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Enhancement of Power Quality in Wind Connected Energy System using Power Filter Compensation Scheme

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Abstract—*Wind is an ample renewable source of energy that can be used to supply power in remote areas or it can also be supply power to a grid connected power system, most of load like motoring load, home appliances are non-linear in nature, change in load and variation in wind speed are reasons for power quality issues like fluctuation in voltage, harmonic, low power factor etc. This paper presents a FACTS based Power filter compensator controlled by a tri loop with PI and PID controller. The power filter compensation scheme is used for reduction in losses, power factor correction, mitigation of harmonics, voltage stabilization using MATLAB Simulink software environment.*

1. INTRODUCTION

Wind energy is an ample renewable energy source, by increasing of power demands and limitation of fossil fuel renewable energy source play very important role. Wind energy growing with 20% annual rate from last decades is a remarkable achievement. Wind energy operate without emitting any greenhouse gases, air pollution or other emission that means wind energy is one of the most clean source of renewable energy[1-2].

Wind Energy system is connected to isolated load in remote area or it can use to supply power to a grid system. Wind energy produced by many generators like DFIG, SCIG, direct drive synchronous generator but SCIG is preferably used in wind generation system rather than other generators because of its constant speed operation [3].

Power Quality problem is associated with variation in voltage, current, frequency that causes an equipment failure or malfunction of power system. Harmonics, fluctuation in voltage and dynamic switching excursions can be reasons for equipment failure or fault in the system [4]. Insufficient utilization of electric energy is increased reactive power and poor power factor is distorted voltage and current waveform.

In a modern electrical distribution network, there has been sudden change in non-linear loads like domestic appliances, speed drives power electronics based loads etc. cause power quality problem like variation in voltage, current, frequency and harmonics.

Change in wind speed and load variation can affect prime mover energy and corresponding power into connected system, there are so many methods used to improve quality of power for the system [5], some methods are proposed by controlling the generator excitation and some of methods are proposed for improving quality through FACTS like STATCOM, DVR, UPC etc. are effective but costly and complex.

This paper presents a low cost control device which improves power quality of the system, proposed controller is a FACTS based Power Filter Compensator (PFC) which controlled by a tri loop controller, this tri loop controller has basically three loops, first loop is for stabilization of voltage, second loop is for current and third loop is for maintain maximum energy utilization, sum of these loop is in form of error and this error signal send to PI or PID controller, output of these controller fed to PWM generator which operate IGBT switch to control capacitor bank that improves power quality. This method is simple and low in cost.

A single line diagram of wind connected system is shown in fig. 1. A PFC controller is connected at load bus to improve quality of power.

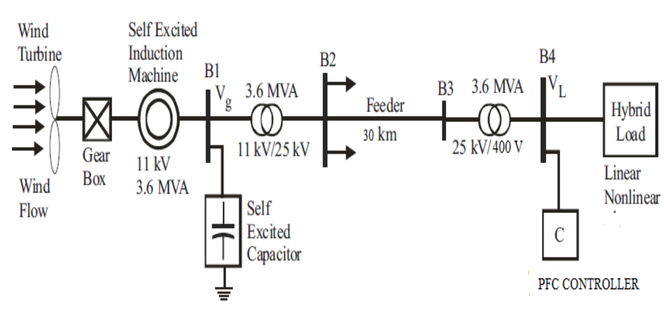

Fig. 1: Single Line diagram of wind connected AC system

2. POWER FILTER COMPENSATOR (PFC)

Power filter compensator (PFC) is a low cost series and shunt switched type filter [6]. PFC is based on tri loop controller controlled by PI and PID controller, tri loop calculate total error from its all three loops and fed to PI or PID controller which generate pulses for pulse width modulation (PWM) in ON-OFF switching sequence. Two IGBT switches are used for switching purpose connected to capacitor bank is connected to the system through a universal bridge (uncontrolled) and a fixed capacitor is also connected as shown in fig. 2.

