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Power Quality Improvement of Wind Farms Generation by UPQC

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***Abstract* – The demand of power is rising steeply with every year so in order to fulfill the demand of the market the non-conventional sources are coming into play and one of the these resources is wind. The power being supplied by wind is not up to the mark due to variation of wind and inverter being implemented in the wind generation system. Thus the need of power quality improvement is very high for wind generation systems. This can be done by using FACTS devices which are very effective in resolving issues related to Power quality. In this paper we will be using UPQC for enhancement of power which is being supplied by the wind turbine to the grid. The UPQC is considered for this job because it solves the purpose of shunt and series compensation simultaneously, hence it has an edge to other FACTS devices. The active power filters in UPQC are controlled by using synchronous reference frame theory (SRF), PI controllers and instantaneous reactive power theory.**

***Index Terms* - APF – active power filter, P – active power, Q – reactive power, SRF- synchronous reference frame, PCC- Point of common coupling**

I. INTRODUCTION

According to the IEEE power quality is defined as "the concept of powering and grounding electronic equipment in such a manner that is suitable to the operation of that equipment and compatible with the premise wiring and other connected equipments"[1]. The present scenario in the world of power sector is that the demand of power is rising and along with that the responsibility of power distribution companies increases for providing perfect quality of power. The issue of power quality arises mainly due to abrupt switching, power electronic devices, high inductive loads, lightening, induction of non conventional sources in grid etc. the main issues with poor power quality is that if affects the working of a device and if the device is a sensitive load then the device could get permanently damaged. Also the harmonics and transient in the power lines cause distortions in the communication lines which are in the vicinity of the power lines. So to removes these problems we need power compensation devices and FACTS devices are quite helpful in this. In FACTS devices the UPQC seems to be very appropriate for this purpose as it have series and shunt active power filters which can compensate voltage and current simultaneously when needed.When the wind farms are connected with the grids without using any power quality improving device the wave of voltage and current at the Point of Common Coupling (PCC) gets distorted as the power from wind has harmonics and transients in it. In this paper we are implementing the wind farm with doubly fed induction generator (DFIG) for power generation

II. POWER QUALITY PROBLEMS

There are various sorts of power quality problems which obstruct the good working of the devices. The power quality of the system is based on various parameters such as voltage, current, frequency, power factor etc, any change in the above mentioned parameters more than the permissible range give rise to the power quality issues.

The following figure gives the overview of power quality parameters:-

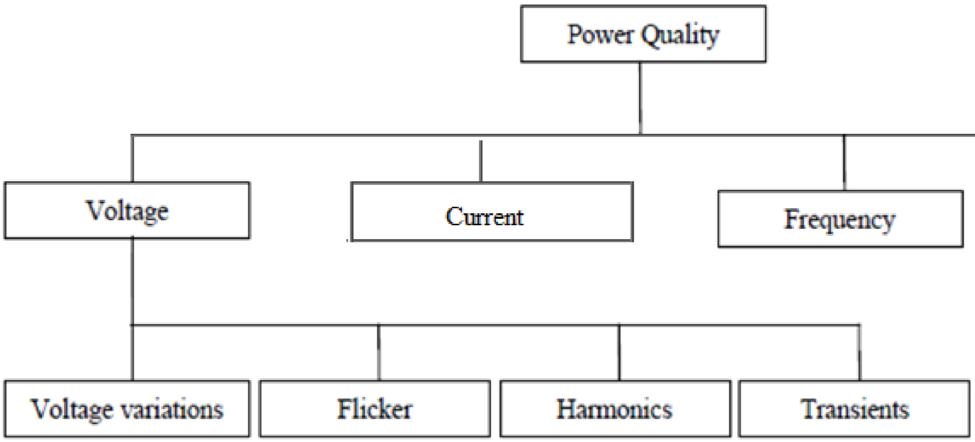


Fig 1 power quality phenomena [6]

III. UNIFIED POWER QUALITY CONDITIONER (UPQC)

The UPQC is one of the FACTS devices which counter the problem of both series and shunt compensation at a time. UPQC is able to solve the above issue because of its configuration as it has two active power filters i.e. series active power filter and shunt active power filters. The series filter is compensates the voltage sag and swell and the shunt filter is there to compensate the reactive power and hence counters the current harmonics and also regulates the DC link voltage [2]. UPQC can works under two configurations i.e. Left shunt UPQC and Right shunt UPQC

