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POWER QUALITY IMPROVEMENT IN WIND BASED GRID CONNECTED SYSTEM WITH PI & FUZZY BASED STATCOM CONTROL SCHEME

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ABSTRACT :

Renewable energy sources, which are expected to be a promising alternative energy source, can bring new challenges when connected to the power grid. Like conventional power plants, wind power plants must provide the power quality required to ensure the stability & reliability of the power system. Increasing amount of wind turbine are connected to electrical power system in order to mitigate the negative environmental consequence of conventional electricity generation. While connecting wind turbine to grid it is important to understand source of disturbance that affect the power quality. In general voltage & frequency must be kept as stable as possible. This stability can be obtained by using FACTS devices. Recently voltage-source or current-source inverter based various FACTS devices have been used for flexible power flow control, secure loading and damping of power system oscillation. The power arising out of the wind turbine when connected to a grid system concerning the power quality measurements, are: active power, reactive power, voltage sag, voltage swell, flicker, harmonics, and electrical behavior of switching operation. However, in a wider sense Fuzzy Logic is almost synonymous with the theory of Fuzzy sets, a theory which relates to classes of objects with un sharp boundaries in which membership is a matter of degree. In this paper fuzzy logic controller is used for controlling the DC capacitor voltage. Simulations using MATLAB / SIMULINK are carried out to verify the performance of the proposed controller.

Keywords- Fuzzy, Wind power, distribution network, induction generator, STATCOM, reactive power, harmonics, Power quality.

I.INTRODUCTION

The renewable energy resources like wind, hydro, biomass etc are necessary to sustainable growth and social progress. So the integration of wind energy into power system is used to minimize the environmental impact on conventional plant [7]-[4].A continuous proliferation of non-linear loads is due to the intensive use of power electronics converter-based power processing units in industries and residential applications. To have sustainable growth and social progress, it is necessary to meet the energy need by utilizing the renewable energy resources like wind, biomass, hydro, co-generation, etc. In sustainable energy system, energy conservation and the use of renewable source are the key paradigm. The need to integrate the renewable energy like wind energy into power system is to make it possible to minimize the environmental impact on conventional plant [1]. The integration of wind energy into existing power system presents technical challenges and that requires consideration of voltage regulation, stability, power quality problems. The power quality is an essential customer-focused measure and is greatly affected by the operation of a distribution and transmission network. The non-linear loads generate serious harmonic currents and reactive power to the distribution and transmission System, which results in a low power factor, leads to voltage notch and reduces the utilization of the distribution system. Traditionally, current harmonics caused by non-linear loads have been dealt with using passive filters consisting of capacitors, inductors and damping resistors. They provide simple solutions but have large size and weight; they cannot provide flexible compensation and may cause resonance problems. Nowadays, the development of power electronics and microelectronics makes it possible to consider active power filters, which can provide flexible current harmonic compensation and contribute to reactive power control and load balancing. Hence Power electronic based FACTS devices like STATCOM can be effectively utilized to improve the quality of power supplied to the customers The increasing use of power electronic based loads (adjustable Speed drives, Switch mode power supplies, etc) to improve system efficiency and Controllability is increasing concern for harmonic distortion levels in end use facilities and on overall power system. The issue of power quality is of great importance to the wind turbine [2]. There has been an extensive growth and quick development in the exploitation of wind energy in recent years. The individual units can be of large capacity up to 2 MW, feeding into distribution network, particularly with customers connected in close proximity [3]. Today, more than 28 000 wind generating turbines are successfully operating all over the world. In the fixed-speed wind turbine operation, all the fluctuation 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. One of the simple methods of running a wind generating system is to use the induction generator connected directly to the grid system. The induction generator has inherent advantages of cost effectiveness and robustness.

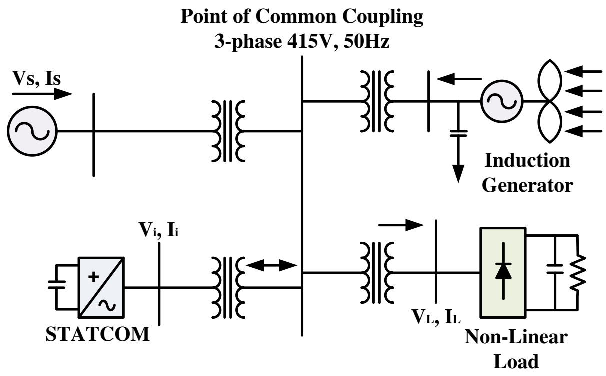

Fig.1. Grid connected system for power quality improvement.

