Comparative Analysis of PQ in RES using Custom Power Devices

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Abstract: *Recently, renewable energy sources have become more popular in power system. These renewable energy sources should perform reliable operation, provide clean energy to the grid with minimum Total Harmonics Distortions (THD).The operating performance of wind electric generators has considerable stress on the quality of electric power and reliability in context with the performance power systems.*
Similar to conventional power plants, wind power plants must provide the power quality required to ensure the stability and reliability of the power system to satisfy the customers connected to the same grid. Development in wind generation system has proven to be an increasing threat to the stability and power quality of the grid connected to the wind power plant. Performance of the induction generator connected with the grid is also analysed for power quality problems for better grid operation. The simulation has been performed with the assistance of MATLAB. To investigate and improvise the system performance Simulink model of modified STATCOM as shunt active filter is also presented. The compensator is designed to inject reactive power to overcome power quality problems and also for better grid operation.

Keywords: Active power filter, Power Quality (PQ), Custom Power Devices (CPD) , Renewable Energy Systems(RES)

1. Introduction

The environmental degradation such as pollution, global warming, and greenhouse gas emissions which are caused by conventional sources of energy and accelerated by ever-growing industrial activities throughout the world is a concern for the non-conventional energy sources which are clean, reliable, and abundant in nature. The emphasis is given on harnessing renewable energy sources (RES) for generating electricity and technological innovation is needed to utilize these energy sources to an optimum level and to obtain greater efficiency and reduction in emissions.

Power quality (PQ) of the medium to low voltage power transmission system is becoming a major area of interest due to increased application of renewable energy penetration to the grid. Integration of renewable energy systems to the grid takes place with the aid of power electronics converters are the major sources of interference resulting in harmonic pollution into the system thereby creating major PQ problems if not properly implemented. Therefore, Performance evaluation of the renewable system with respect to power quality analysis is a paramount activity. Use of Custom Power Devices (CPD) like STATCOM, DVR and combination of series and shunt active power filter are the latest development of interfacing devices between distribution supply system and consumer appliances to compensate reactive power and harmonic disturbances.

The proposed compensator comprises voltage source converter, (VSI) which consists of advanced power semiconductor switches to provide flexibility in voltage control for power quality improvement. This method is preferable for the applications with frequently fluctuating loads and power flow. By using high frequency switching PWM, the high speed switching converter will generate smooth current with low harmonic content. Paper presents modelling of an induction generator using MATLAB.

2. Grid-Connected Renewable Energy Systems

Power providers want to be sure that your system includes safety and power quality components. These components include switches to disconnect your system from the grid in the event of a power surge or power failure (so repairmen are not electrocuted) and power conditioning equipment to ensure that your power exactly matches the voltage and frequency of the electricity flowing through the grid. A grid-connected system allows you to power your home or small business with renewable energy during those periods (daily as well as seasonally) when the sun is shining, the water is running, or the wind is blowing. Any excess electricity you produce is fed back into the grid.

