POWER QUALITY INTENSIFICATION FOR A GRID CONNECTED WIND TURBINE ENERGY SYSTEM

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Abstract- Wind has been a standout amongst the most other sources of sustainable power over these years. There have been huge improvements in the wind turbine industry supporting this vital source as a standard sustainable asset. a comprehensive control of a wind turbine system connected to an industrial plant is discussed in this research work, where an algorithm has been developed allowing a control structure that utilizes a four-leg inverter connected to the grid side to inject the available energy, as well as to work as an active power filter mitigating load current disturbances and enhancing power quality. A four-wire system is considered with three-phase and single-phase linear and nonlinear loads. During the connection of the wind turbine, the utility-side controller is designed to compensate the disturbances caused in presence of reactive, nonlinear or unbalanced single and intra-phase loads, in addition to providing active and reactive power as required. When there is no wind power available, the controller is intended to improve the power quality using the dc-link capacitor with the power converter attached to the grid. The main difference of the proposed methodology with respect to others in the literature is that the proposed control structure is based on the conservative power theory decompositions. This choice provides decoupled power and current references for the inverter control, offering very flexible, selective, and powerful functionalities. Real-time software benchmarking has been conducted in MATLAB to evaluate the performance of the proposed control algorithm for full real-time implementation.

I. INTRODUCTION

Power Quality (PQ) related controversies are of most solicitude in wind energy systems now days. The wind energy is one of the most distinct and important sources of energy which is growing at a rapid rate. [1] The broad usage of electronic gear, for example, data innovation hardware, control gadgets, adjustable speed drives (ASD), programmable logic controllers (PLC), energy-effective lighting and so on prompted a quintessential difference in electric load nature. These loads are at the same time the significant causers and the real casualties of puissance quality issues. [2]-[4] All these loads would cause perturbances in voltage waveform due to their non-linearity. The most critical areas are the perpetual process industry and the information technology services. All electrical inventions are inclined to failure when presented to at least one power quality quandaries. The electrical creation may be an electric engine, a transformer, an engenderer, a PC, a printer, correspondence hardware, or a household appliance. The accessibility of electric power with high caliber is vital for the running of the modern society. If some sectors

are slaked with the quality of the potency provided by utilities, some others are more inductively authorizing. To evade the astronomically immense losses cognate to PQ quandaries, the most inductively authorizing consumers must take action to avert the quandaries. Among the sundry measures, separate of less sensitive gear can assume a vital role. When even the strongest equipment is influenced, at that point different measures must be taken, for example, establishment of recovering innovations, dispersed age or an interface invention to avert PQ problems.

II. SURVEY ON EXISTING TECHNOLOGY

The induction generator is driven by an even hub wind turbine through its gear boxes. One converter is used; it's situated between the rotor terminals and power module. In this framework, the power stream of the rotor is unidirectional ($\omega r < \omega s$), the rotor assimilates the vitality from the FC framework.

Power electronic converter between the rotor and FC modify the recurrence and sufficiency of the rotor voltage. The control of the rotor voltage endorses the framework to work at a variable-speed. The proton trade film (PEM) FC control plant is the most perfect hotspot for half breed vitality frameworks with higher power thickness and lower working temperature. In any case, profiting a FC control plant with a battery pack bodes well while slaking the pinnacle control requests or transient occasions.

A. PQ theory

In 1982 p-q theory firstly publish in the Japanese language in local conference at Japan. At the end of 1960 to the beginning of 1970 some paper is publish about the basic idea of compensation of reactive power. In 1980 and 1981 Takahashi A. NABAE and K. Fujiwara gives basic hint to emergence of the p-q theory [5].

In PQ hypothesis, the three-stage is converted into a two-stage reference outline in order to eliminate the dynamic and receptive segments in a rearranged way. Distinctive power hypotheses have been proposed and actualized in electrical power frameworks to examine current and voltage segments, for example, the instantaneous power (PQ) theory for a three-stage framework made. The P-Q theory is predicated on the ab0 transformation, factitiously kenned as the Clarke Transformation, which consists in an authentic matrix to transform three phase voltages and current.

One favorable position of applying the ab transformation is the disagreement of zero-succession segments into the zero-grouping axis.

