

Simulation and Analysis of Active Power Filter for Mitigation of Power Quality Problems in a Wind Based Distributed Generation

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Abstract-- The adoption of natural energy sources has seen a phenomenal rise during recent decades. The reason is an improvement in their energy conversion capabilities, as well as simplification of their associated electronic control circuitry. The result at their use at a localized distributed generation level. This work is an attempt to understand and present the power quality impacts of wind and solar power generation at a localized system of distribution voltage level. The simulation is finalized in MATLAB/SIMULINK. Next a very popular solving these power quality problems namely, active power filter beside its shunt type is tested over the simulated model. Moreover, its control algorithm is implemented mathematically with P-Q theory and the results are analyzed for better power quality improvement.

Keywords- Active Power filter, Current Harmonics, Local Power System, P-Q Theory, Wind Power

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I. INTRODUCTION

NOWADAYS active filtering of electric power becomes major technology for mitigation of harmonics in a single-phase power line generated by loads. Harmonic is to be defined as a requisite collective of the sustaining frequency introduced in electrical power that causes continuous distortion [1]. The major cause of harmonics is the use of nonlinear devices like the Uninterruptible Power Supply (UPS) system, and rectification system, etc. The current harmonics introduced in the circuit result to be the greater voltage distortion which results in an abnormal operation of switching devices, greater power loss & temperature rise [2, 3]. To reduce harmonics contents by employing active power filter control purposed to purify the performance [4, 5].

Historically passive filters are used to eject these current harmonics' but now a day's research is to be done on active power filters as correlated to the passive filters. It can be recognized as a better solution to cancel out the problem created by nonlinear loads [6, 7]. Low voltage distribution systems composed of non-conventional energy systems such as wind energy systems; PV systems, small-scale hydro systems, etc. are discussed in [8, 9]. These types of a distributed systems can be operated isolated or they may be interconnected to the medium voltage distribution network [10]. Its application is discussed [11] from the local side are that it provides reliability, reduces emission, also provides both thermal and electricity

needs, improve power quality & reduce the cost of energy. The microgrid can be used for varieties of loads with a single operating system such as power and heating loads in [12]. The microgrid advantages are discussed also in [13].

Their difference between microgrids & the general energy resources are defined as such as the microgrid is installed normally near to the consumer load; they also have a smaller capacity as compared to the conventional grid [14-16]. The impact which occurs in distribution generation on power quality depends upon the factors such as type of distribution generation, its interference with power quality, the feeder voltage regulation practice [17, 18].

In this paper, a shunt active power filter with hysteresis control using clerk transformation is implemented to overcome harmonic distortion in a small scale wind power (DG)

The remaining parts of the manuscript are organized as follows: Section 2 describes the wind power distributed generation. Section 3 outlines and discusses exhaustively the power quality issues in distributed generation. Section 4 highlights the working principle of shunt active power filter. and its need. Section 5 describes the methodology, results, and discussions. Finally, conclusions are discussed in section 6.

A. POWER QUALITY ISSUES IN DISTRIBUTED GENERATION

The contact which arises in distribution generation on power quality depends upon the factors such as type of distribution generation, its interference with power quality, the feeder voltage regulation practice. In this system wind turbines are used to produce electrical energy, the wind turbine is linked to the generator (mostly induction) by a multiple ratio gearbox.

The kinetic energy of the wind rotates the rotor blades of the wind turbine and transfers this wind energy to the generator through the gearbox [18]. There are some positive as well as negative effects of power quality on distribution generations; the positive impacts are backup generation and on-site power supply. The negative impacts include voltage flicker, harmonics, voltage sags, sustained interruption, voltage regulation, etc [19].

B. ACTIVE POWER FILTER AND ITS NEED

Nowadays the introduction of nonlinear loads causes greater damage to the quality of electrical power. The change in the amplitude of the supply system and the boost up in the harmonics contents is the basic effect on the system [20]. Also, these power quality complications are seriously faced today by the industrial customer, especially in the micro grid which exploits local distributed generation units.