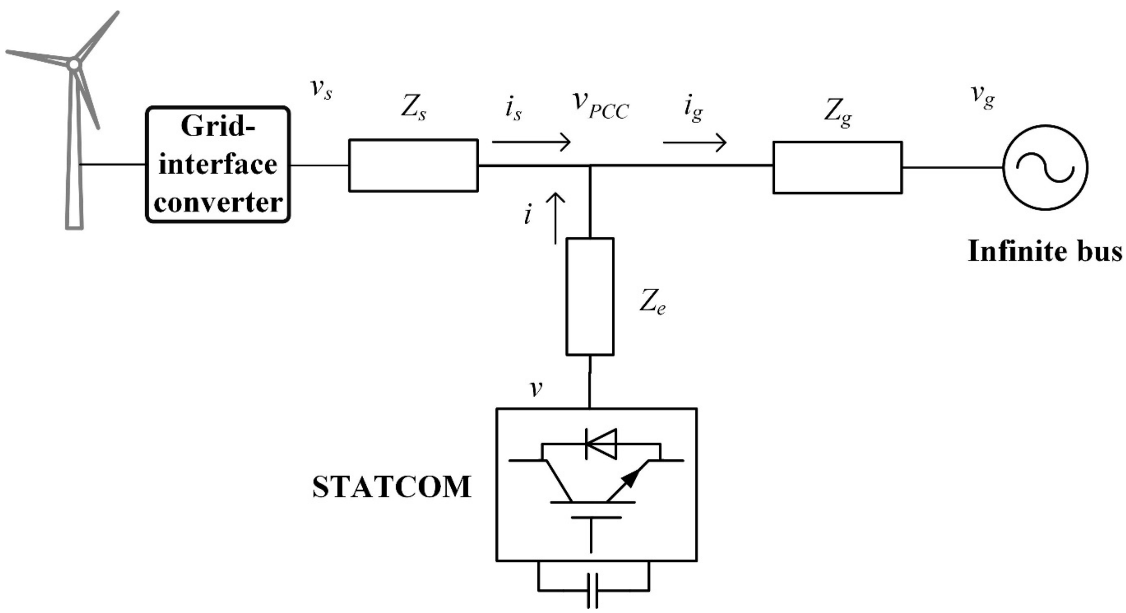

Fig.1 wind to Grid connection WITH STATCOM

3. Materials and Methods:

3.1 Power Quality Mitigation Techniques:

There are different solutions to mitigate Power Quality problems. The solution adopted will be tailored specifically to the problem and site. The measures used in this paper to deal with Power Quality disturbances are,

1) Static VAR Compensator (SVC).

2) Static Synchronous Compensator (STATCOM).

3) Harmonic Filters.

4) Surge arresters.

One of the most common methods of controlling harmonic distortion is to place a passive shunt harmonic filter close to the harmonic producing load(s), which is a source of harmonic current. The objective of the harmonic filter is to shunt some of the harmonic current from the load into the filter, thereby reducing the amount of harmonic current that flows into the power system. The simplest type of shunt harmonic filter is a series inductance/capacitance (LC)

3.2 Modelling of LC Filter to improve Power Quality

Harmonic filters are designed to have low impedances to ensure that the harmonic currents are flowing between the loads and the filters, rather than reaching the power source and the other components of the electrical power generation and distribution systems.

In general, harmonic filters are “shunt” filters because they are connected in parallel with the power system and provide low impedance paths to ground for currents at one or more harmonic frequencies. For power applications, shunt filters are almost always more economical than series filters.

Power harmonic filters are mainly used to either block harmonic currents from flowing through electrical power distribution systems or locally isolate and cancel them. There are three main classifications of filters: (1) passive, (2) active, and (3) hybrid.

Passive filters are made up of reactive components like capacitors, inductors, and resistors. They are tuned to provide a low impedance path for specific currents with undesirable harmonic frequencies. Active filters rely on active power conditioning electronic devices to compensate for unfavourable harmonic currents but are more expensive to install than passive filters. Hybrid filters are combinations of active and passive filters, used in specific applications to take benefits of both filters.

LC filter is a second-order passive filter, which contains two reactive components that are inductor and capacitor. The designed LC filter reduces the Total harmonic distortion in the system and can also improve power factor of the system.