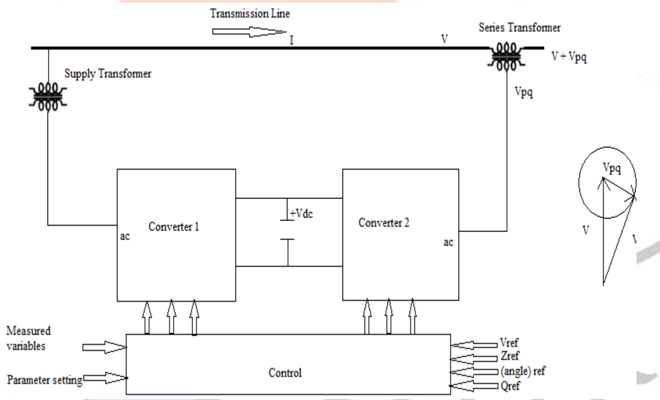


Fig 2 Basic configuration of UPQC [4]

IV. CONTROL STRATEGY FOR UPQC

- **Controller for series APF**

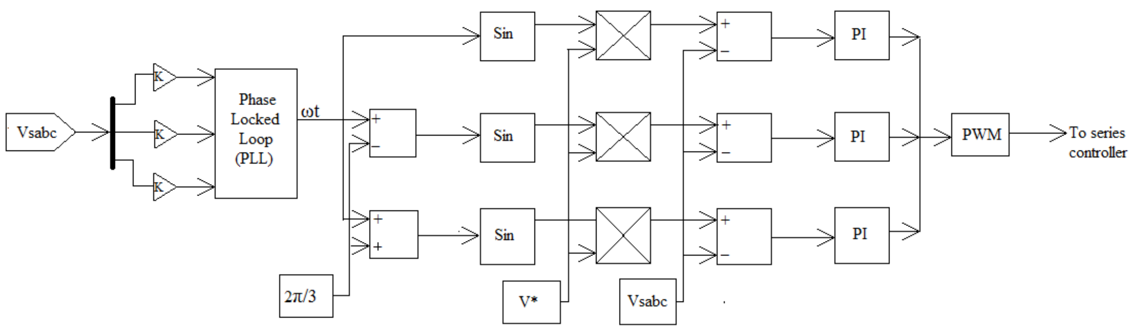


Fig 3 Series controller

In the control strategy for the series filter the supply from the source is being fed to the PLL by multiplying it with a suitable gain 'k' further the weighted gain 'wt' is multiplied with the sin function to obtain sinωt, sin(ωt-2π/3) and sin(ωt+2π/3). Further these signals are multiplied with the desired voltage value which we require at the PCC. Now to create the error signal we compare the source voltage with the voltage vectors formed after multiplying desired voltage with sinωt, sin(ωt-2π/3) and sin(ωt+2π/3) in previous steps. Now this error is injected into the PI controller and after that the signal are send to pulse width modulator with carrier frequency of 1080 Hz. Hence the PWM send gate pulses to the series controller according to the variation in the line voltage. Hence the series filter triggers at that particular instant to tackle the voltage fluctuation and harmonics thus smoothening the voltage waveform.