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. 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. In the event of increasing grid disturbance, a battery energy storage system for wind energy generating system is generally required to compensate the fluctuation generated by wind turbine. A non-linear load on a power system is typically a rectifier (such as used in a power supply), or some kind of arc discharge device such as a fluorescent lamp, electric welding machine, or arc furnace. Because current in these systems is interrupted by a switching action, the current contains frequency components that are mUltiples of the power system frequency. It changes the shape of the current waveform from a sine wave to some other form and also create harmonic currents in addition to the original (fundamental frequency) AC current.The most used unit to compensate for reactive power in the power systems are either synchronous condensers or shunt capacitors, the latter either with mechanical switches or with thyristor switch, as in Static

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VAR Compensator (SVC). The disadvantage of using shunt Capacitor is that the reactive power supplied is proportional to the square of the voltage. Consequently, the reactive power supplied from the capacitors decreases rapidly when the voltage decreases [3] .To overcomes the above disadvantages; STATCOM is best suited for reactive power compensation and harmonic reduction. It is based on a controllable voltage source converter (VSC). Fuzzy logic control theory is a mathematical discipline based on vagueness and uncertainty. It allows one to use non-precise or ill-defined concepts. Fuzzy logic control is also nonlinear and adaptive in nature that gives it robust performance under parameter variation and load disturbances. Many control approaches and applications of fuzzy logic control have appeared in the literature since Mamdani published his experiences using a fuzzy logic controller on a test-bed plant in a laboratory. An extensive introduction to the historical development, current state and concepts involving fuzzy control systems can be found. The fundamental advantage of the fuzzy logic controller over the conventional controller is a less dependence of the mathematical model and system parameters as known widely.

II. STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

The STATCOM is a shunt-connected reactive-power compensation device that is capable of generating and/ or absorbing reactive power and in which the output can be varied to control the specific parameters of an electric power system. It is in general a solid-state switching converter capable of generating or absorbing independently controllable real and reactive power at its output terminals when it is fed from an energy source or energy-storage device at its input terminals. Specifically, the STATCOM, which is a voltage-source converter which when fed from a given input of dc voltage, produces a set of 3-phase ac-output voltages, each in phase with and coupled to the corresponding ac system voltage through a relatively small reactance (which is provided by either an interface reactor or the leakage inductance of a coupling transformer). The dc voltage is provided by an energy-storage capacitor.

A STATCOM based control technology has been proposed for improving the power quality which can technically manages the power level associates with the commercial wind turbines. A STATCOM can improve power-system Performance like:

1. The dynamic voltage control in transmission and distribution systems,
2. The power-oscillation damping in power-transmission systems,
3. The transient stability;
4. The voltage flicker control; and
5. The control of not only reactive power but also (if needed) active power in the connected line, requiring a dc energy source.

A STATCOM is analogous to an ideal synchronous machine, which generates a balanced set of three sinusoidal voltages at the fundamental frequency with controllable amplitude and phase angle. This ideal machine has no inertia, is practically instantaneous, does not significantly alter the existing system impedance, and can internally generate reactive (both Capacitive and inductive) power.

III. WIND DRIVEN INDUCTION GENERATOR WITH STATCOM

The STATCOM is a three-phase voltage source inverter having a capacitor connected to its DC link. Fig 2 shows a neutral clamped topology of VSI for STATCOM application.

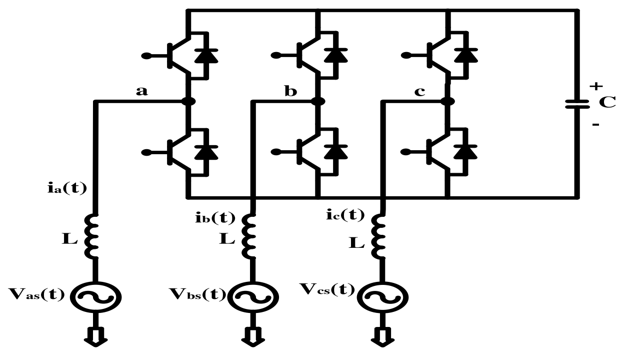

Fig 2.Six Pulse VSI STATCOM

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But in the proposed system with STATCOM, reactive power requirement of induction generator and load is supplied by the STATCOM instead of grid. The STATCOM injects a compensating current of variable magnitude and frequency component at the PCC [8]-[10].