Normally, the a- and b- pivot don't have any commitment from zero-sequence components. The three-phase framework has three wires (no impartial conduit), no zero-sequencing current parts are available and i0 can be dispensed with in the above conditions, disentangling them. The present examination will be focused on three-wire frameworks. It is worth to take note of that in the above condition, q is indistinguishably commensurate to that characterized in Akagi, Kanazawa and Nabae and Watanabe, Stephan and Aredes, be that as it may, with a less flag. With this difference in motion, for an adjusted positive arrangement voltage source and adjusted capacitive or inductive load, the nascent receptive (fanciful) control characterized in will have a similar extent and flag of that ascertained using customary power hypothesis (Q = 3VIsinf).

Beneath Figure 1 demonstrates the simple working of PQ Theory. Generally used for the estimation of the remunerating streams. In this figure, pcand qc are the remittance reference potencies.
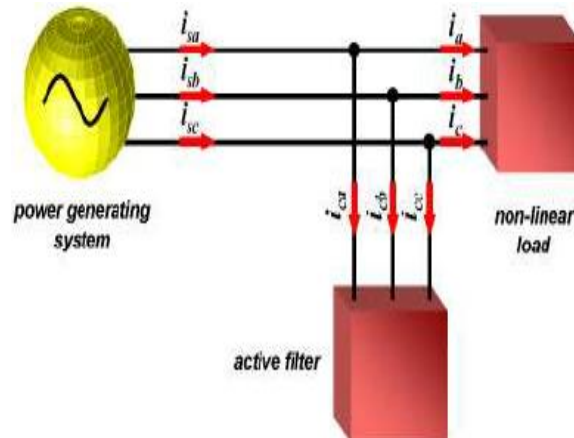

Fig.1 Basic working of PQ theory

III. PROPOSED TECHNOLOGY

A control structure has been formulated in three-stage four-wire frameworks that give greater usefulness to the grid side converter of a wind turbine framework using the CPT [6] as a replacement local to inducing distinctive current references for particular perturbances payment, where both single-and three-stage loads are victualed. Three-stage, four-wire inverters have been acknowledged using traditional three-leg converters with "split-capacitor" or four-leg converters. [7],[8],[15] In a three-leg conventional converter, the AC unbiased wire is directly associated with the electrical midpoint of the dc bus. In four-leg converter, the AC unbiased wire association is given through the fourth switch leg. The "four-leg" converter topology has preferable controllability over the "split-capacitor" converter topology. [9]-[11] The considered framework comprises of single-and three-phase linear and

nonlinear (even and uneven) loads. [12] The CPT is used to distinguish and to measure the measure of resistive, responsive, unbalanced, and nonlinear attributes of a specific load under various supply voltages condition for four-wire framework.

This undertaking proposes an exhaustive control strategy for a consecutive wind turbine framework that is associated with a modern plant. In order to supply the accessible dynamic power alongside full remittance of load current perturbances a four leg inverter is utilized at the matrix side. Considerable adaptability and the relief of the perturbances are contributed completely predicated on the Conservative Power Theory. The outcomes consequently got incorporated an improvement in THD for sundry operation conditions alongside the great execution of the calculation. The structure of the strength converter used in the wind turbine framework is a consecutive converter with a permanent magnet synchronous engenderer (PMSG) associated with a similar transport with the heaps. The loads are a cumulating of linear and very inductive load causing harmonics at the purpose of Prevalent coupling (PCC). The model of the wind turbine framework considered in this research work is depicted in.

A. Conservative Power Theory

It demonstrates that the Conservative Power Theory (CPT) [6] furnishes a fitting foundation to adapt with astute networks characterization needs, and a stage for the advancement of helpful control methods for distributed switching power processors and static reactive compensators. The CPT, proposed here breaks down the potency and current in the stationary frame, as indicated by terms specifically related to electrical attributes.
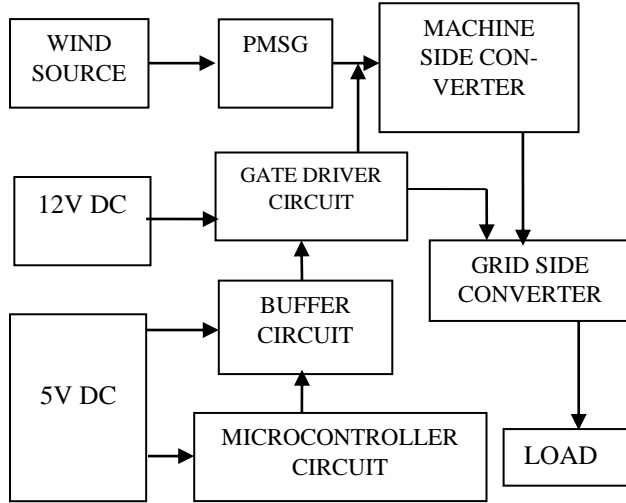
IV. BLOCK DIAGRAM

