS (positive small), ZE (zero), NS (negative small), NM (negative medium) and NB (negative big).

We use Gaussian membership functions [8] and 49 control rules are developed, which are shown in table 1.

Fuzzification: It is the process of representing the inputs as suitable linguistic variables .It is first block of controller and it converts each piece of input data to a degree of membership function. It matches the input data with conditions of rules and determines how well the particular input matches the conditions of each rule.

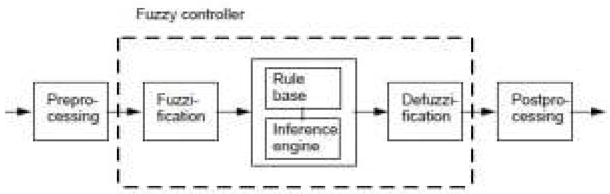


Fig.3. Fuzzy control block diagram

Table I
Control Rules

ΔI / ΔV	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NM	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

The membership functions for the inputs (for ΔV and ? I) are shown in Fig.4 and Fig.5.

The number of fuzzy levels is not fixed and it depends on the input resolution needed in an application. The larger the number of fuzzy levels, the higher is the input resolution. The fuzzy control implemented here uses sinusoidal fuzzy-set values

Decision making: The control rules that associate the fuzzy output to the fuzzy inputs are derived from general knowledge of the system behavior. However, some of the control actions in the rule table are also developed using "trial and error" and from an "intuitive" feel of the process to be controlled. In this effort, the control rules for the STATCOM in Table 1 resulted from the understanding of STATCOM's behaviour and experimental tests of its VSI's performance.

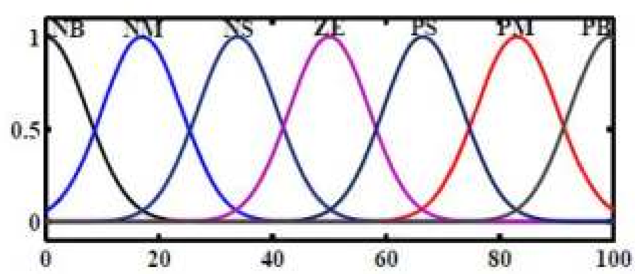


Fig.4. Membership function for ΔI

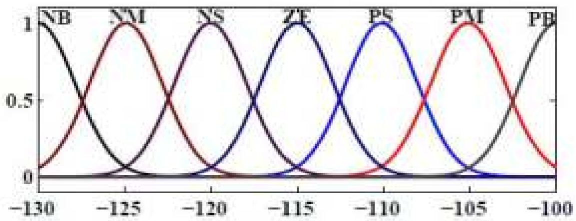


Fig.5. Membership function for ΔV

Defuzzification: It is the Process of converting fuzzified output into a crisp value. In the Defuzzification operation a logical sum of the results from each of the rules performed. This logical sum is the fuzzy representation of the change in firing angle (output). A crisp value for the change in firing angle is calculated. Correspondingly the grid current changes and improves the power quality. Fig.5. Membership function for ?V.

III.SYSTEM PERFORMANCE

The proposed control scheme is simulated using MATLAB/SIMULINK in power system block set. The simulation parameters used for the system is given Table II.

Table II
System Parameters

S.L. NO:	Parameters	Ratings
1	Grid voltage	3 phase,400 V, 50 Hz
2	Induction Motor/Generator	150 KVA,400 V, 50 Hz Speed=1440 rpm,Rs=0.016 ohms, Rr=0.015 ohms, Ls=0.06 H, Lr=0.06 H
3	Line series Inductance	0.0002 H
4	Inverter Parameters	Dc link voltage=650 V Dc link capacitance=1.1 μF Switching frequency=2 KHz
5	Load Parameter	Non linear load 25 Kw
6	Wind turbine	Base wind speed=11 m/s

eural networks and fuzzy logic has received attention. The idea is to lose the disadvantages of the two and gain the advantages of both. In case of Neural networks the model.

A.Voltage Source Inverter Operation

The three phase injected current into the grid from the 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 for Bang-Bang current controller [1]. The choice of narrow hysteresis band switching in the system improves the current quality.