Anciently passive filters are used to defeat these current harmonics but now a day's research is to be done on active power filters as measured to the passive filters. For example, an active power filter (shunt) is used to overcome the harmonics current. This type of active power filter can be recognized as a better solution to defeat the problem created by nonlinear loads [21].

a. ACTIVE POWER FILTERS AND ITS TYPES

It is an electronic device worn to modify power quality problem's especially whereas voltage sag & current, voltage harmonics as shown in figure 1 [22]. In nonlinear load conditions, Active filtering technology is widely used current, voltage harmonics dependent on time.

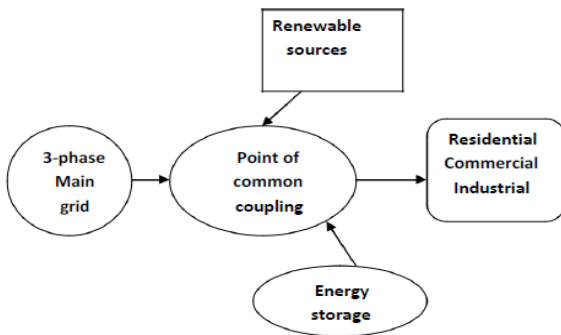


Fig. 1. Block diagram of local power system

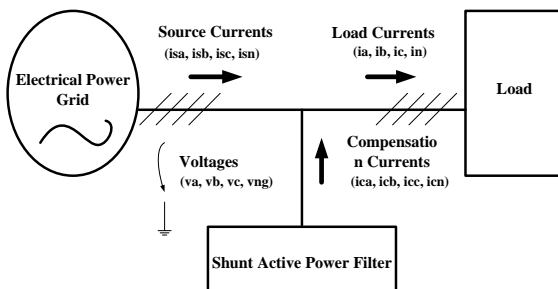


Fig. 2. Active Power Filter [1]

AF is used as a buffer between supply terminal voltages & PWM voltage produced by active filter by connecting series-

inductor at the input of voltage source Inverter Bridge [23-26]. Classifications of APF occupying on topology, types of converter & on no: of phases, so converter based includes PWM with current, voltage fed PWM inverter bridge structure.

Further converter types are categorized by voltage source inverter and current source inverter. Whereas APF also is divided according to their cartography like Shunt, Series active & compound active power filters [27, 28]. Fig 2 shows the working principle of shunt active power filter in a wind-based distributed generation.

II. PROPOSED METHODOLOGY

The block diagram of the methodology is shown in figure 3. This describes the simulation of the microgrid structure, design of the shunt active power filter with a localized power system. Afterward, the control strategy for such a system namely active-reactive theory with hysteresis control technique is implemented over a system and the calculation of total harmonic distortion in each phase of a localized power system.

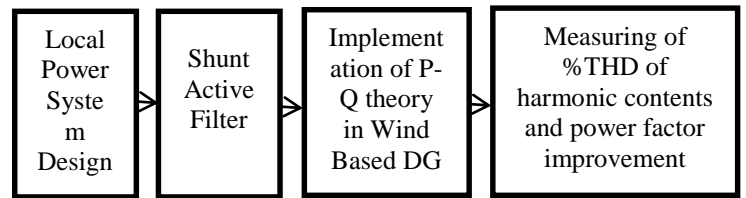


Fig. 3 Layout of Research work

A. ADOPTION OF P-Q THEORY IN SAPF IN LOCAL POWER SYSTEM WITH WIND-BASED DISTRIBUTED GENERATION

Shunt active power filter is widely in practice and practice can be contrivances to overcome the problems of quality of the power system, also many active filters are employing an entire world. Gyugyi in 1976 first introduced the concept of active filtering technology. Figure 4 illustrates the fundamental concept afterward compensation of shunt current. Further, this displays the providing of power source to a nonlinear load of a source that is being compensated by SAPF.

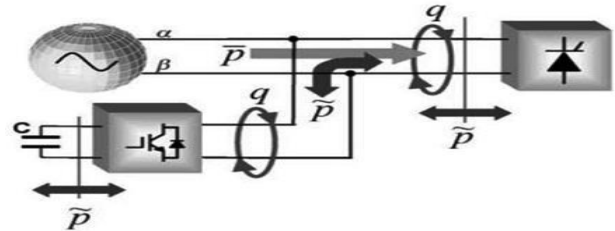


Fig. 4. Adoption of P-Q theory in SAPF in local power system

The controller of the filter found out the compensating reference current in real-time and the power converter source to symphonize compensating reference current with steep integrity. Here APF acts as a source of current control of a three-phase basis, which creates the harmonic current in opposite phase, angle i.e. 180 degrees depending on reference currents ica , icb , and icc .