The shunt connected ST A TCOM is connected to the PCC through interfacing inductors. The induction generator and load is also connected to the PCC [13]. The STATCOM compensator output is controlled, so as to maintain the power quality norms in the grid system.

IV. REFERENCE CURRENT GENERATION FOR STATCOM

Reference current for the ST ATCOM is generated based on instantaneous reactive power theory [7]-[l0]. A STATCOM injects the compensation current which is a sum of reactive component current of IG, non-linear load and harmonic component current of non-linear load. Pq theory gives a generalized definition of instantaneous reactive power, which is valid for sinusoidal or non sinusoidal, balanced or unbalanced, three-phase power systems with or without zero sequence currents and/or voltages.

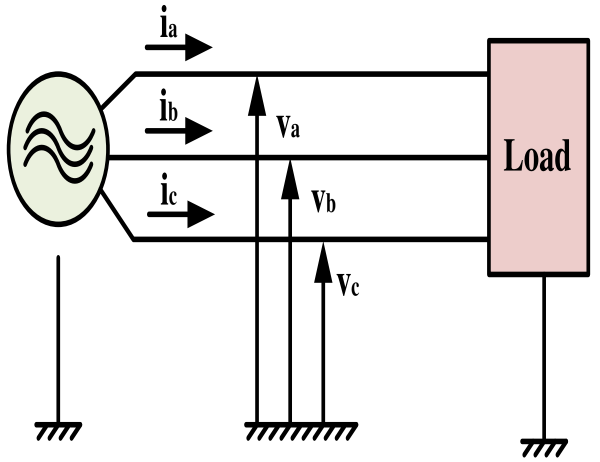

Fig .3 Three phase power system

Fig.3 shows the three phase power system, instantaneous

Voltages, va,vb,vc in volts and instantaneous currents,ia,ib,ic in amps of a three phase system are expressed as instantaneous space vectors ' v' and 'i' given by (1)

$$v = \begin{pmatrix} v_a \\ v_b \\ v_c \end{pmatrix} \quad i = \begin{pmatrix} i_a \\ i_b \\ i_c \end{pmatrix} \qquad (1)$$

'p' is the instantaneous active power of a three-phase circuitin Watts, given by (2)

$$P=v.\,i \qquad (2)$$

Instantaneous active power of a three-phase circuit ' p' is

the scalar product of instantaneous voltage and current. It is the product of the sum of three phase voltages and current, given by (3)

$$P= vaia+vbib+vcic \qquad (3)$$

Instantaneous active power consists of average component and oscillatory component as given by (4)

$$P = Pdc + Pac \qquad (4)$$

'Pdc' is the average component of instantaneous active power in watts and 'Pac' is the oscillatory component of instantaneousactive power in watts. ' q' is the instantaneous reactive power of a three-phase circuit in VAR, given by (5)

$$q = IIv \; x \; ill \qquad (5)$$

Instantaneous reactive power of a three-phase circuit ' q' is the vector product of instantaneous voltage and current, given by (6)

$$q = \begin{pmatrix} q_a \\ q_b \\ q_c \end{pmatrix} = \begin{pmatrix} \begin{vmatrix} v_b & v_c \\ i_b & i_c \end{vmatrix} \\ \begin{vmatrix} v_c & v_a \\ i_c & i_a \end{vmatrix} \\ \begin{vmatrix} v_a & v_b \\ i_a & i_b \end{vmatrix} \end{pmatrix} \qquad (6)$$

Total current is the sum of instantaneous active, reactive and harmonic component of current given by (7)

$$i = i_p + i_q + i_h \qquad (7)$$

'ip', 'iq' and 'ih' are of instantaneous active, reactive and harmonic component of current respectively. 'ip' is the instantaneous active component current in amps given by (8)

$$i_p = \frac{p_{dc} \cdot v}{v_a{}^2 + v_b{}^2 + v_c{}^2} \qquad (8)$$

Since it is a non linear load reactive component and harmonic component current are used as a reference current for STATCOM. The reference current for the three phases as given by (9), (10), (11).