The choice of the current band depends on the operating voltage and the interfacing transformer impedance. The compensated current for the nonlinear load and demanded reactive power is provided by the inverter. The real power transfer from the batteries is also supported by the controller of this inverter. The three phase inverter injected current are shown in Fig. 7.

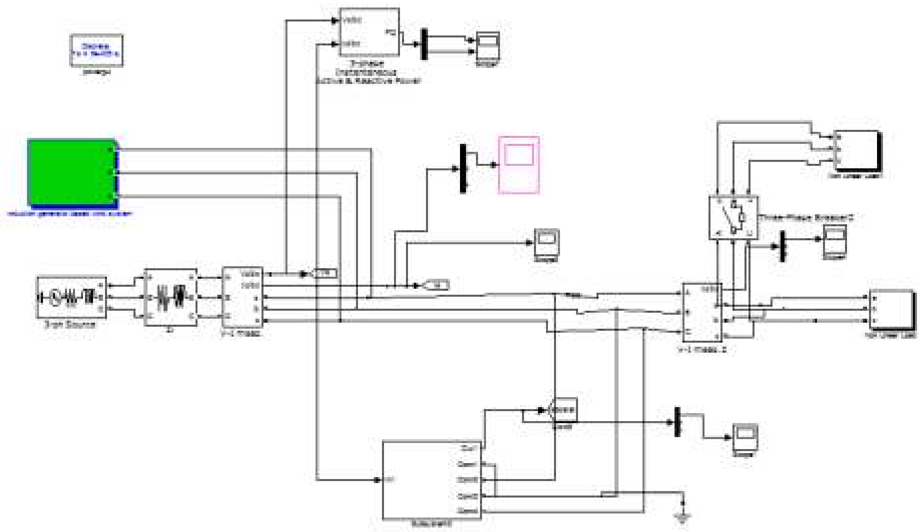


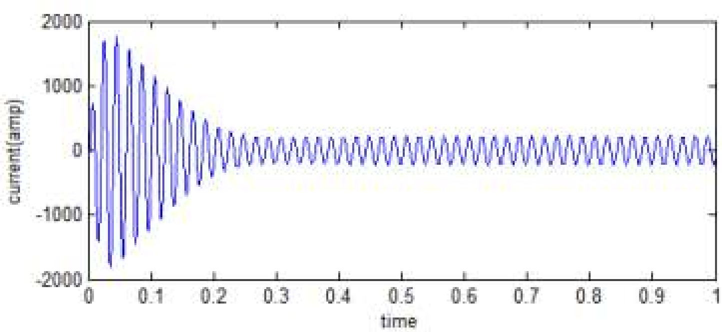
Fig.6. SIMULINK diagram of the system

B.STATCOM—Performance Under Load Variations

The wind energy generating system is connected to the grid having the nonlinear load. The bang-bang current controller and fuzzy controller for STATCOM is implemented in MATLAB/SIMULINK. The main SIMULINK diagram of the control schemes with STATCOM is shown in fig 6.

The nonlinear load used a bridge rectifier with RL load. The load parameters are varied arbitrarily to see the operation of the bang-bang current controller and fuzzy controller implemented for STATCOM.

In this controller is a two input and one output fuzzy controller. The first input is error, second input is change in error and output is constant.