When PWM operate IGBT switches, one switch is turn on and another switch is turn off that time a resistor and inductor connected with switches act as a low pass filter, when PWM turn off first switch second will turn on that time the connected capacitor bank fed reactive power to grid and low pass filter will out of circuit.

This scheme is very simple to install and low cost as compare to other FACTS schemes.

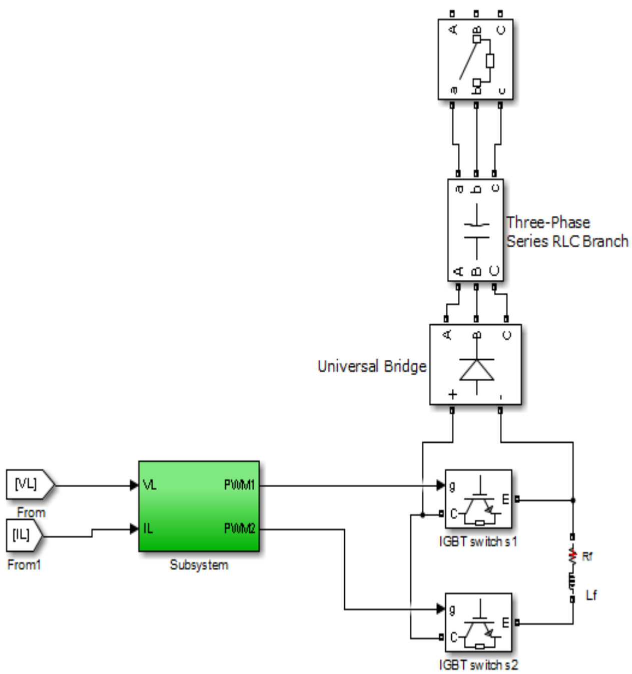

Fig. 2: Simulation diagram of Power filter compensator

3. SIMULATION OF TRI LOOP CONTROLLER

In this paper a tri loop based dynamic driven error controller is used for controlling the IGBT switches through PWM generator, tri loop controller has three loops, first loop collect Root Mean Square (RMS) value of load voltage and takes account of difference in voltage that is an error of voltage at load bus, second loop takes RMS value of current that called current error tracking loop and third loop is for maximum energy utilization under varying wind and load condition as shown in fig. 3 [7].

In second loop and third loop time delay is used and delay is taken by error method for fast response of system. Sum of error from all three loops is fed to PI or PID controller, PI controller has proportional and integral gains are 1and 5 and PID controller has proportional, integral and derivative gains are 0.5,10 and 1 respectively. The output from PI or PID is fed to PWM which compare with a fixed signal to and produce two pulses, these pulses are use to operate IGBT switches.

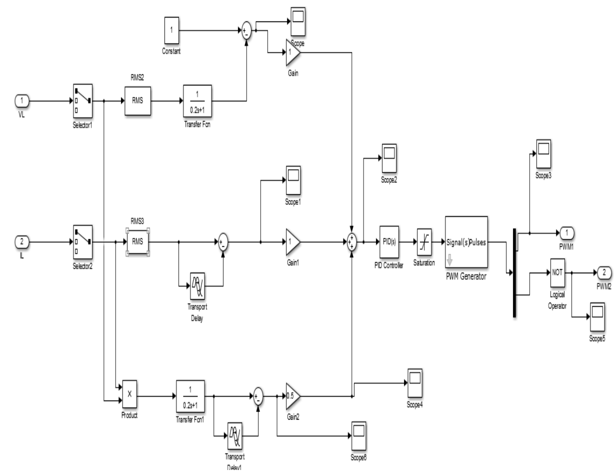

Fig. 3: Simulation diagram of tri loop controller

4. SIMULATED WIND ENERGY SYSTEM MODEL

The simulated wind energy system for proposed method is shown in fig. 4. A wind connected generator system generates the power for supplying different loads through a 30 km transmission line, the output of generator is fluctuated frequently due to change in wind speed and load. Linear and non-linear loads are connected to the system as shown in fig. 4, power filter compensation (PFC) scheme is connected at load bus for improving power quality of the system and a fixed capacitor bank is also connected with PFC scheme.