$$i_{af^*} = i_{ap^*} - i_{as^*} = i_{aq} + i_{ah} \qquad (9)$$

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$$i_{bf^*} = i_{bp^*} - i_{bs^*} = i_{bq} + i_{bh} \quad (10)$$

$$i_{cf^*} = i_{cp^*} - i_{cs^*} = i_{cq} + i_{ch} \quad (11)$$

'iaf" , 'ibf" and 'ief" are the STATCOM reference current of three phases respectively.' iap*', 'ibp*' and 'iep" are fundamental active component current of three phases respectively. Similarly 'ias'" 'ibs" and 'ies" are the STATCOM source current of three phases respectively. iaq', 'ibq' and 'ieq , are the sum of instantaneous reactive Component current of induction generator and load of three phases respectively. 'iaq', 'ibq' and 'ieq' are the instantaneous harmonic component current load of three phases respectively.

V. HYSTERESIS CONTROLLER

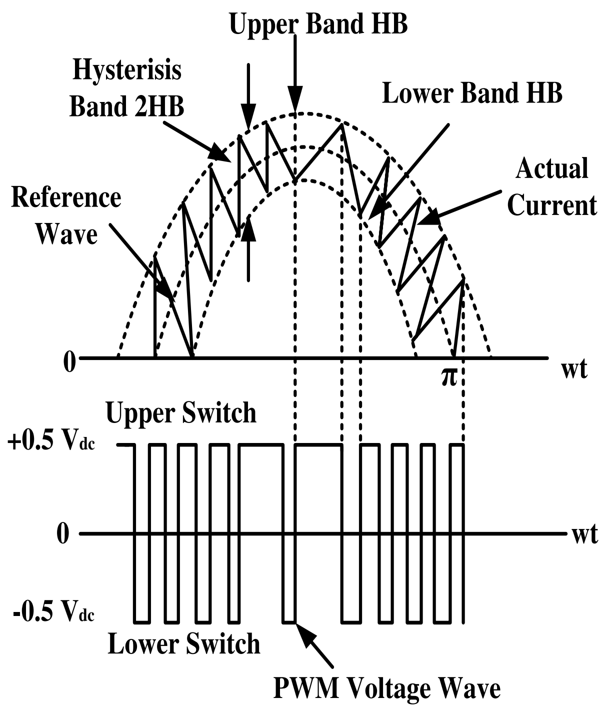

Fig.4. Hysteresis current Modualtion

With the hysteresis control, limit bands are set on either side of a signal representing the desired output waveform [6]. The inverter switches are operated as the generated signals within limits. The control circuit generates the sine reference signal wave of desired magnitude and frequency, and it is compared with the actual signal. As the signal exceeds a prescribed hysteresis band, the upper switch in the half bridge is turned OFF and the lower switch is turned ON. As the signal crosses the lower limit, the lower switch is turned OFF and the upper switch is turned ON. The actual signal wave is thus forced to track the sine reference wave within the hysteresis band limits.

VI. CONSTRUCTION OF FUZZY CONTROLLER

Figure 5 shows the internal structure of the control circuit. The control scheme consists of Fuzzy controller, limiter, and three phase sine wave generator for reference current generation and generation of switching signals. The peak value of reference currents is estimated by regulating the DC link voltage. The actual capacitor voltage is compared with a set reference value. The error signal is then processed through a Fuzzy controller, which contributes to zero steady error in tracking the reference current signal.

A fuzzy controller converts a linguistic control strategy into an automatic control strategy, and fuzzy rules are constructed by expert experience or knowledge database. Firstly, input voltage *Vdc* and the input reference voltage *Vdc-ref* have been placed of the angular velocity to be the input variables of the fuzzy logic controller. Then the output variable of the fuzzy logic controller is presented by the control Current *I*max. To convert these numerical variables into linguistic variables, the following seven fuzzy levels or sets are chosen as: NB (negative big), NM (negative medium), NS (negative small), ZE (zero), PS (positive small), PM (positive medium), and PB (positive big) as shown in Figure.6.