- **Controller for Shunt APF**

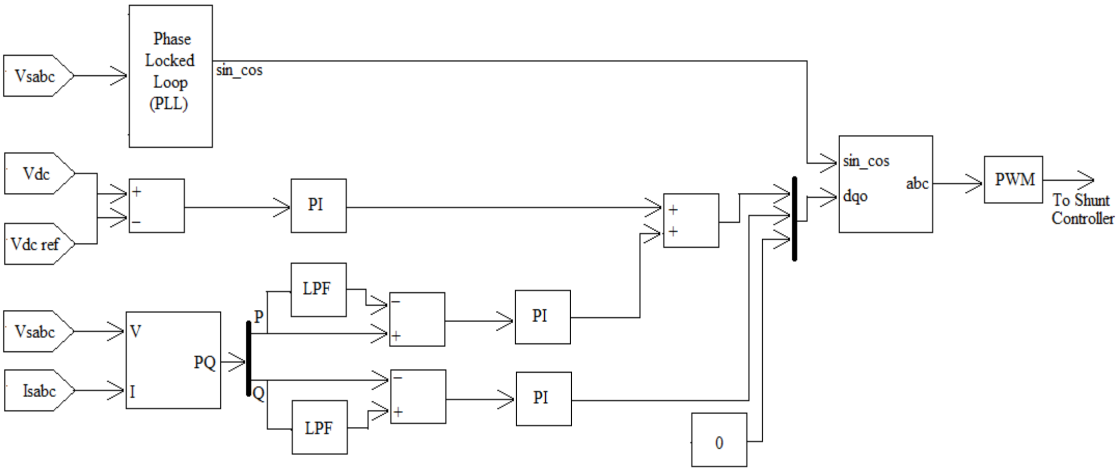


Fig 4 Shunt controller

The controller above described works on the Synchronous Reference Theory and instantaneous Reactive power theory. In this the voltage an current from the source side are fed to the P&Q generating block and hence we get active and reactive power i.e. P&Q respectively. After this the P&Q are fed to the low pass filters (LPF). Then the P&Q from LPF is compared with P&Q from the PQ generating block. Then the error is send to the PI controllers, output of PI controller fed with P is added to the output of PI controller being fed with difference of Vdc and Vdc ref. this component is regarded as 'd' axis component and along with that the Q signal from PI controller is regarded as 'q' component in 'dqo' axis. Now these 'd' and 'q' components are given to the multiplexer with a constant '0' to produce 'dqo' components. Further these components are fed into inverse Park's transformation block along with 'sin_cos' being generated at PLL which was fed by Vabc from source. Thus this inverse Park's transformation block converts components into 'abc' rotating frame by multiplying with matrix T , which is given as[3];-

$$\sqrt{\frac{2}{3}}\begin{bmatrix} \cos\theta & -\sin\theta & \frac{1}{\sqrt{2}} \\ \cos\left(\theta-\frac{2\pi}{3}\right) & -\sin\left(\theta-\frac{2\pi}{3}\right) & \frac{1}{\sqrt{2}} \\ \cos\left(\theta+\frac{2\pi}{3}\right) & -\sin\left(\theta+\frac{2\pi}{3}\right) & \frac{1}{\sqrt{2}} \end{bmatrix}$$

Then the output of inverse Park's transformation block id fed to the PWM and hence gate pulse[5] are produced to be given to the shunt controller to compensate the reactive power & mitigate current harmonics.

V. Simulation and Results

In this section we have compared the power quality of the grid in which power from wind farms was being injected with and without using UPQC

- **Supply from wind farm**

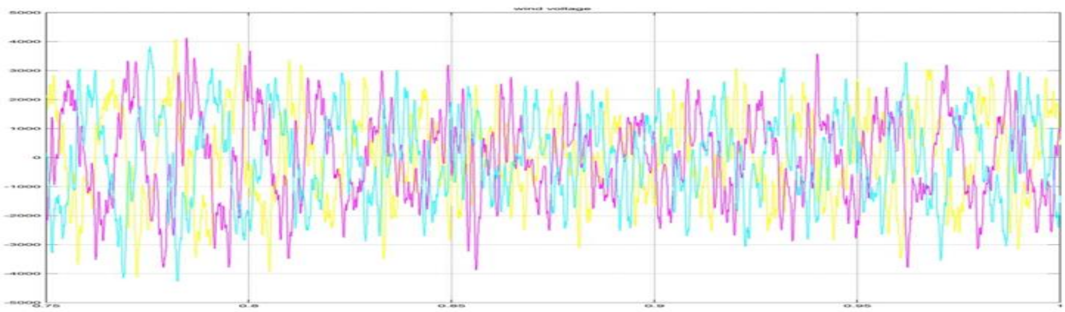


Fig5 Voltage from wind farm

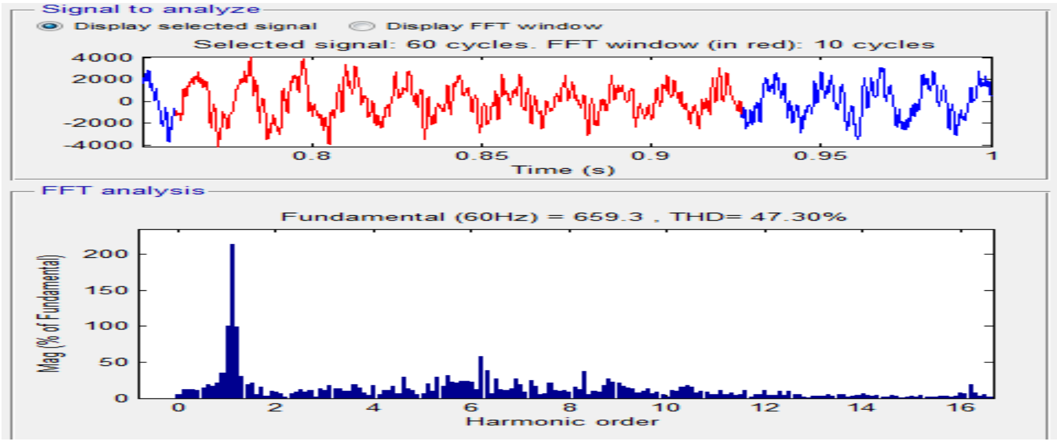


Fig6 voltage THD from wind turbine

The above waveforms shows that the voltage being fed into the grid is very much distorted as the THD level of voltage is 47.30% which is not acceptable.