Fig.2 Block Diagram

V. SYSTEM CONFIGURATION

A. Permanent Magnet Synchronous Generator

It is a generator where the excitation field is given by an everlasting magnet in lieu of a loop. The term synchronous alludes here to the way that the rotor and attractive field pivot with a similar flurry, in light of the fact that the magnetic field is caused through a pole mounted sempiternal magnet system and current is incited into the stationary armature.

An aeonium magnet synchronous generator is portrayed by the nonattendance of gearbox and lessened dynamic weight, other than having a high-power density and a high proficiency (transient of the copper losses in rotor). For the most part the wind turbine generator predicated on rotational scurry can be spited into two sorts: adjusted and variable speed WTGS. Calibrated speed turbines are more effortless to interface with the electrical network. In any case, factor speed turbines can remove more energy from the wind and are created s preferred by the wind industry.

B. Machine side controller

The reason for the machine side converter is to track the ideal point of the rotor to extract the maximum power subsisting in the turbine. For a given wind turbine, the maximum power happens at the greatest power coefficient of the turbine. [13] For a given wind celerity, there is an ideal rotor speed that gives the ideal tip speed proportion

$$\lambda_{opt} = \frac{R_\omega \omega_\omega, opt}{v_\omega}$$

By analyzing the tip speed proportion of the wind turbine, one can extract the greatest power from the rotor by computing the ideal rotor speed as

$$\omega_{\omega,opt} = \frac{v_\omega \lambda_{opt}}{R_\omega}$$

At that point, this ideal rotor reference is subtracted from the measured rotor speed to engender the celerity error. The internal current controller is shown the current in quadrature reference, the direct current reference in this work is set to zero.

C. Four legged CPT based converter

The composing and demonstration of current-controlled voltage source inverter is done. The control conspires for the four-leg matrix side inverter is shown. The figure shows the schematic graph of the grid tied four leg inverter unit, comprising of a four-leg voltage source converter (VSC)and the system stack that are associated with the appropriation organize at PCC[14].

The inductance of the filter is L_f and R_f is the ohmic loss of the inductor. The machine side converter is associated in parallel with the VSC dc-interface capacitor C_{dc}. It is demonstrated that the network side inverter unit is controlled in an abc-reference outline. V_{pcc} Is

directed by the matrix speaking to the PCC/load voltage. The control objective is to endorse the breeze source to infuse its accessible vitality, and also to fill in as a active power filter for changing force quality predicated on CPT functionalities. The circuit has both adjusted and lopsided linear and nonlinear burdens.

The inverter unit control framework comprises of two feed control loops. The first loop showed is a speedy loops controlling the yield current, displaying that io,abcn can quickly track their particular reference orders i∗o,abcn, while i∗o,n is steady as i∗ o,n =−(i∗o,a + i∗o,b + i∗o,c). The external loop delineated is a more steady loop controlling the dc-interface voltage. The dc-connect keeps the power adjust between the puissance which is circulated to the framework in the yield of the inverter and the puissance in the dc-interface. The coveted inverter yield current is the summation of the dynamic current gave from the wind system (torpid) and the remittance of undesirable load current perturbances appropriated by the CPT method.

VI. SIMULATION RESULTS

The four-leg inverter is used to disseminate the dynamic energy to the load that is being incited by the wind. The re-enactment is performed using MATLAB 2015a. The Fig 3. Contains the simulation diagram. Fig 4. Demonstrates the twisted yield waveform got for a three-stage sinusoidal waveform requiring power quality improvement. In Fig 5. The three-stage sinusoidal waveform with enhanced THD is gotten because of the establishment of a four-leg inverter in the circuit. Fig 6. Demonstrate the single stage wave form with a lot of harmonics, Fig 7. Demonstrates the single stage waveform in advance of and after the payment respectively and the remittance of undesirable load current perturbances appropriated by the CPT system.