The fuzzy controller is characterized as follows:

1) Seven fuzzy sets for each input and output;
2) Fuzzification using continuous universe of discourse;
3) Implication using Mamdani's 'min' operator;
4) De-fuzzification using the 'centroid' method.

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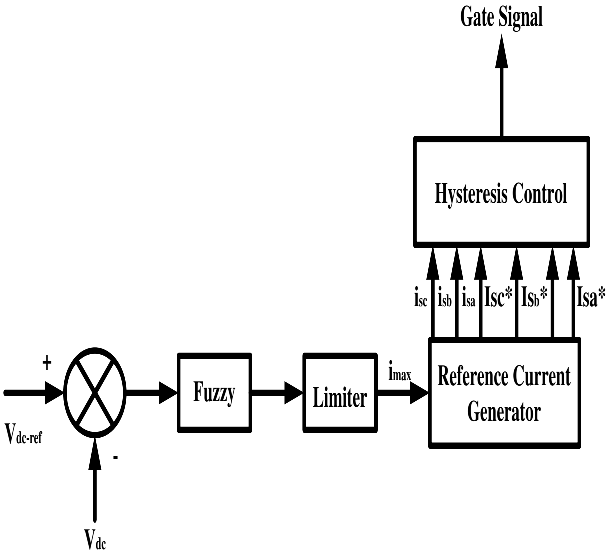

Fig.5.Conventional fuzzy controller

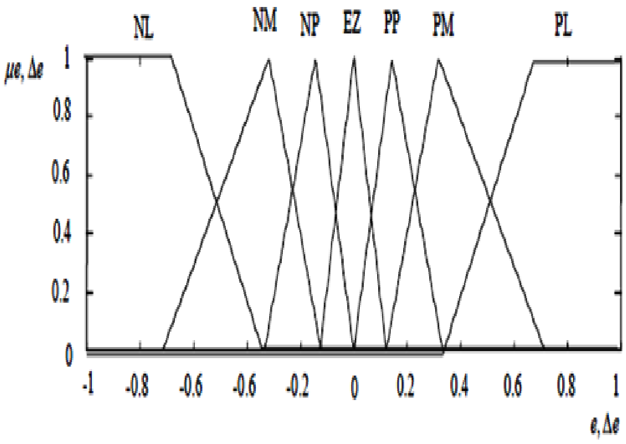

Fig.6. Membership functions for Input, Change in input, Output.

Fuzzification: the process of converting a numerical variable (real number) convert to a linguistic variable (fuzzy number) is called fuzzification. De-fuzzification: the rules of FLC generate required output in a linguistic variable (Fuzzy Number), according to real world requirements, linguistic variables have to be transformed to crisp output (Real number).
Database: the Database stores the definition of the membership Function required by fuzzifier and defuzzifier. Rule Base: the elements of this rule base table are determined based on the theory that in the transient state, large errors need coarse control, which requires coarse in-put/output variables; in the steady state, small errors need fine control, which requires fine input/output variables. Based on this the elements of the rule table are obtained as shown in Table 1, with '*Vdc*' and '*Vdc-ref*' as inputs.

Δe \ e	NL	NM	NS	EZ	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	EZ
NM	NL	NL	NL	NM	NS	EZ	PS
NS	NL	NL	NM	NS	EZ	PS	PM
EZ	NL	NM	NS	EZ	PS	PM	PL
PS	NM	NS	EZ	PS	PM	PL	PL
PM	NS	EZ	PS	PM	PL	PL	PL
PL	NL	NM	NS	EZ	PS	PM	PL

Fig.7. Rules for fuzzy logic controller

VII.MATLAB MODELEING AND SIMULATION RESULTS

Performance of STATCOM connected to a weak supply system for power factor correction and load balancing. The variation of performance variables such as supply voltages (*v*sa, *v*sb and *v*sc), terminal voltages at PCC (*v*ta, *v*tb and *v*tc), supply currents (*i*sa, *i*sb and *i*sc), load currents (*i*la, *i*lb and *i*lc), STATCOM currents (*i*ca, *i*cb and *i*cc) and DC link voltage (*V*dc) are shown below. Fig.5 Matlab/Simulink Model of proposed power circuit, along with control circuit. The power circuit as well as control system are modeled using Power System Block set and Simulink. The grid source is represented by three-phase AC source. Three-phase AC loads are connected at the load end. STATCOM is connected in shunt and it consists of PWM voltage source inverter circuit and a DC capacitor connected at its DC bus. An IGBT-based PWM inverter is implemented using Universal bridge block from Power Electronics subset of PSB. Snubber circuits are connected in parallel with each IGBT for protection. Simulation of STATCOM system is carried out for linear and non-linear loads. Here simulation is carried out at different load