- **System without compensation**

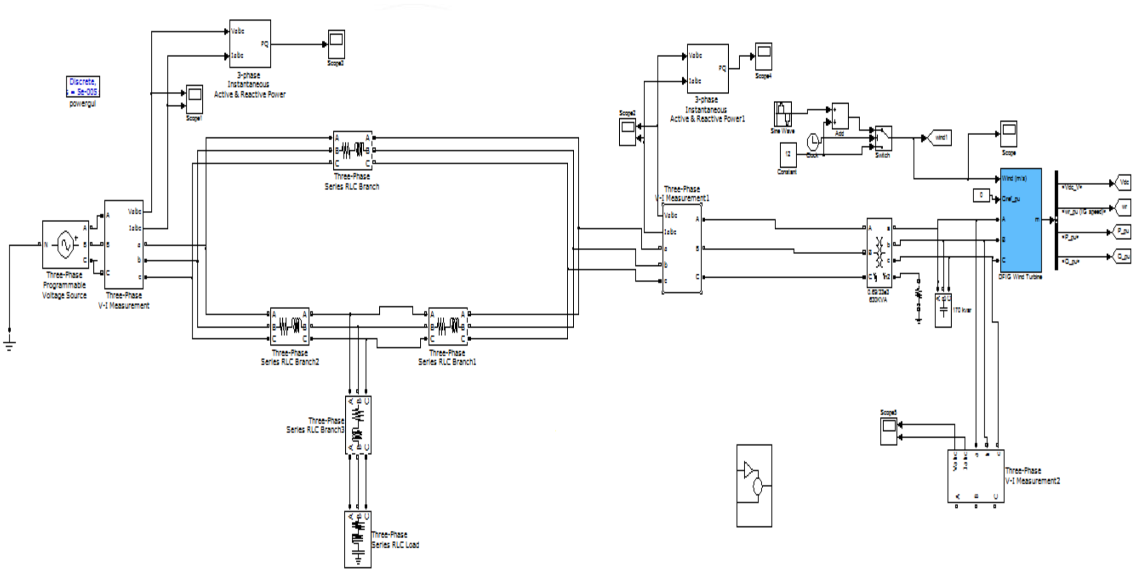


Fig7 System with compensation

As we have taken Programmable voltage source so the effect on the voltage waveform on the grid side not much but current waveforms gets fully distorted and analysis is shown below