The harmonics spectrum of the grid current and total harmonic distortion (THD) without any recompense is shown in Fig. 8. Since there are single and three phase loads as well as other loads in the system, the THD is contrasting for each phase. The current of phase-a and phase-c contain THD of 5.84% and 5.35%, respectively. In Fig. 9 the grid current spectrum is demonstrated after the inverter is set to compensate the load nonactive current components. The THD of phases-a and phase-c were reduced to about 2.46% and 2.68%, respectively. Phase-b initially had much less harmonics because it does not have nonlinear single-phase load as the other phases.
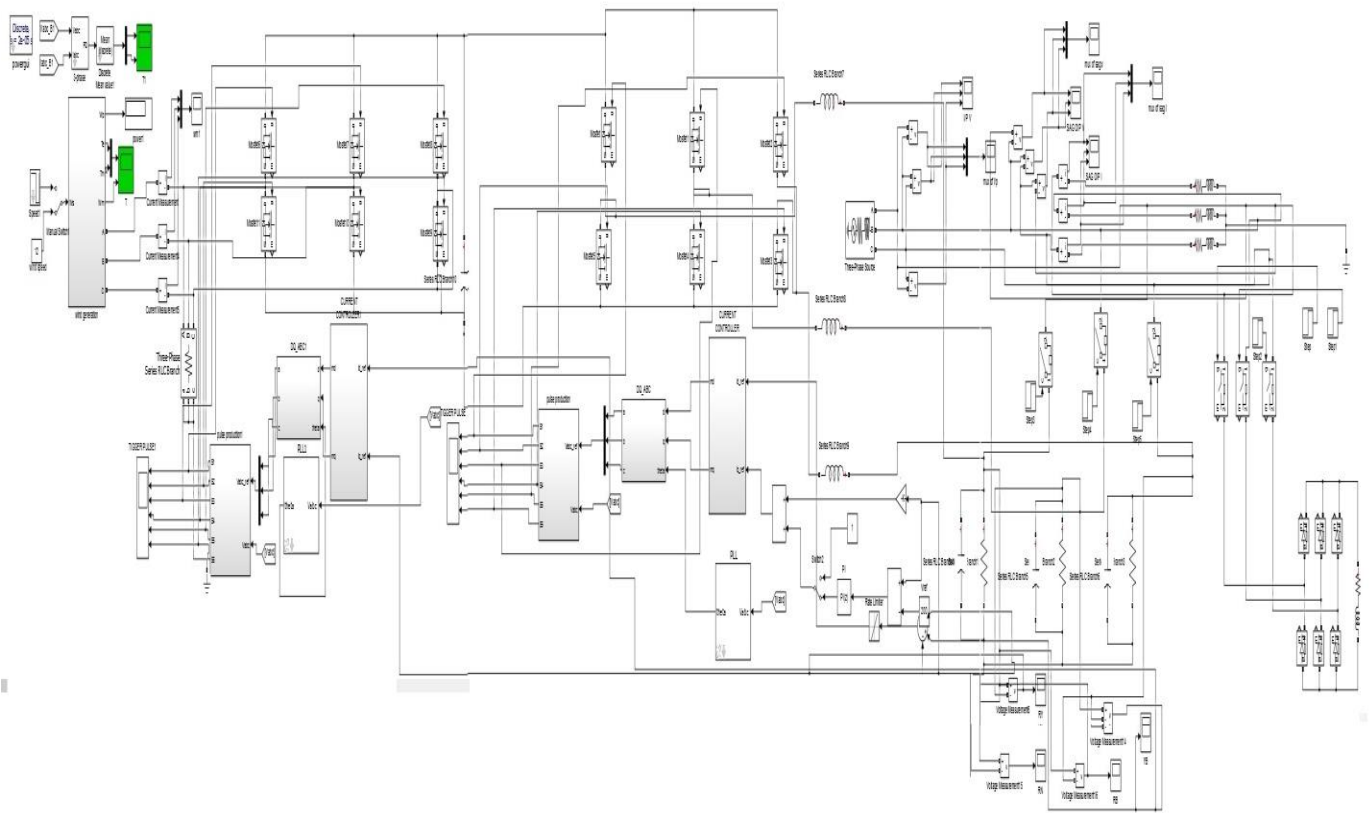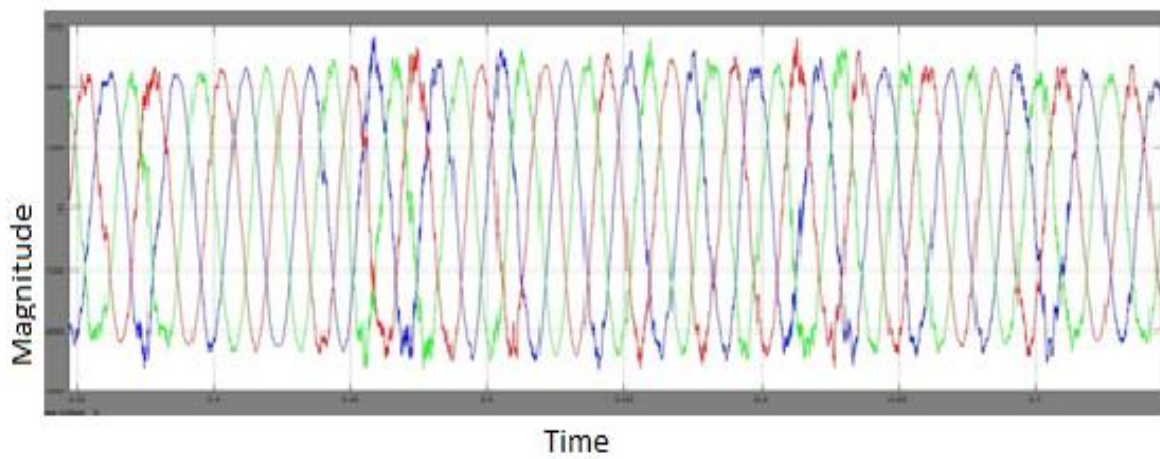
Fig.3 Simulation Diagram
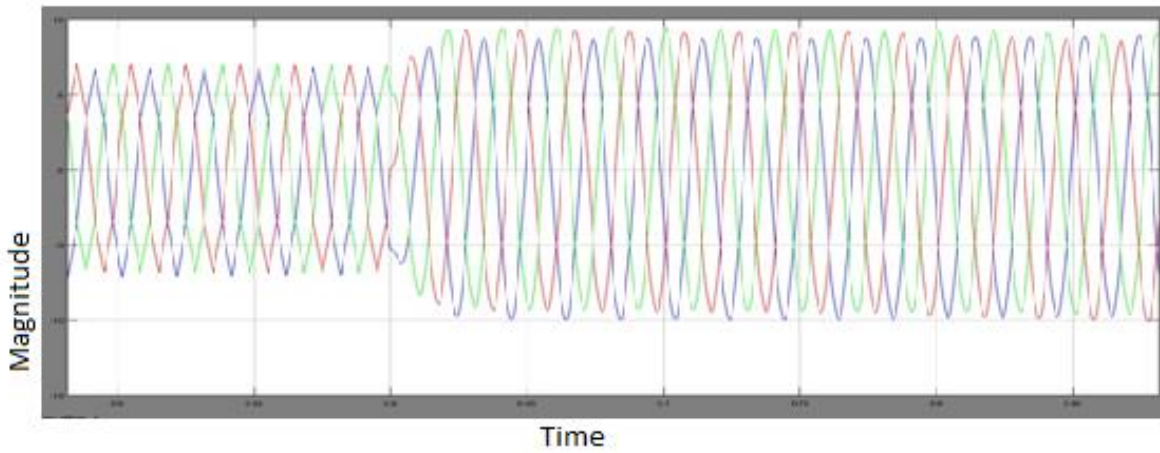