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conditions, 1). Balanced Non-Linear Load Condition with conventional controller 2). Balanced Non-Linear Load Condition with Fuzzy Controller

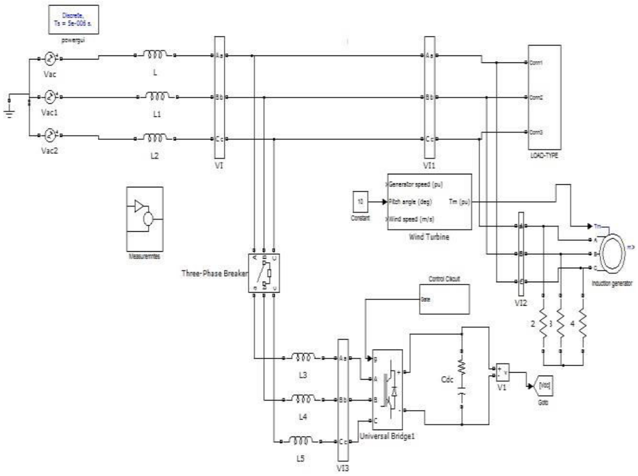

Fig.8 Matlab/Simulink of Proposed Statcom-Power Circuit

Case 1: Balanced Non-Linear Load Condition with Conventional Controller

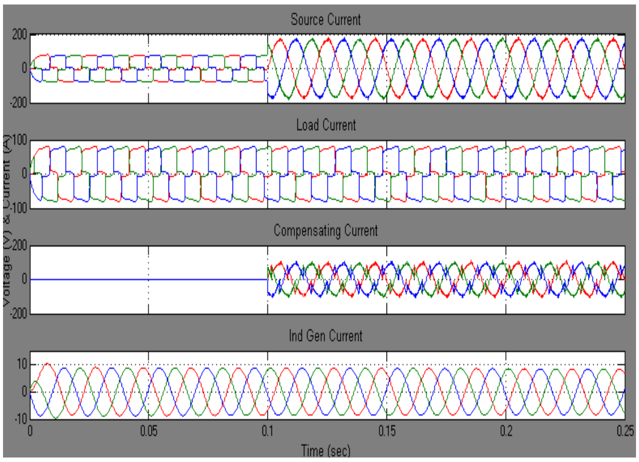

Fig.9 Simulation results for Balanced Non Linear Load

(a) Source current. (b) Load current. (c) Inverter injected current.

(b)

(d) wind generator (induction generator) current. Fig. 9 shows the source current, load current and compensator current and induction generator currents plots respectively. Here compensator is turned on at 0.1 seconds, before we get some harmonics coming from non-linear load, then distorts our parameters and get sinusoidal when compensator is in on.

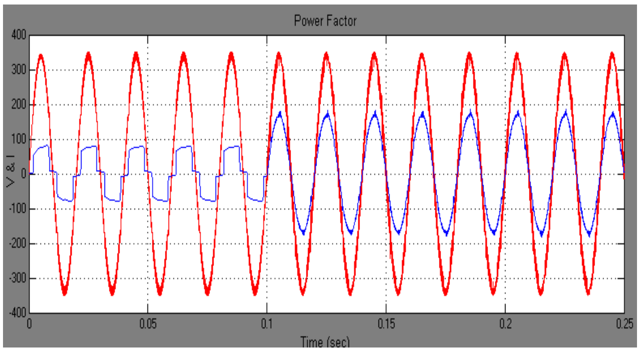

Fig.10 Simulation results power factor for balanced Non- linear Load with conventional controller

Fig. 10 shows the power factor it is clear from the figure after compensation power factor is unity.