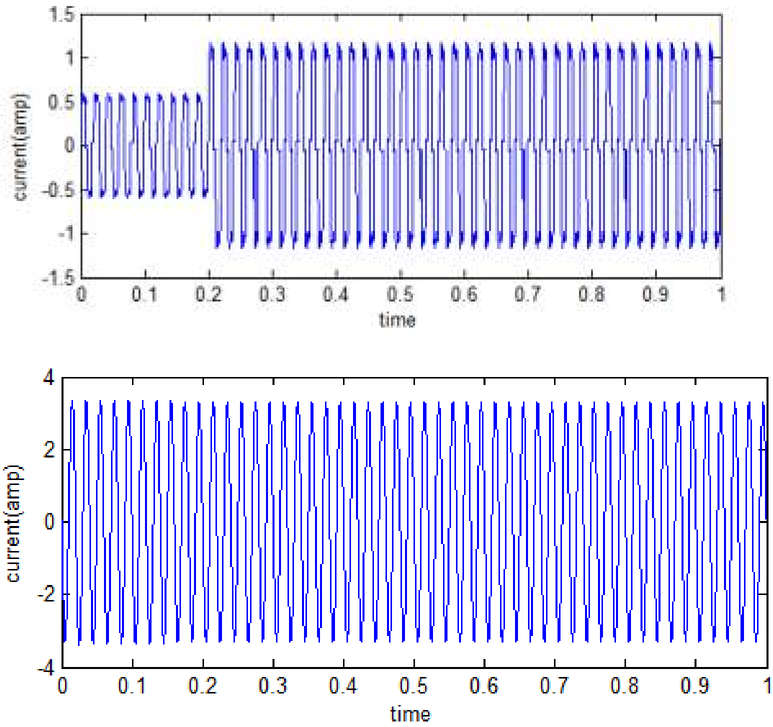


Fig.8. (a) Source Current. (b) Load Current (c) Wind generator (Induction generator) current.

The above figures are shows without statcom . Source current and load currents are shown in Fig. 8(a) and Fig.8 (b). The generated current from wind generator at PCC is shown in Fig 8 (c).

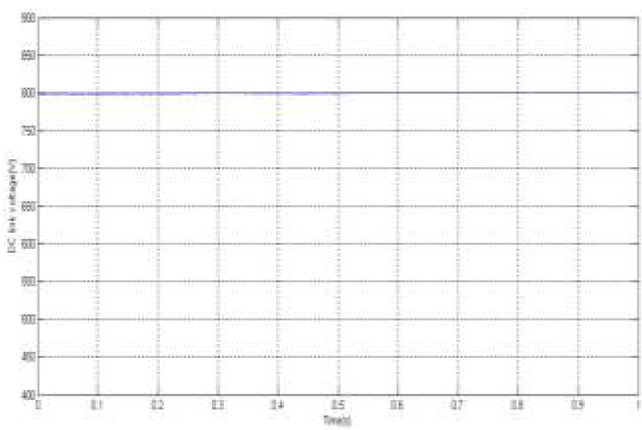


Fig.9. DC link voltage.

The performance of the system is measured by switching ON the STATCOM at time T= 0.05s and an increase in additional load is given at time T=0.2s.The load current and source currents are shown in Fig.10 (a) and Fig.10 (b) respectively. While the injected current from STATCOM is shown in Fig.10 (d) and the generated current from wind generator at PCC is shown in Fig.10 (c). When STATCOM controller is made ON, it starts to mitigate the reactive demand as well as harmonic current [1].The additional demand is fulfil by STATCOM compensator with the help of BESS. This can be easily seen in the source current (grid current).Because whatever changes occurs in the load or induction generator occurs it can't be seen in the source current and it is free from harmonics also.