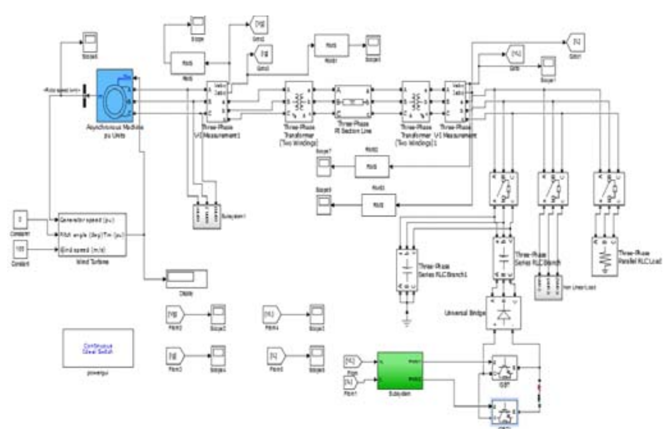

Fig. 4: Simulated wind energy system

5. SIMULATION RESULTS

Simulation results of proposed scheme are obtained in MATLAB Simulink software.

Case a) Without compensation scheme

The dynamic response of active power at generator bus and load bus are shown in fig 5 and 6, reactive power at generator bus and load bus are shown in fig. 7 and 8.

Frequency spectra are shown in fig. 9 and 10 for generator and load bus respectively for calculation of total harmonic distortion.