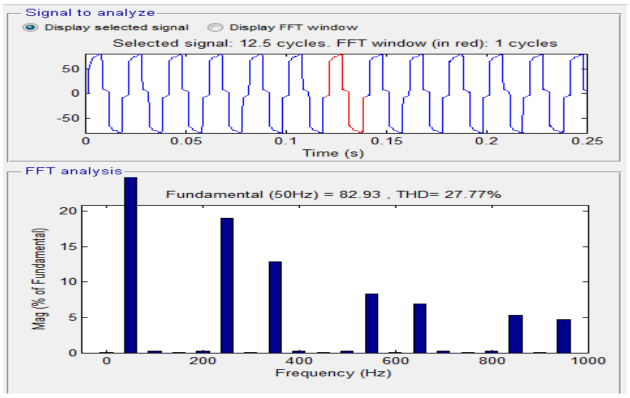

Fig. 11 FFT Analysis of Phase-A Source Current for Balanced Non-Linear Load

Fig.11 shows the FFT Analysis of Phase-A Source Current for Balanced Non-Linear Load, here we get 27.77%.

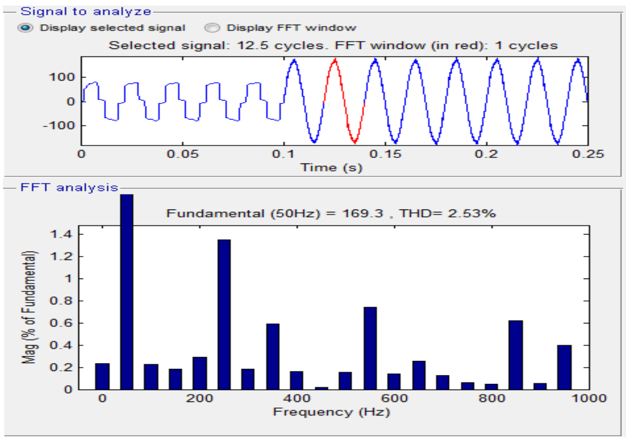

Fig. 12 FFT Analysis of Phase-A Source Current for Balanced Non-Linear Load with conventional controller

Fig.12 shows the FFT Analysis of Phase-A Source Current for Balanced Non-Linear Load, here we get 2.53%.

Case 2: Balanced Non-Linear Load Condition with Fuzzy Controller

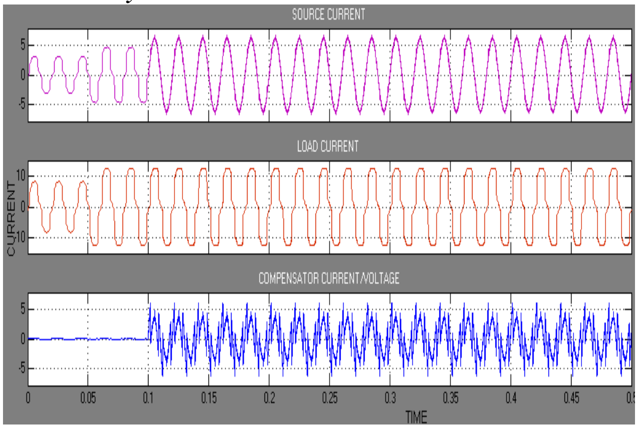

Fig:13. Simulation results for Un Balanced Non Linear Load using fuzzy controller (a) Source current. (b) Load current. (c) Inverter injected current

Fig.13. shows the simulation results of proposed converter using fuzzy logic controller, Source current, load current, compensating current respectively.

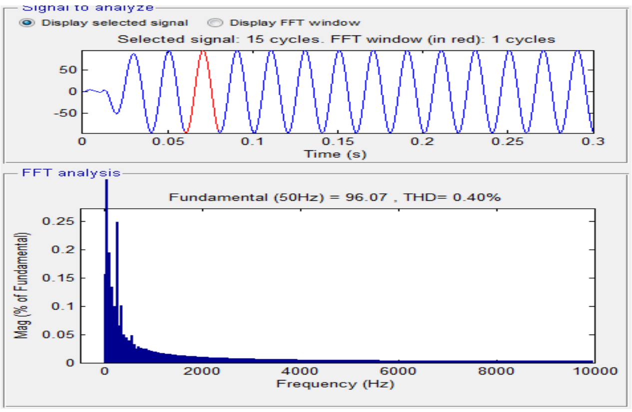

Fig.14 THD for inverter using fuzzy controller

Fig.14 shows the THD analysis of the source current using the fuzzy controller, we get 0.40%