Fig.4 Three phase waveform with harmonics

Fig.5 Three phase waveform after passing through Four leg converter
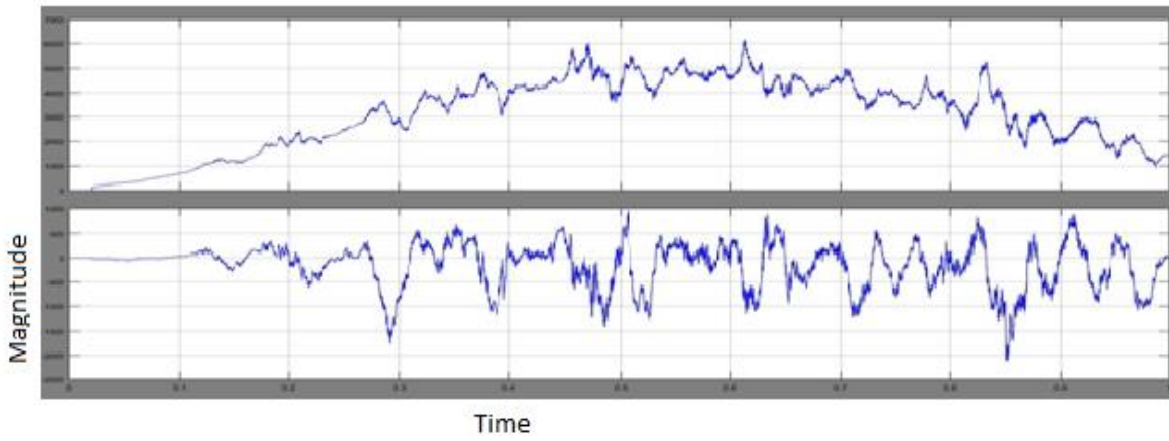

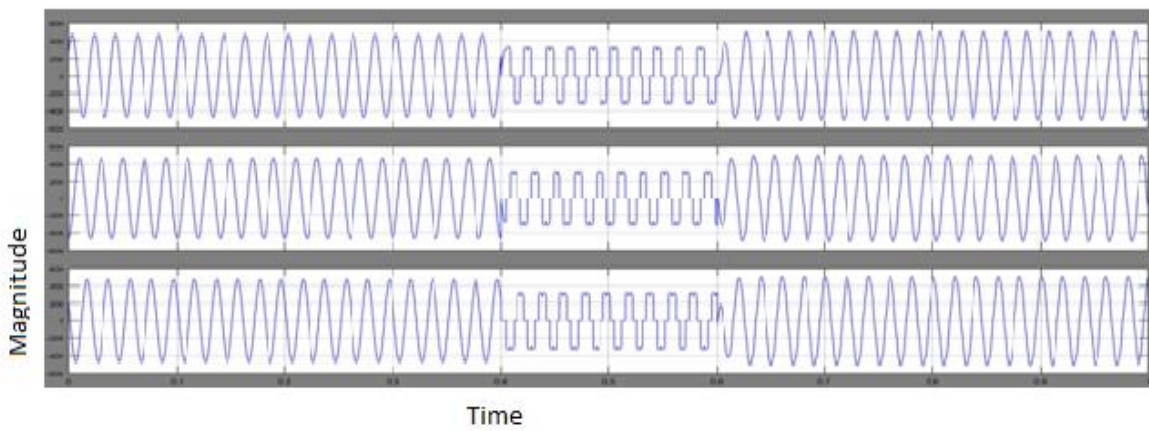Fig.6 Single phase waveform with harmonics