4. Results and Discussions:

4.1 Analysis of Power Quality Parameters:

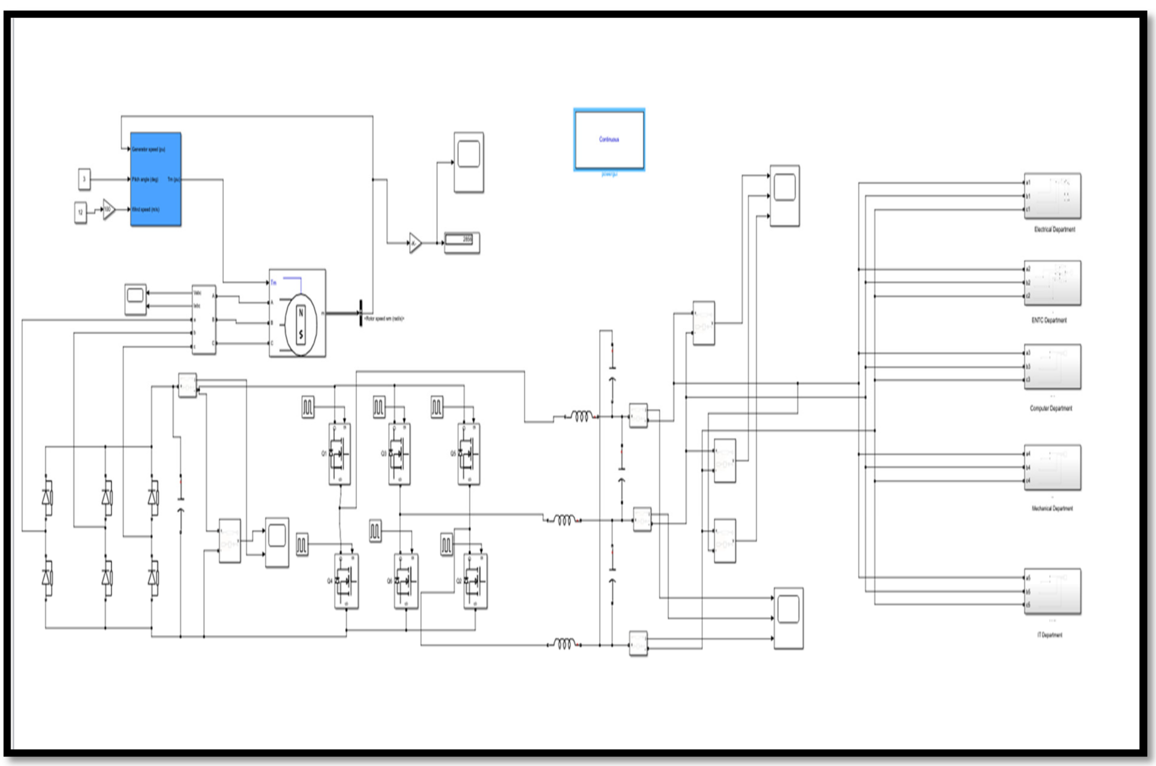

Fig:2: Simulink Model of Wind Generation System with Filter.

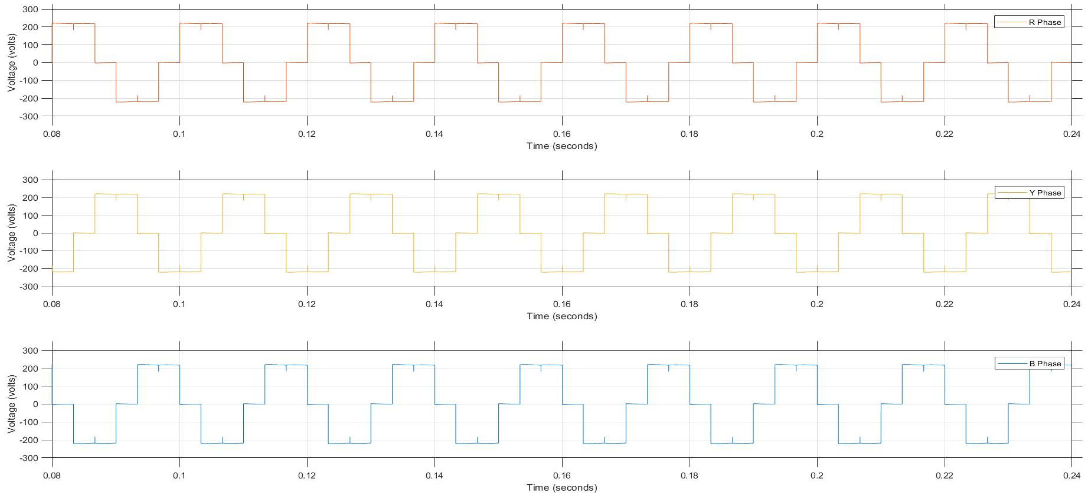

Fig:3: Three-phase Inverter Output Voltage Waveform without Filter.

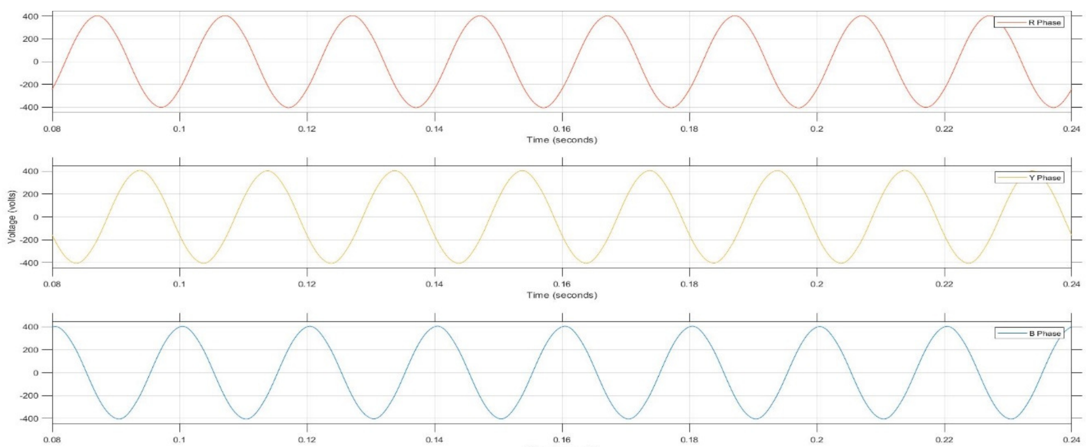

Fig: 4: Three-phase Inverter Output Voltage Waveform with Filter.