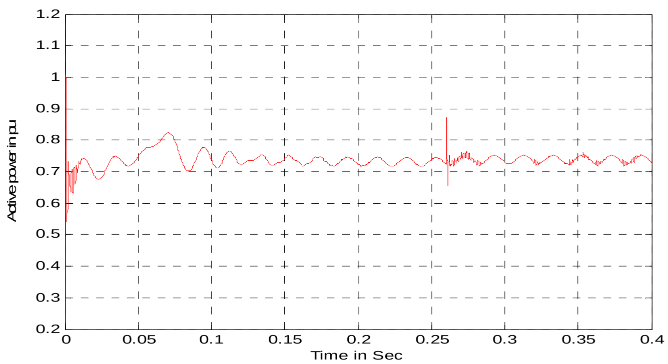

Fig. 5: Active power in pu at generator bus without compensation

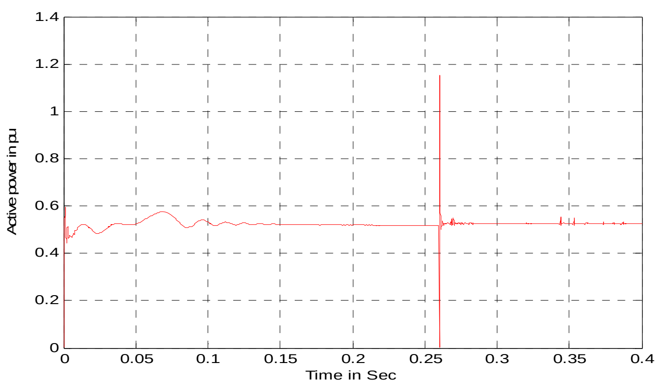

Fig. 6: Active power in pu at load bus without compensation

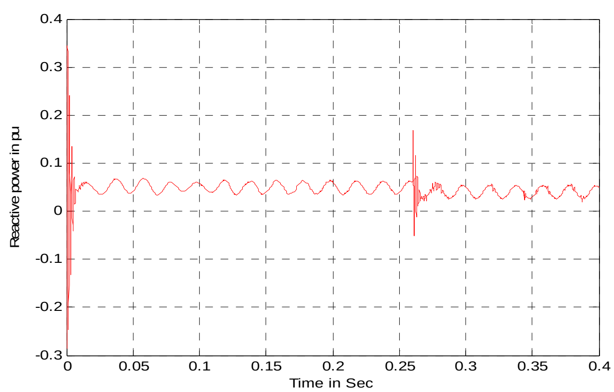

Fig. 7: Reactive power in pu at generator bus without compensation

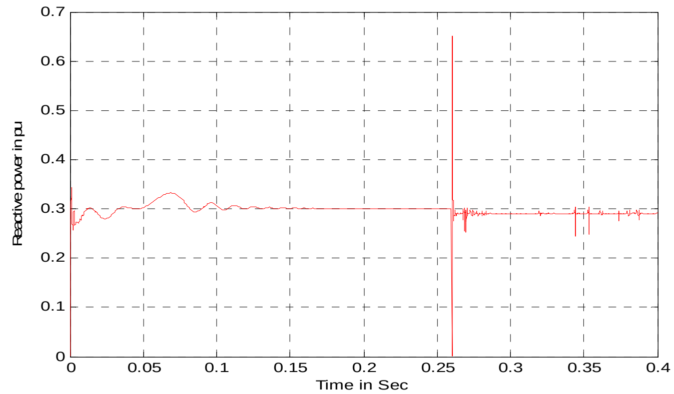

Fig. 8: Reactive power in pu at load bus without compensation

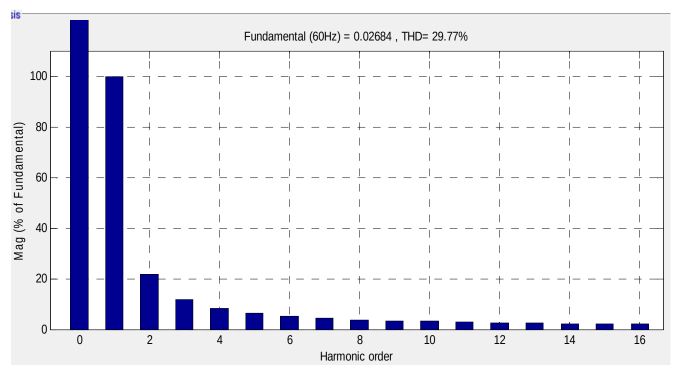

Fig. 9: The frequency spectrum of voltage waveform at generator bus without compensation

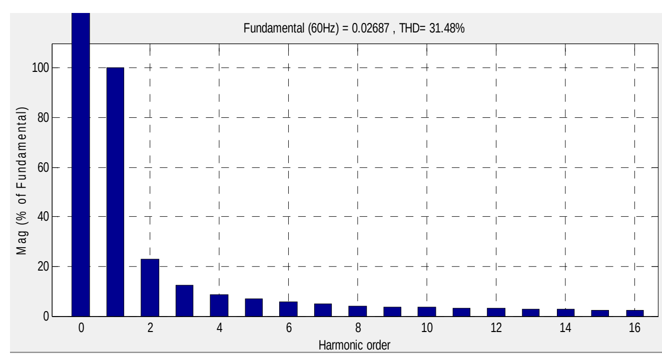

Fig. 10: The frequency spectrum of voltage waveform at load bus without compensation

Case b) PWM based PFC controller with PI controller compensation

The dynamic response of active power at generator bus and load bus with PI based PFC controller are shown in fig 11 and 12, reactive power at generator bus and load bus with PI based compensation scheme are shown in fig. 13 and 14 respectively.

Frequency spectra are shown in fig. 15 and 16 for generator and load bus respectively for calculation of total harmonic distortion when PI based power filter compensation scheme is employed. Reactive power is supplied by the PFC to the system at load bus so utilization of active power is increased and THD becomes less.