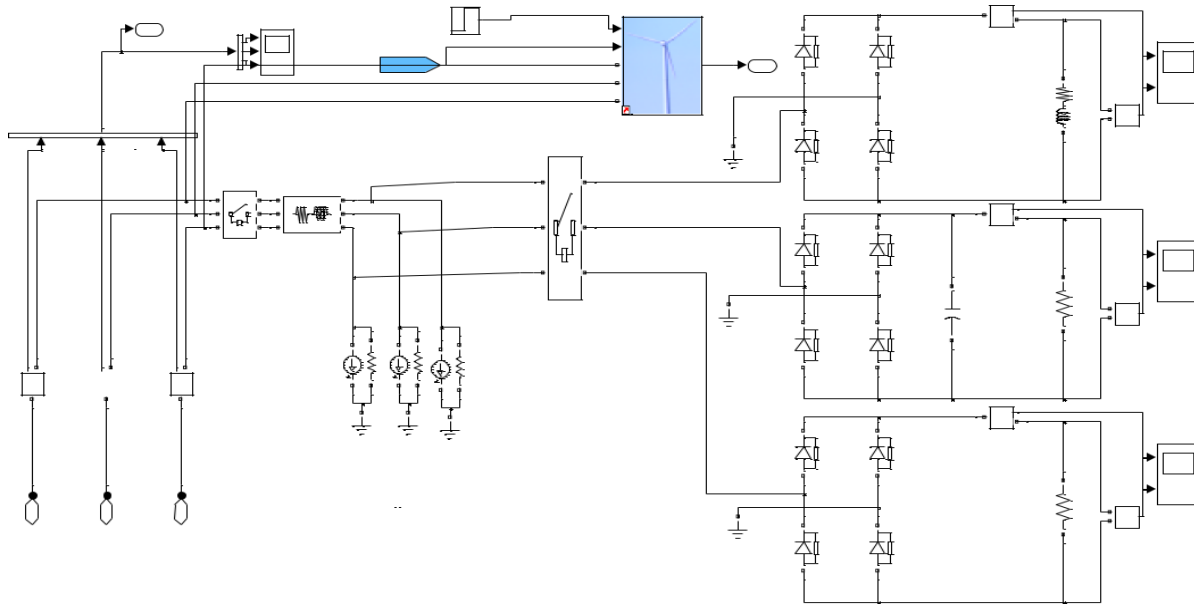


Fig. 5. Simulink Diagram of Non-linear Load with Wind Power based D.G

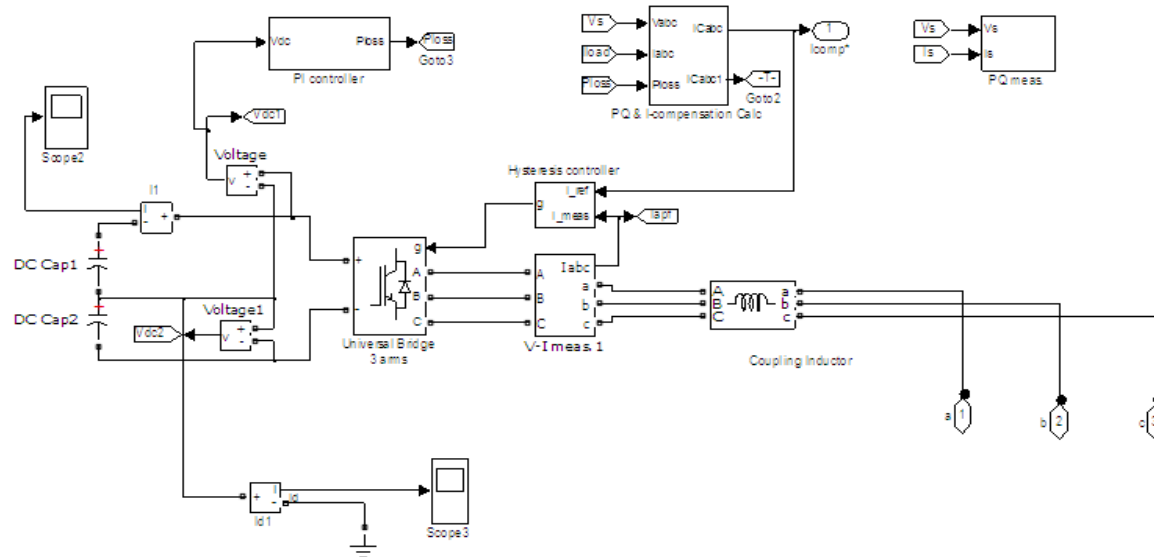


Fig. 6. Simulink diagram of Shunt APF

The real power (p) which is calculated from the load can be divide into two parts

- (i) Average part (p)
- (ii) Oscillating part ($p\sim$)

Correspondingly the imaginary power (q) of the load can be divided into two parts:

- (i) Average part (q)
- (ii) Oscillating part ($q\sim$).

Then unwanted portions of the real and imaginary powers of the load should be compensated are preferred.

B. OPERATION OF SHUNT ACTIVE POWER FILTER

To obtain the signals for fast switching insulated gate bipolar transistor inverter, gain current signals sent to PWM converter as reference signals. Concluded interfacing inductor, these currents are inserted in the system near the load. The performance of shunt APF of individual of the system impedance as it matches the implanted currents with reference current signals and tries to decreases the disturbances shown in figure 6.

Referring to general the following steps are required for the working principle of shunt active power filter to obtain reference harmonic currents of the active power filter.

1. Calculation of load currents $i_\alpha, i_\beta, i_\gamma$ & Source voltages $V_\alpha, V_\beta, V_\gamma$

$$\begin{bmatrix} i_\alpha \\ i_\beta \\ i_o \end{bmatrix} = \begin{bmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \\ \sqrt{\frac{2}{3}} & -\frac{1}{\sqrt{6}} & -\frac{1}{\sqrt{6}} \\ 0 & \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} \end{bmatrix} \cdot \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} V_\alpha \\ V_\beta \\ V_o \end{bmatrix} = \begin{bmatrix} \sqrt{\frac{2}{3}} & -\frac{1}{\sqrt{6}} & -\frac{1}{\sqrt{6}} \\ 0 & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \cdot \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (2)$$

2. Calculation of instantaneous real & imaginary active, reactive power.

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix} \cdot \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (3)$$

3. Calculation of reference currents from oscillatory part of a result obtained from the above step.

$$\begin{bmatrix} i_{c1} \\ i_{c2} \end{bmatrix} = \frac{1}{V_\alpha^2 + V_\beta^2} \begin{bmatrix} V_\alpha & V_\beta \\ V_\beta & -V_\alpha \end{bmatrix} \cdot \begin{bmatrix} p \\ q \end{bmatrix} \quad (4)$$

$$\begin{bmatrix} i_{c1} \\ i_{c2} \end{bmatrix} = \frac{1}{V_\alpha^2 + V_\beta^2} \begin{bmatrix} V_\alpha & V_\beta \\ V_\beta & -V_\alpha \end{bmatrix} \cdot \begin{bmatrix} p_{osc} \\ q_{osc} \end{bmatrix} \quad (5)$$

5. Finally, obtaining reference harmonic currents.

$$\begin{bmatrix} I_{ca} \\ I_{cb} \\ I_{cc} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \end{bmatrix} \cdot \begin{bmatrix} I_{c1} \\ I_{c2} \\ I_{c3} \end{bmatrix} \quad (6)$$

III. RESULTS AND DISCUSSIONS

Results showing the load & source voltages, currents of a 3- ϕ power supply, shunt active power are coupled parallel with source and load (Nonlinear load & distributed generation). The

breaker of an active power filter is switched on for 0.8 seconds to 3.8 seconds. Results are showing to mitigate current harmonics. Specification of the simulated model has described as following:

Table 1 Local power system parameters with wind-based distributed generation using shunt active power filter

S. No	Parameters	Values
1	3- phase Power Supply	400 Volts
2	Frequency	50 Hz
3	Breaker opening time	0.8 to 3.8 sec
4	Coupling inductor	2 mH
5	Wind Generator type	Squirrel-cage induction generator
6	Wind turbine output power	10 KW
7	Wind speed	9 m/sec
8	DC-Link controller	P-I
9	DC-Link Voltage	680 volts
10	Dc link Filter capacitance	400 Micro Farad

The figures of supply voltage and load source current are given below

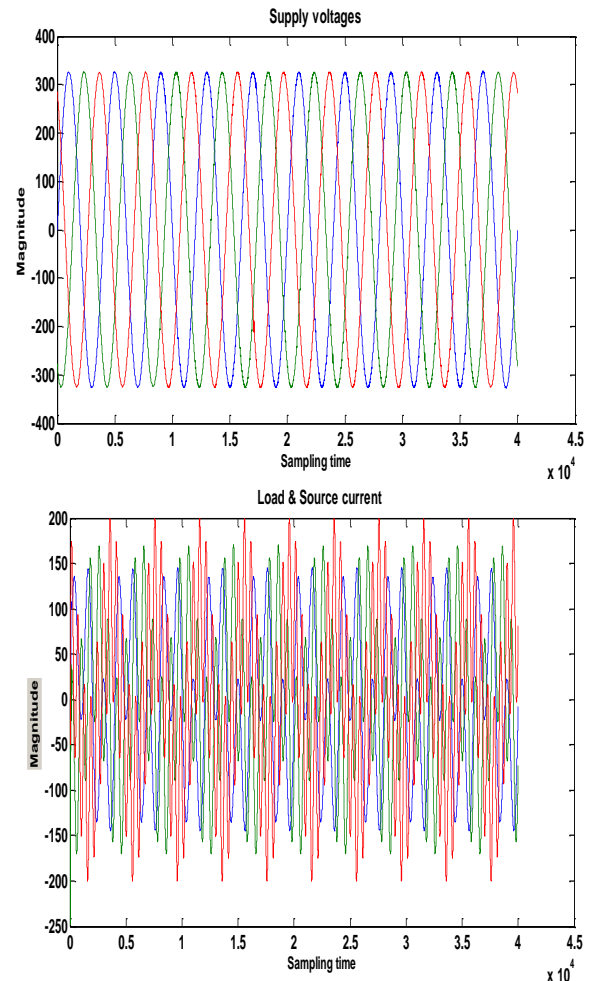


Fig. 7. Supply Voltage & Load Current Source

Also, the figures of instant active & reactive power without filters are shown in figure 8.