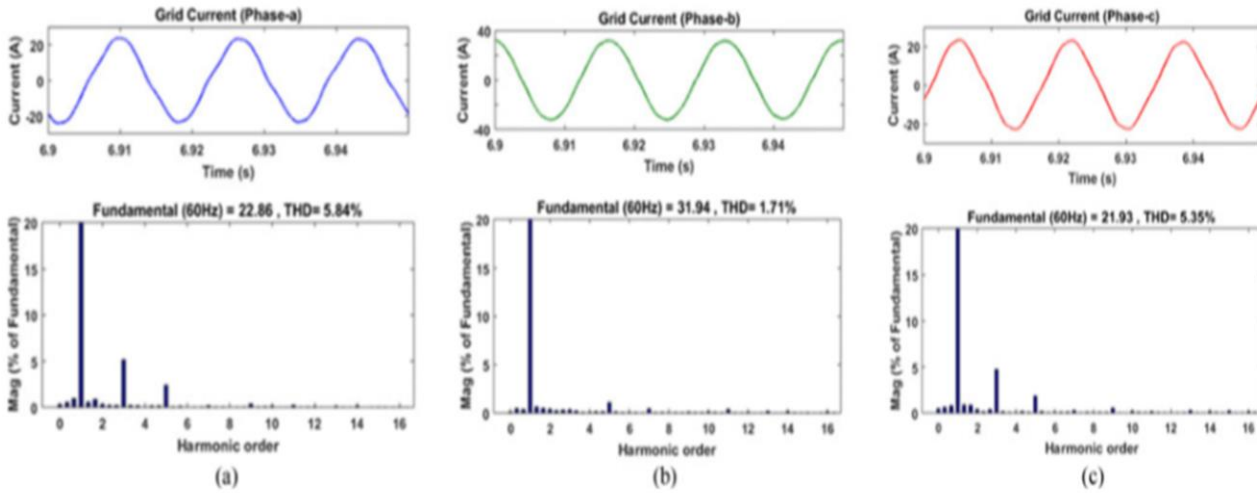Fig.7 Single phase waveform after passing through Four leg converter

Fig.8 Spectrum and THD of grid current without power quality improvement: (a) phase-a; (b) phase-b; and (c) phase-c.
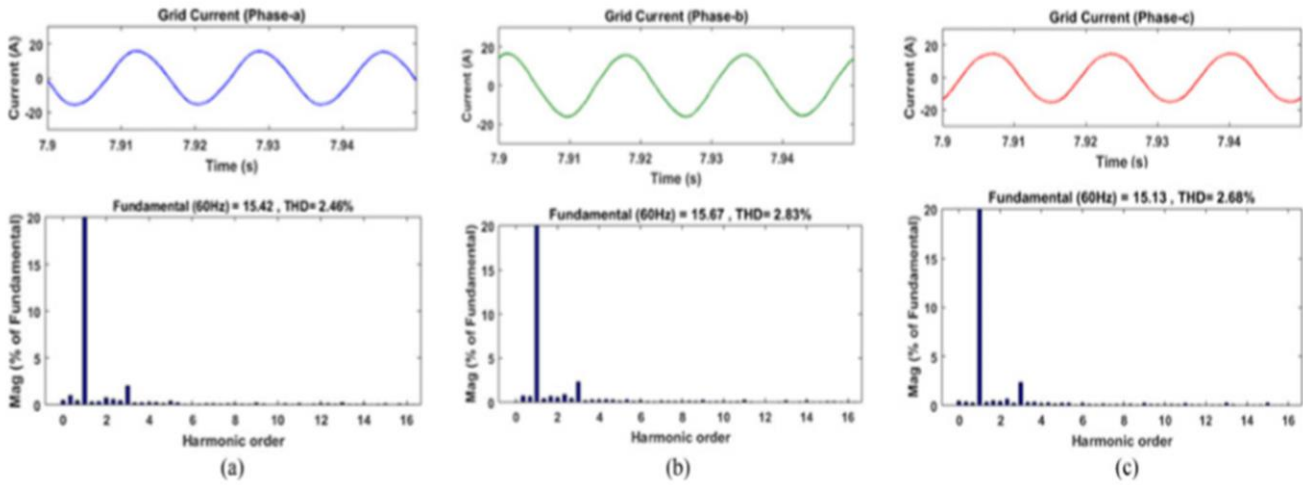

Fig.9 Spectrum and THD of grid current with nonactive compensation: (a) phase-a; (b) phase-b; and (c) phase-c.

VII. CONCLUSION

This research work addressed a comprehensive control method for a back-to-back wind turbine system connected to an industrial plant. The Conservative Power Theory used here decomposes the power and current in the stationary frame, according to terms directly related to electrical characteristics, such as average power transfer, reactive energy, unbalanced loads and nonlinearities. The control uses the four-leg inverter at the grid side to supply available active power from the wind turbine system along with full compensation of load current disturbances. The four leg inverter has a spilt capacitance which enables the reduction in the disturbance, noise and the harmonics. The output waveform is subjected the Fourier analysis and thus the Total Harmonic Distortion (THD) is obtained. The Total Harmonic Distortion has been reduced from 5.84% as of normal waveform without any nonactive compensation to 2.46% when the waveform is subjected to nonactive compensation.

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