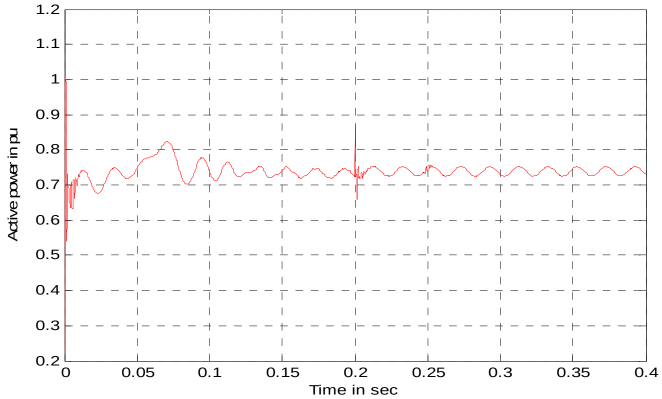

Fig. 11: Active power in pu at generator bus with PI scheme

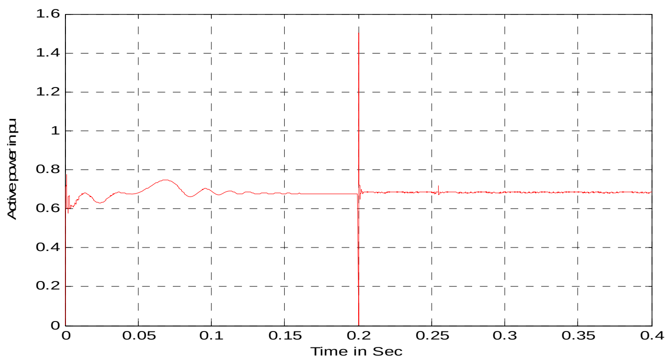

Fig. 12: Active power in pu at load bus with PI scheme

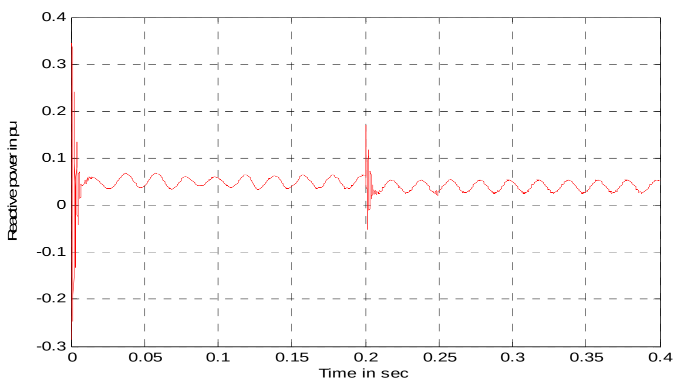

Fig. 13: Reactive power in pu at generator bus with PI scheme

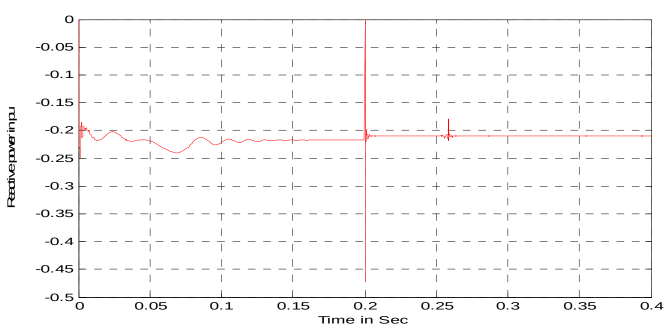

Fig. 14: Reactive power in pu at load bus with PI scheme

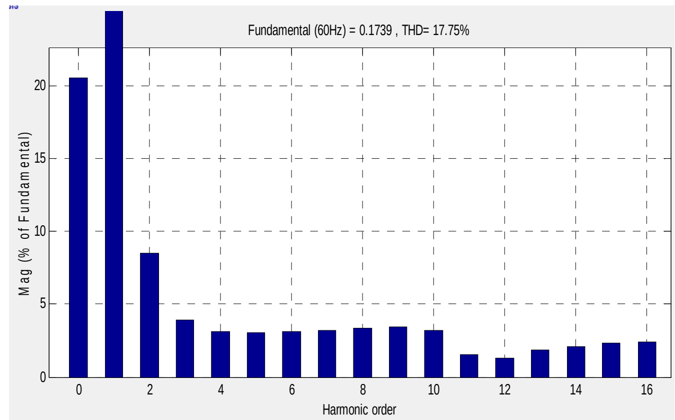

Fig. 15: The frequency spectrum of voltage waveform at generator bus with PI scheme