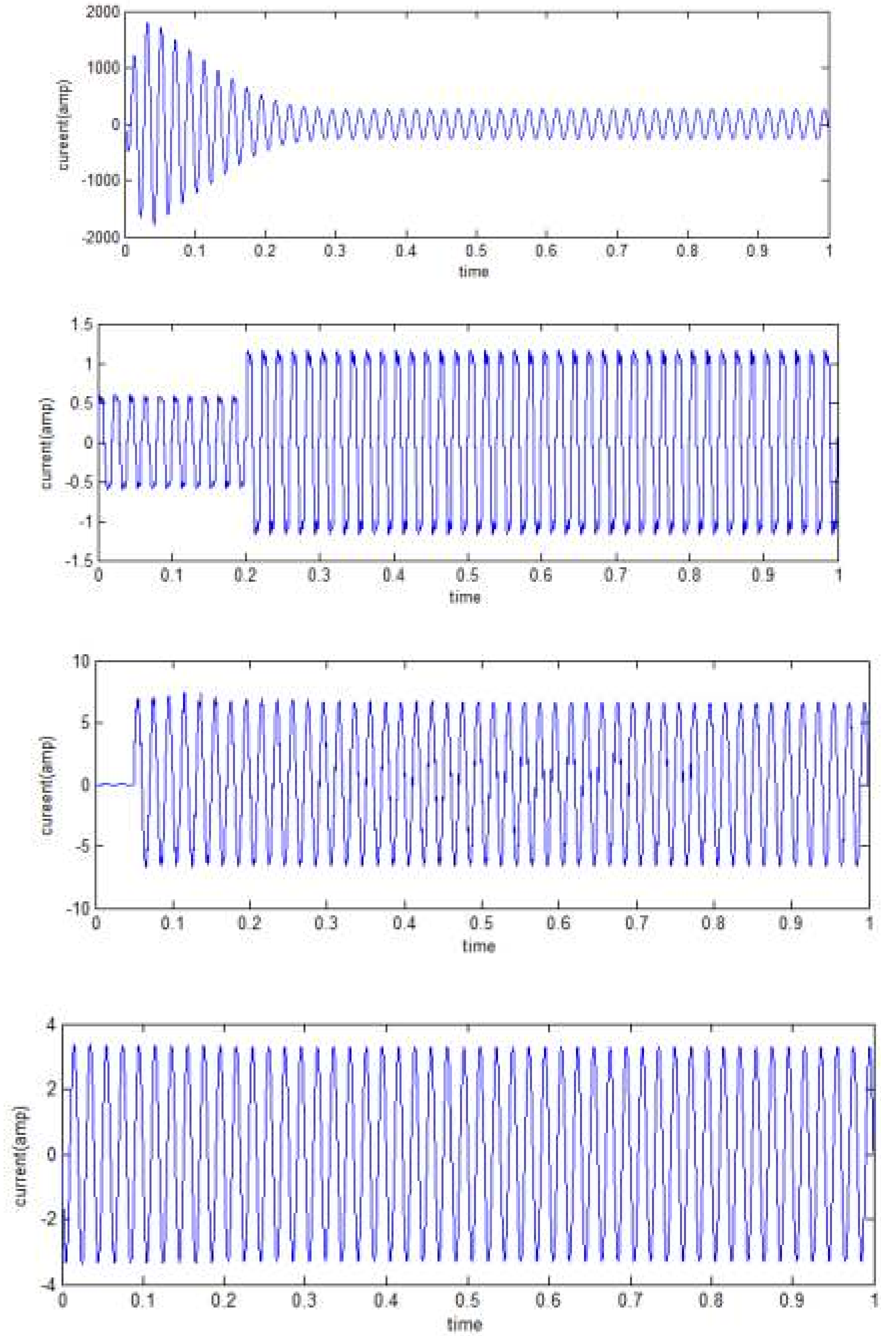
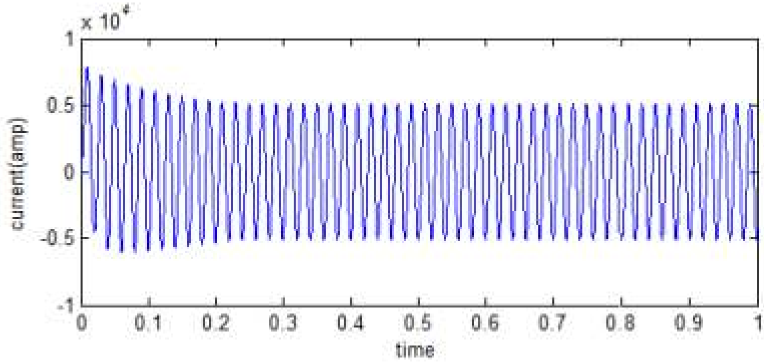


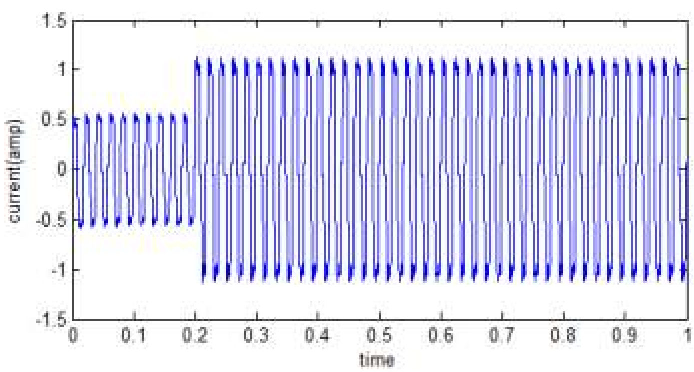
Fig.10. (a) source current (b) load current (c) Inverter current (d) Wind generator current