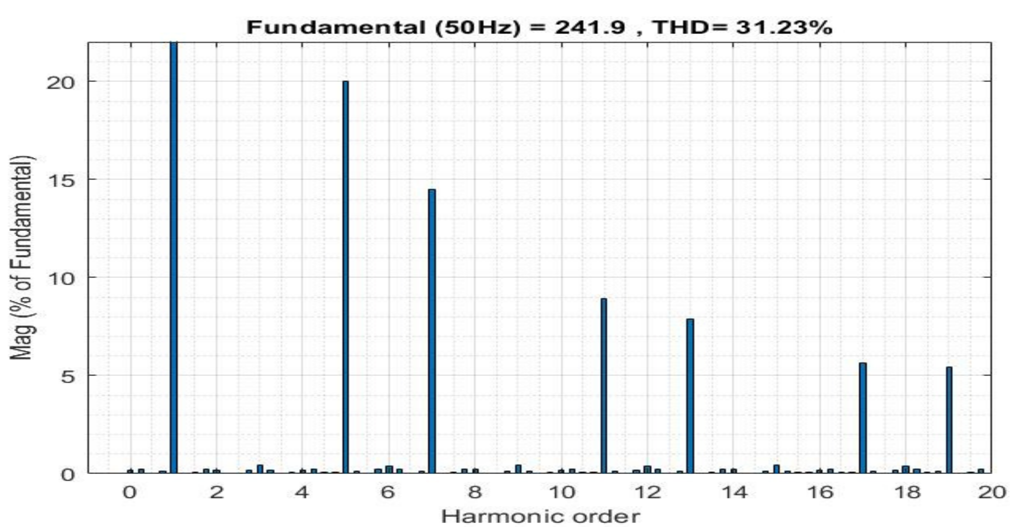

Fig: 5: Total Harmonic Distortion without Filter

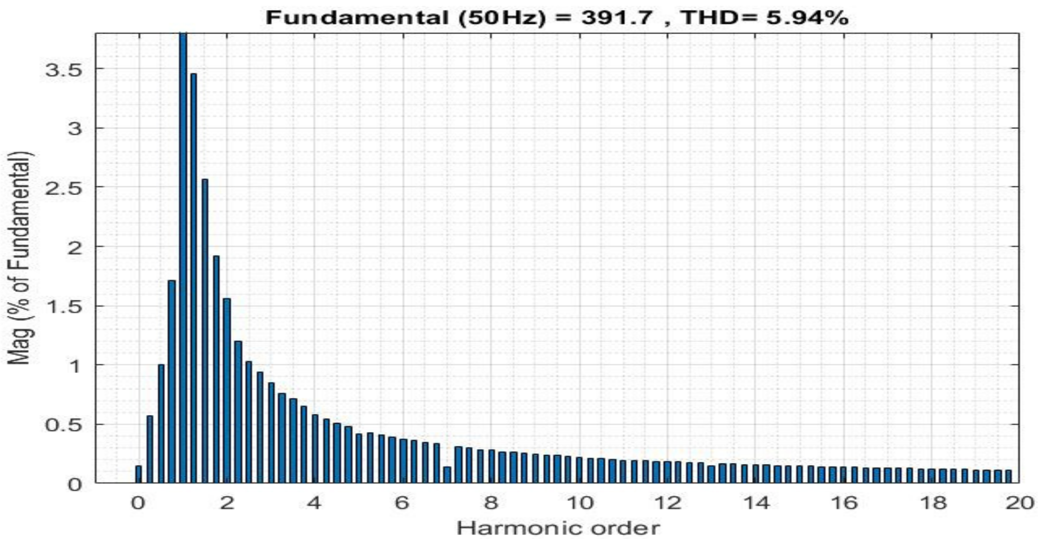

Fig: 6: Total Harmonic Distortion with Filter

Fig:2 depicts the simulink Model of Wind Generation System with Filter. The simulation results are compared with LC filter and Without LC filter. Fig.3 and Fig.5 shows the response without use of LC filter and Fig. 4 and Fig.6 shows the response with application of LC filter. Without LC filter the waveform is two step response which is not sinusoidal and total harmonic distortion is 31.23%. After application of LC filter, the response observed is a pure sine wave with harmonic reduction (THD) from 31.23 % to 5.94%. Also it is noteworthy that the passive filter circuit filters out only a single harmonic. There should be a separate filter for each compromise that needs to be filtered. Passive filters can have multiple switching steps for multiple frequencies. It may also have multiple steps focusing on specific frequencies. The tuning frequency, capacity and network impedance determine the efficiency of the filter. Each harmonic requires one step to reach the desired frequency. With a negative filter, the frequency of the filter level cannot be adjusted to match the current relationship with the filter, so avoid high-frequency filters. Additionally, negative filtering can be done not only from the 3rd harmonic to the 25th harmonic, but also beyond that. Each filter must have a filter step to prevent all possible low levels (i.e. higher harmonics) from developing. Passive filters are often used as tuned filters. In commercial networks, these filters are usually tuned to harmonics of the order of ν = 5, 7, 11, 13, ...

4.2 Design and development of STATCOM to improve Power Quality