VIII. CONCLUSION

This proposed model is implemented using Matlab Simulink software and the obtained resultant waveforms were evaluated and the effectiveness of the system stability and performance of power system have been established. This paper presents the STATCOM-based control scheme for reactive power compensation and harmonic reduction in grid connected wind generating system feeding different load conditions such as balanced, load conditions with different controllers. The Simulation results shows the grid voltage and current are in-phase, making the power factor unity, which implies that the reactive power demand of Induction generator and load is no longer, fed by the grid rather it is supplied by the STATCOM. The latter feature enables its application for compensation of dips coming from the supplying network. The simulation results show that the performance of converter system has been found to be satisfactory for improving the power quality at the consumer premises. Rectifier-based non-linear loads generated harmonics are eliminated by inverter.. When single-phase rectifier loads are connected, inverter currents balance these unbalanced load currents. By using conventional controller we get THD value is 2.53%, but using the fuzzy logic controller THD value is 0.4%.

REFERENCES

[I] J. 0 .Q.Tande 'Applying Power Quality Characteristics of wind turbine for Assessing impact on Voltage Quality', Wind Energy, pp 52, 2002.

[2] Z. Chen, E. Spooner, 'Grid Power Quality with Variable Speed Wind Turbines', IEEE Trans on Energy Conversion, Vol. 16, No .2, pp 148- 154, June 200 I.

[3] G.Satyanarayana., K.N.V Prasad, G.Ranjith Kumar, K. Lakshmi Ganesh, "Improvement of power quality by using hybrid fuzzy controlled based IPQC at various load conditions," Energy Efficient Technologies for Sustainability (ICEETS), 2013 International Conference on , vol., no., pp.1243,1250, 10-12 April 2013.

[4] A.Arulampalam, M.Bames & NJenkins, Power quality and stability improvement of a wind farm using ST A TCOM, Proc. TEE

Generation, Transmission & Distribution, Vol. 153, No.6, 2006, 701-710.

[5] Z.Saad-Saoud, M.1.Lisboa, 1.B.Ekanayake, N. Jenkins & G.Strbac, Application of STATCOMs to wind farms, Proc. TEE Generation, Transmission & Distribution, Vo1.I45, No. 5, 1998, 511-516.

[6] A.Arulampalam, 1.B.Ekanayake & NJenkins, Application study of a ST A TCOM with energy storage, Proc. lEE Generation, Transmission & Distribution, Vol. 150, No. 3, 2003, 373-384.

[7] Fang Zheng Peng, Jih-Sheng Lai, 'Generalized Instantaneous Reactive Power Theory for Three-phase Power Systems', IEEE on instrumentation and measurement, vol. 45, no. I, Feb, 1996.

[8] G. Satya Narayana, Ch. Narendra Kumar, Ch. Rambabu " A Comparative Analysis of PI Controller and Fuzzy Logic Controller for Hybrid Active Power Filter Using Dual Instantaneous Power Theory" International Journal of Engineering Research & Development, Vol-4, Issue-6, p.p. 29-39, Oct, 2012

[9] Fang Zheng Peng, , George W. Ott, Jr., and Donald J. Adams,' Harmonic and Reactive Power Compensation Based on the Generalized Instantaneous Reactive Power Theory for Three-Phase Four-Wire Systems' IEEE Trans on power electronics, vol. 13, no. 6, nov 1998.

[10] Leszek S. Czamecki:lnstantaneous Reactive Power p-q Theory and Power Properties of Three-Phase Systems' IEEE Trans on power delivery', vol. 21, no. I, Jan 2006.

[11] K. Derradji Belloum, and A.Moussi,'A Fixed Band Hysteresis Current Controller for Voltage Source AC Chopper'World Academy of Science, Engineering and Technology 452008.

[12] 1. Dalessandro, U. Drofenik, S D. Round and 1.W. Kolar, 'A Novel Hysteresis Current Control for Three-Phase Three-Level PWM Rectifiers', Swiss Federal Institute of Technology (ETH) Zurich, Power Electronic Systems Laboratory.

[13] D. Dragomir, N. Golovanov, P. Postolache, C. Toader, 'The connection to the grid of wind turbines'.