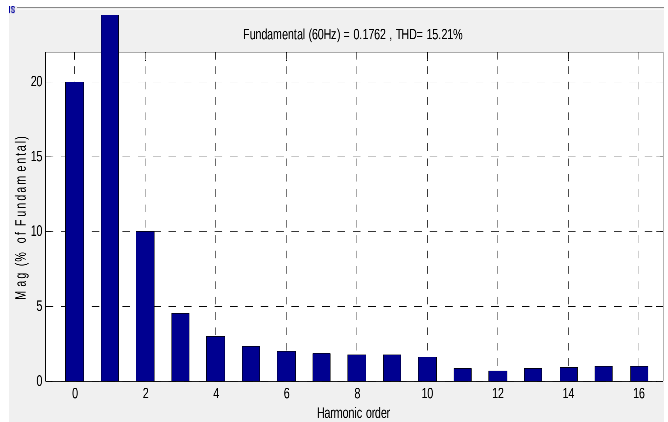

Fig. 16: The frequency spectrum of voltage waveform at load bus with PI scheme

Case c) PWM based PFC controller with PID controller compensation

The dynamic response of active power at generator bus and load bus with PID based PFC controller are shown in fig. 17 and 18 and reactive power at generator bus and load bus with PI based compensation scheme are shown in fig. 19 and 20 respectively.