A STATCOM is a controlled reactive-power source. It provides the desired reactive-power generation and absorption entirely by means of electronic processing of the voltage and current waveforms in a voltage-source converter (VSC). A single-line STATCOM power circuit is shown in Fig. 3.6(a), where a VSC is connected to a

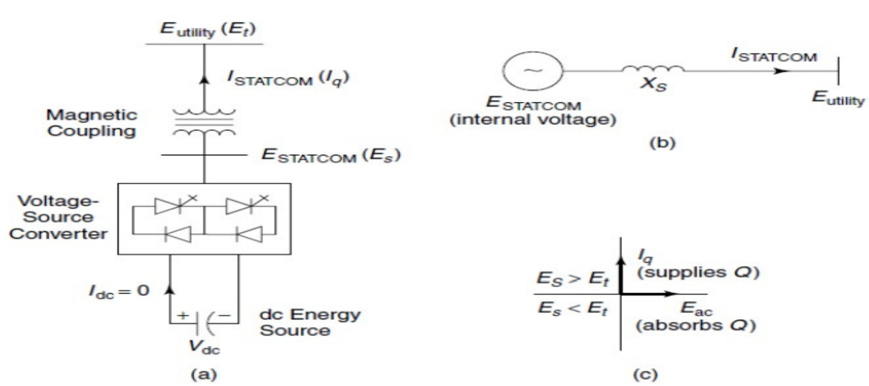

Fig: 7(a),(b),(c) STATCOM Power circuit, Equivalent circuit, Power exchange respectively

utility bus through magnetic coupling. In Fig. 3.6(b), a STATCOM is seen as an adjustable voltage source behind a reactance meaning that capacitor banks and shunt reactors are not needed for reactive-power generation and absorption, thereby giving a STATCOM a compact design, or small footprint, as well as low noise and low magnetic impact. The exchange of reactive power between the converter and the ac system can be controlled by varying the amplitude of the 3-phase output voltage. Fig 7(a),(b),(c) depicts the STATCOM Power circuit, Equivalent circuit and Power exchange respectively. If the amplitude of the output voltage is increased than that of the utility bus voltage *Et*, then current flows through the reactance. It is from the converter to the ac system. Converter generates capacitive-reactive power for the ac system. If the amplitude of the output voltage is decreased below the utility bus voltage, then the current flows from the ac system to the converter and the converter absorbs inductive-reactive power from the ac system.

4.3 Case Study of An Educational System

A case study of an Educational Institute with 25 KV/400V, 4 MVA distribution system is considered to analyse the impact of power quality parameters. Simulation with MATLAB Simulink has been presented here.