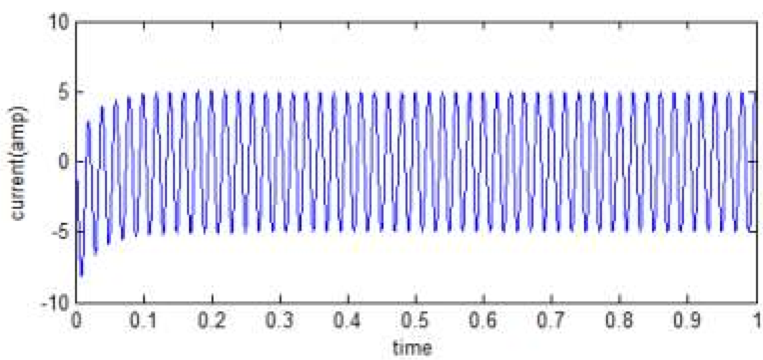
The DC link voltage regulates the source current in The grid system, so the DC link voltage is maintained constant across the capacitor [1] as in Fig.9.System is analyzed and performance of the system is evaluated. One of the easiest measurements of harmonics is the total harmonic distortion (THD) measurement through FFT analysis.

C.Implementation Using Fuzzy Controller

The model of this system is also developed in MATLAB/SIMULINK. To investigate the performance of the system a load variation is inserted at time T= 0.2 s and the STATCOM is ON from time T=0.05 s. Fig.11 shows the load current, inverter injected current, wind generator current and source current. Whatever changes occurs in the load or induction generator occurs it can't be seen in the source current and it is free from harmonics by the suitable operation of STATCOM by using fuzzy logic controller.







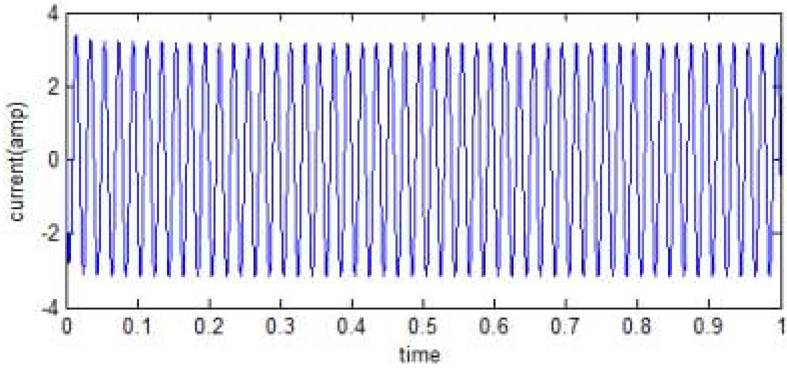


Fig 11 (a) source current(b) load current, (c)Inverter current (d) wind generator current

Comparison of Two Control Schemes for STATCOM:

Results of two control schemes are summarized in the table below. From this table we can conclude that the %THD reduces more with Fuzzy logic controller.

Table .III
Comparison of two control schemes

Parameters	% of THD (in source current)
Without STATCOM	2.07
With STATCOM (Bang-Bang controller)	1.79
With STATCOM (Fuzzy controller)	0.11

By using BANG-BANG current controller the THD in the source current reduced to 1.79% and by using Fuzzy logic controller the THD is reduced to 0.11%.

CONCLUSION

The paper presents the STATCOM-based control Scheme for power quality improvement in grid connected wind generating system with nonlinear loads. The operation of the STATCOM is simulated using two controllers: Bang-Bang current controller and Fuzzy controller .STATCOM injects current to the grid and it cancel out the reactive and harmonic parts of the induction generator current and load current .When we are reducing the wind generating system output, it will not affect the source current magnitude.

The THD analysis revealed that the fuzzy logic controller is good compared to bang-bang controller. The fuzzy logic controller is simpler and has faster response. The integrated wind generation and STATCOM with BESS have shown the outstanding performance.

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