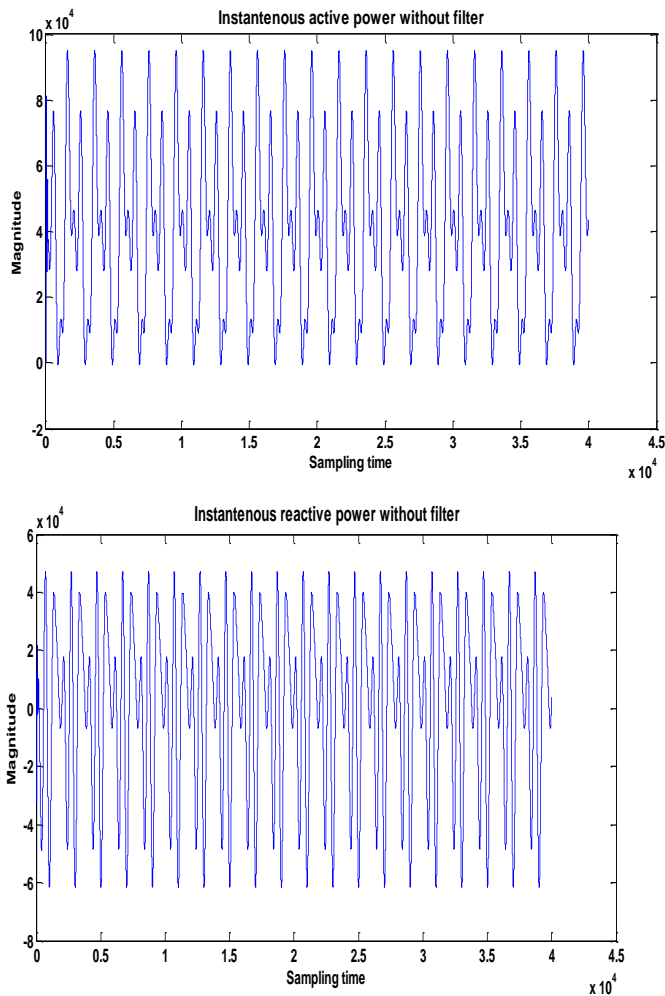


Fig. 8. Active & Reactive power without Filter

The waveform of considerable improvement in active & reactive power is shown in fig. 9 when a shunt active power filter is used.