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Table 1: System Parameters

Sr. No.	Parameter	Value
1	Transmission line voltage	25 kV
2	Transformer	25 kV / 400 V, 4 MVA
3	Line frequency	50 Hz
4	Nominal Voltage	400 V

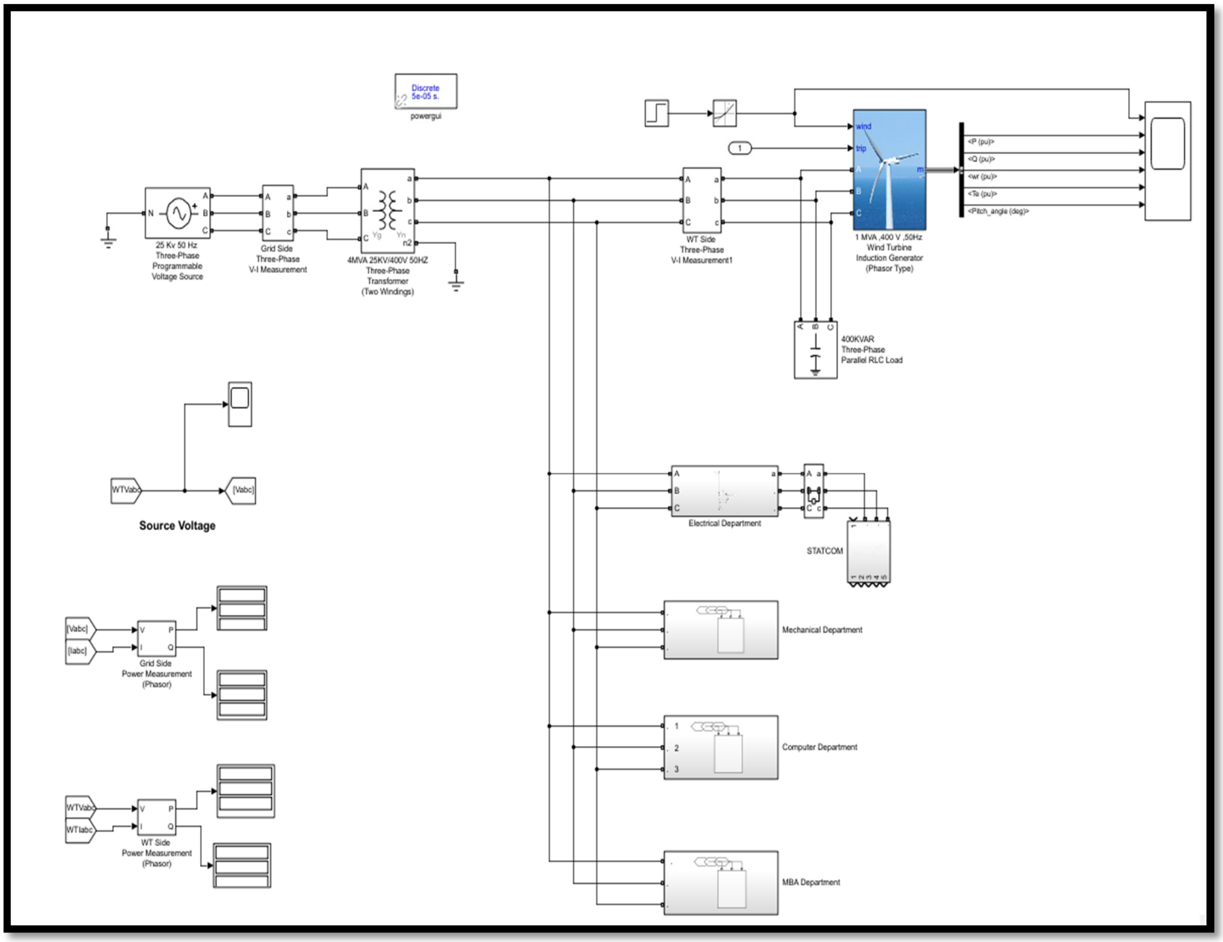

Fig.8 Simulation model of case study

Fig.8 shows the simulation model of the considered case study of an educational institute. Fig.9 is the three-phase voltage and current output of the inverter. We observe from the Inverter Output voltage and current that, is not a pure sinusoidal wave but a non-sinusoidal waveform containing harmonics. The reason being it is the power quality issue of harmonic distortion. The STATCOM & LC Filter is also connected to the system with the Inductor in series and the Capacitor in parallel. Now, we observe in Fig.10 that the three-phase voltage and current outputs of the inverter becomes sinusoidal waveforms. This shows that the harmonic content in the system has been reduced with the application of STATCOM. The waveforms shown are for the D3 department.