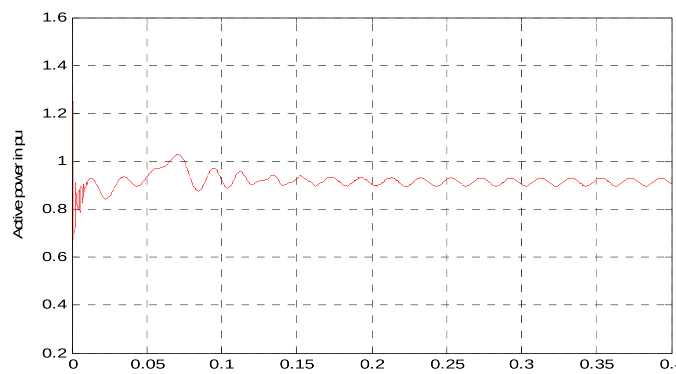

Fig. 16: Active power in pu at generator bus with PID scheme

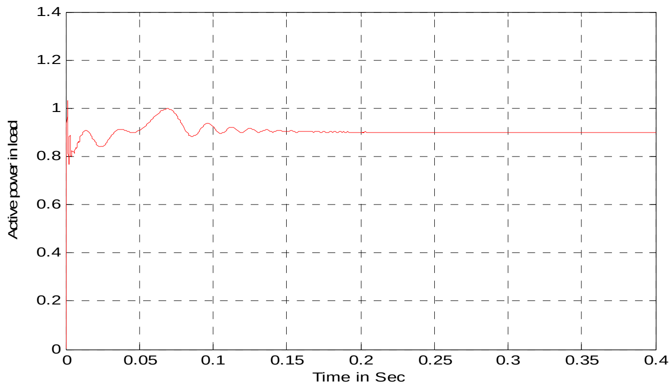

Fig. 17: Active power in pu at load bus with PID scheme

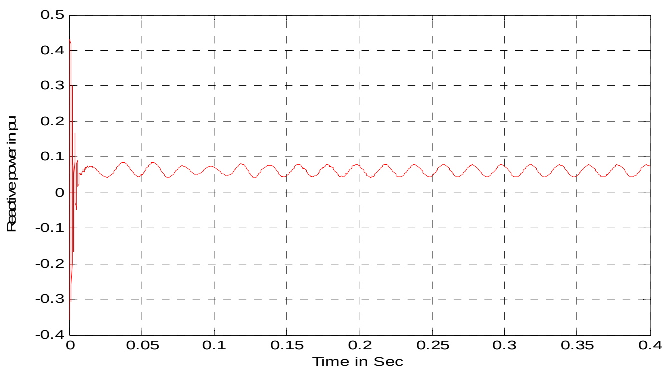

Fig. 18: Reactive power in pu at generator bus with PID scheme

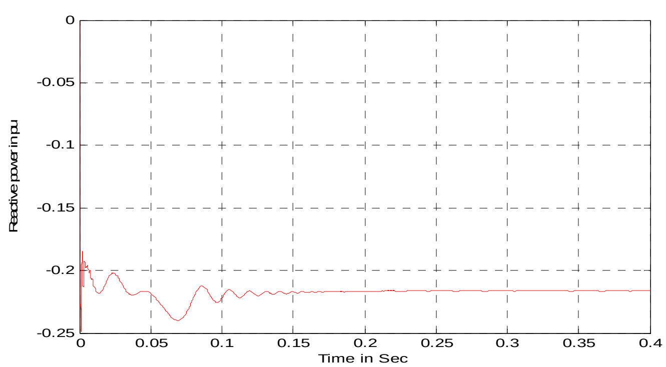

Fig. 19: Reactive power in pu at load bus with PID scheme

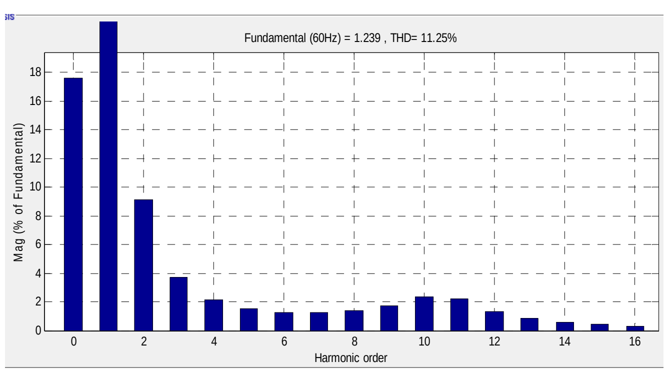

Fig. 20: The frequency spectrum of voltage waveform at generator bus with PID scheme

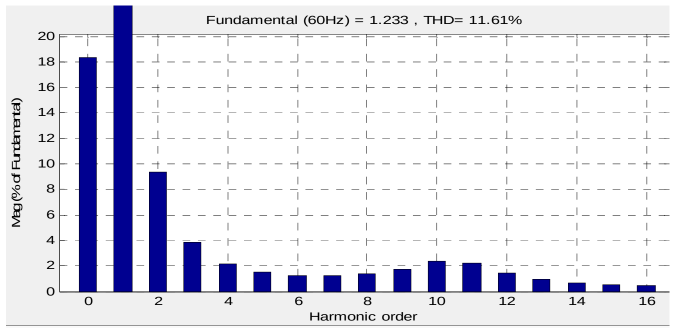

Fig. 21: The frequency spectrum of voltage waveform at load bus with PID scheme

6. CONCLUSION

This paper presents FACTS based power filter compensation scheme (PFC) using PI and PID controller for enhancement of power quality wind energy system. The power filter compensator using PWM is based on complementary switching process of capacitor bank connected with IGBT switch. The switching process controlled with the help of tri loop controller and pulse width modulation (PWM).

Total harmonic distortion are reduced up to 11.29% when PID based PFC scheme is employed where THD were 31.48% and 15.21% at load bus are obtained with PI based compensation scheme and without compensation respectively.

This scheme is fully validated for power quality enhancement and PID controller based scheme gives better results than PI based controller as shown in above results. Results of proposed scheme are obtained in MATLAB Simulink environment. The proposed scheme can be extended other power quality issues like power factor.

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