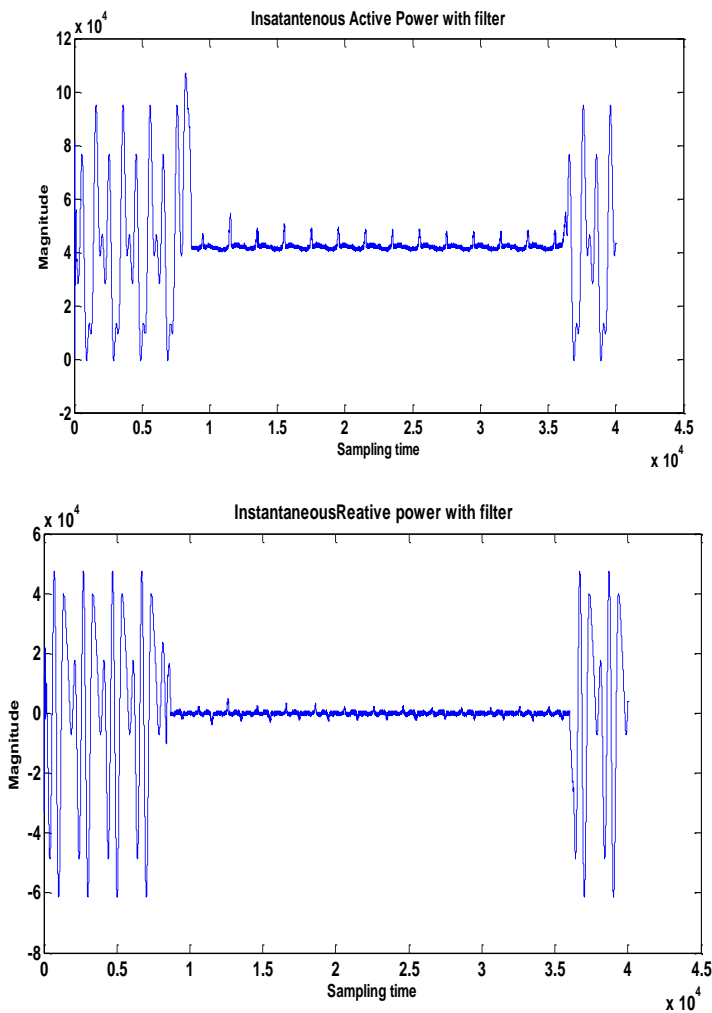


Fig. 9. Improved Active and Reactive Power with Filter

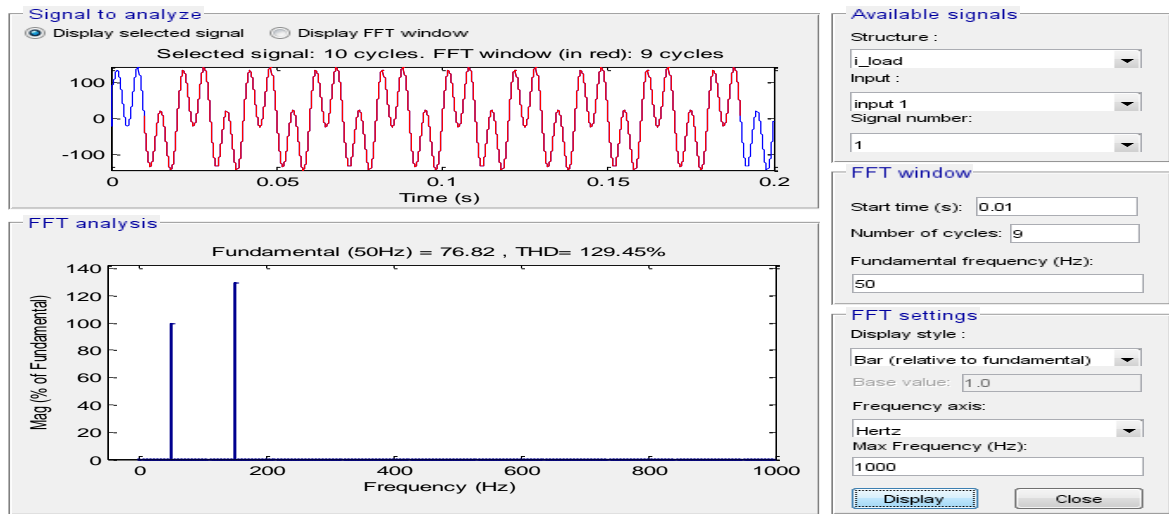


Fig. 10 FFT analysis of %THD on phase A without Filter

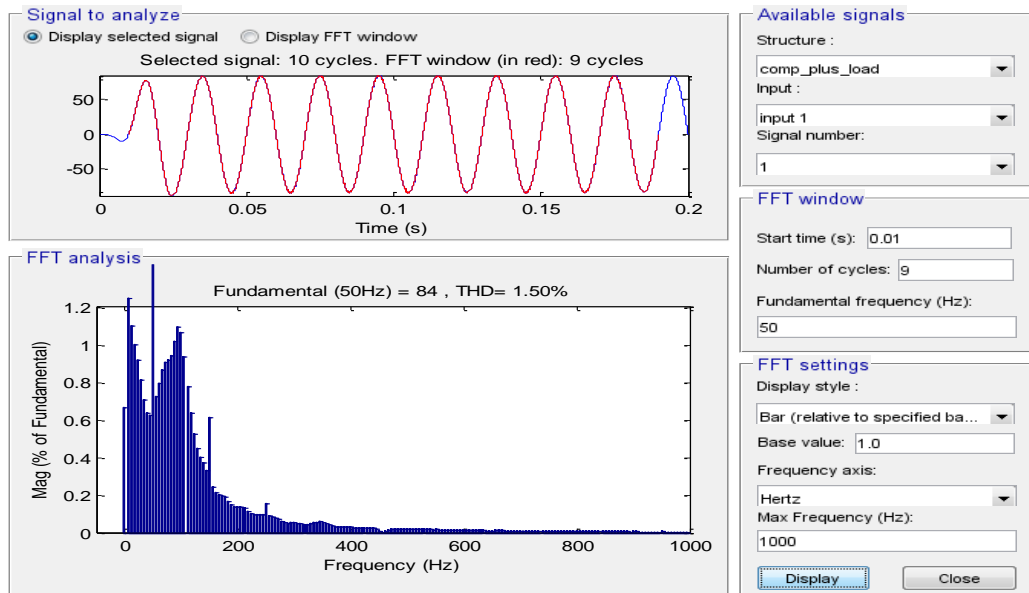


Fig. 11 FFT analysis of %THD on phase A with Filter

A. Analysis of FFT %THD for Harmonics with and Without Filter on Phase A

It is clear from these figures that THD decreases from 129.46% to 1.50% as shown in figs. 10 & 11.

IV. CONCLUSION

Attainment of shunt active power filter investigated on 3- Φ 400V power system with a wind generator acting as a distributed energy source.

- I. Instantaneous active power theory in conjunction with Clarke's transformation is found to provide reference harmonic current by choosing disturbance harmonics with more precision & ease of implementation.
- II. Results show that THD has been reduced significantly within the standard recommendation of IEEE-519. We can also observe that the power (active & reactive) and power factor also be enhanced.

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