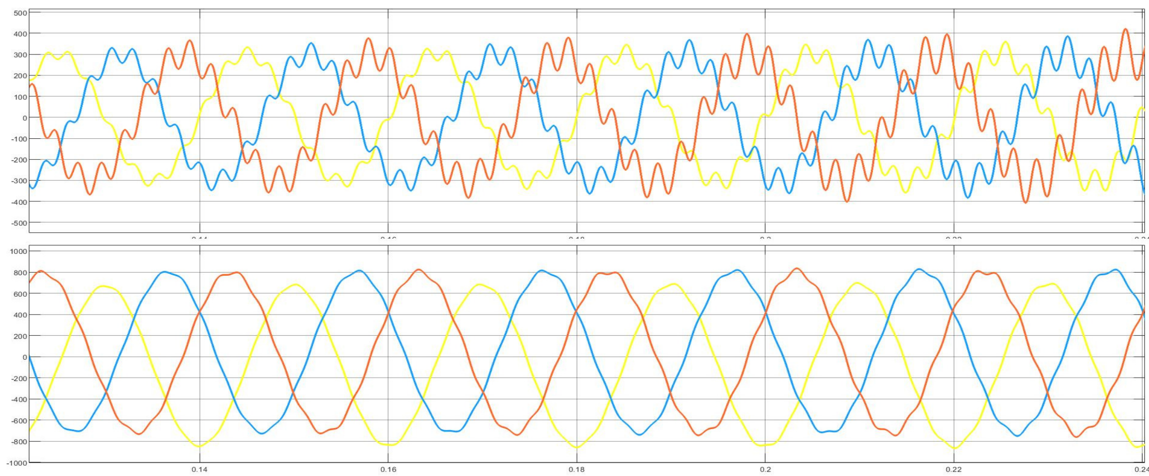

Fig 9 : Waveforms of D3 Department without STATCOM: (a) Voltage and (b) Current.

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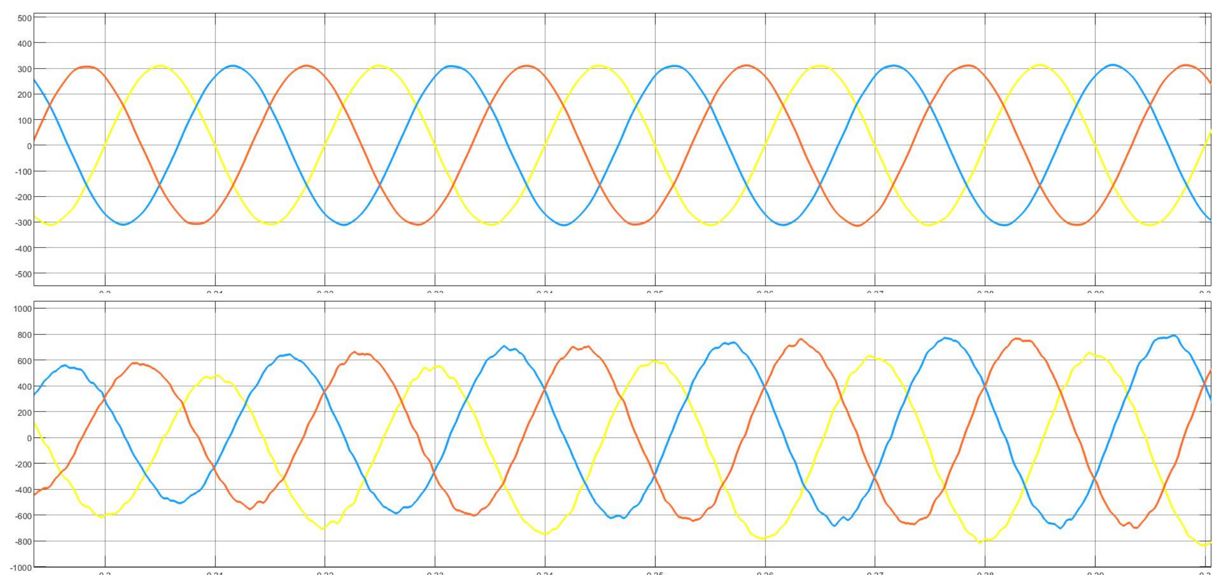

Through Fast Fourier Transform (FFT) Analysis we calculate the Total Harmonic Distortion (THD) in the system. The figures shown below display the THD values with and without application of STATCOM. In Fig. 11(a), we observe that the THD (Total Harmonic Distortion) is 33.88% and it has been reduced to 0.62% In Fig. 12 with application of STATCOM. Likewise all the five departments are analysed for power quality parameter of Total Harmonic Distortion especially in current. The results are tabulated in Table 2 given below.

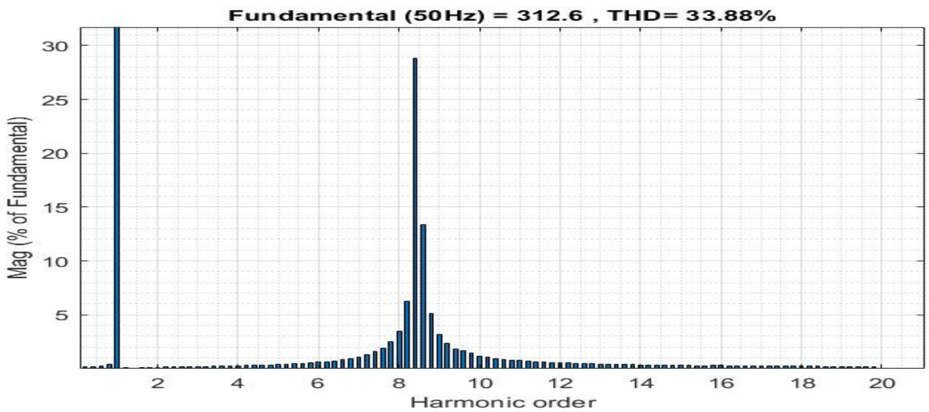

Fig .11.Total Harmonic Distortion without STATCOM

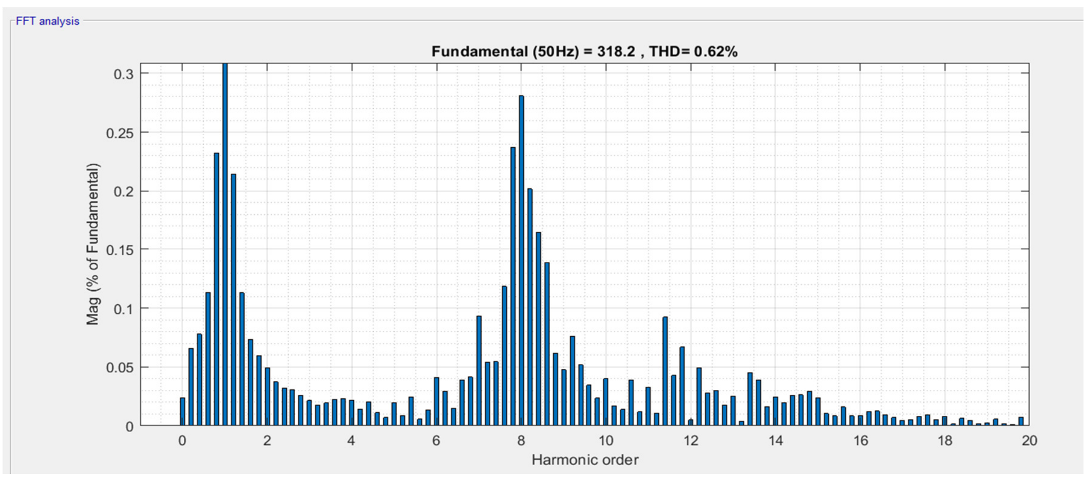

Fig .12. Total Harmonic Distortion with STATCOM

Table 2: THD analysis of all departments with and without STSTCOM

Department	Load	Total Harmonic Distortion Without STATCOM	Total Harmonic Distortion with STATCOM
D1	100 KVAR	13.38 %	0.61 %
D2	250 KVAR	25.79 %	0.52 %
D3	400 KVAR	33.88 %	0.62 %
D4	550 KVAR	40.59 %	0.55 %
D5	600 KVAR	41.52 %	0.48 %

5. Conclusions:

The paper presents the STATCOM-based scheme for power quality improvement in grid connected wind generating system. The operation of the STATCOM in MATLAB/SIMULINK for maintaining the power quality is simulated. The power quality problems faced after integrating wind plant to the supply grid has been simulated and revealed. From the findings after simulating a case study for five different departments with the influence of grid tied wind power generation, the total harmonic distortion has been reduced by application of STATCOM from 33.88% to 0.62% for department D3 under consideration of a case study. As THD is the major factor of the power quality, the attention was given to reduce it and matain as per the standards prescribed by IEEE 519. Similar analysis is also carried out for all the departments of an institute and promising reduction in current THD has been observed.

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