a. Current at PCC

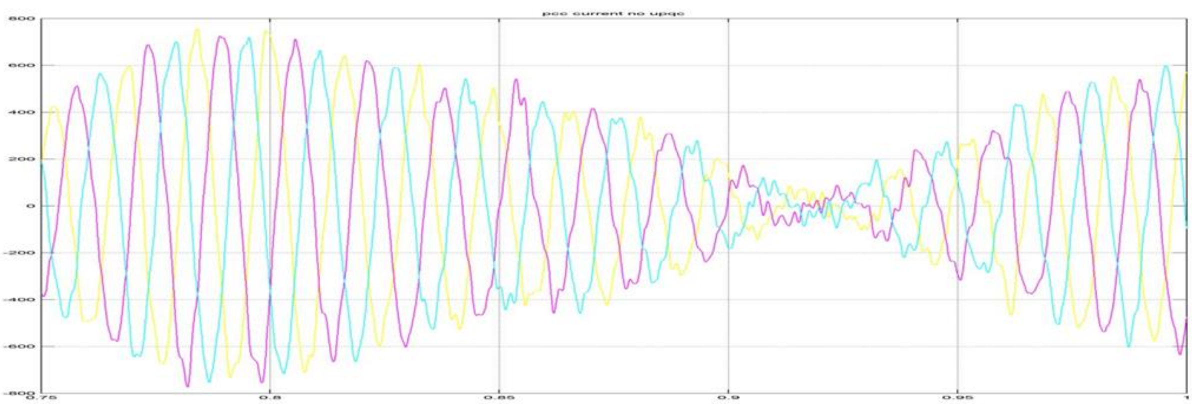


Fig 8 Current at PCC

Corresponding to this waveform the THD analysis of the current is shown below

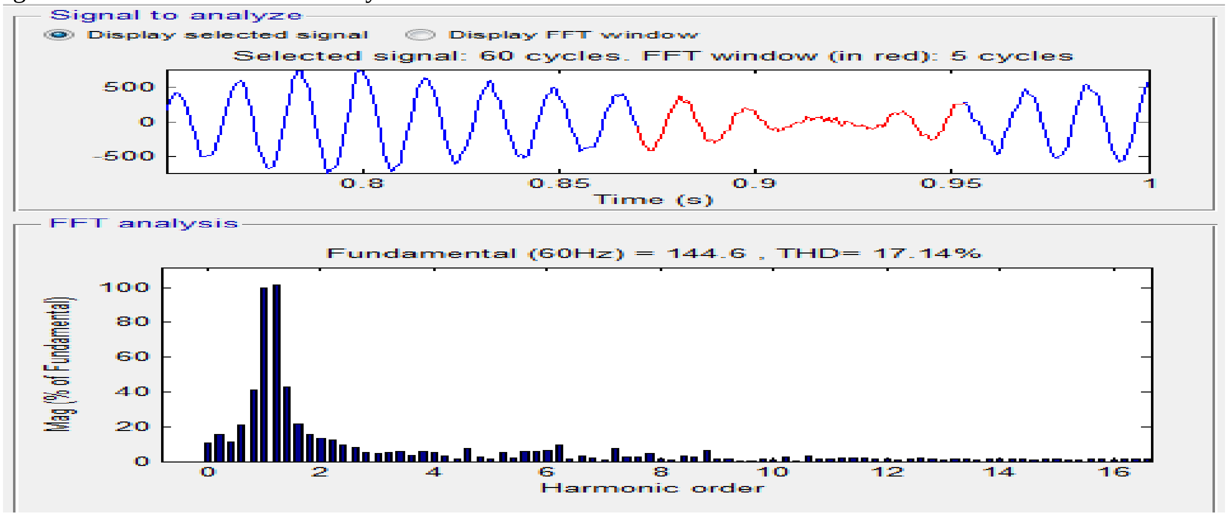


Fig 9 Current wave and THD at PCC

It is observed from the above waveform that the current waveform gets fully distorted when the system is run without using any compensation device, harmonics are also injected in the waveform and the magnitude of the current wave is varying enormously from 50 ampere to 800 ampere which affects the grid in horrible manner. Following is the THD of the above wave is 17.14%

b. Current at source

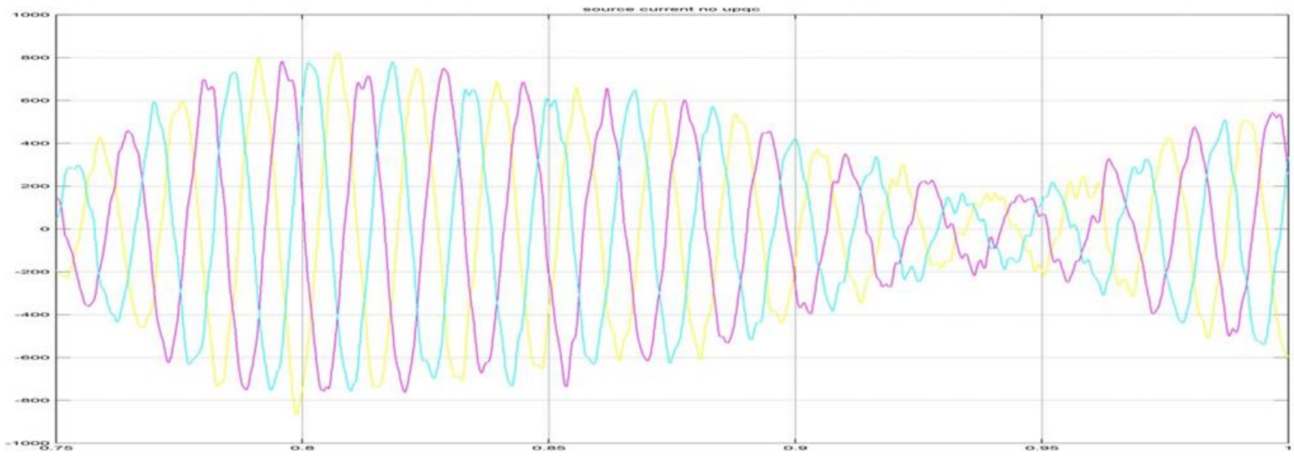


Fig 10

Current at source

The current waveform at the source side also gets distorted as we can see the current varying in very large range which affects the whole grid. The below figure describes the THD analysis of the above waveform which gives percentage of the distorted waveform

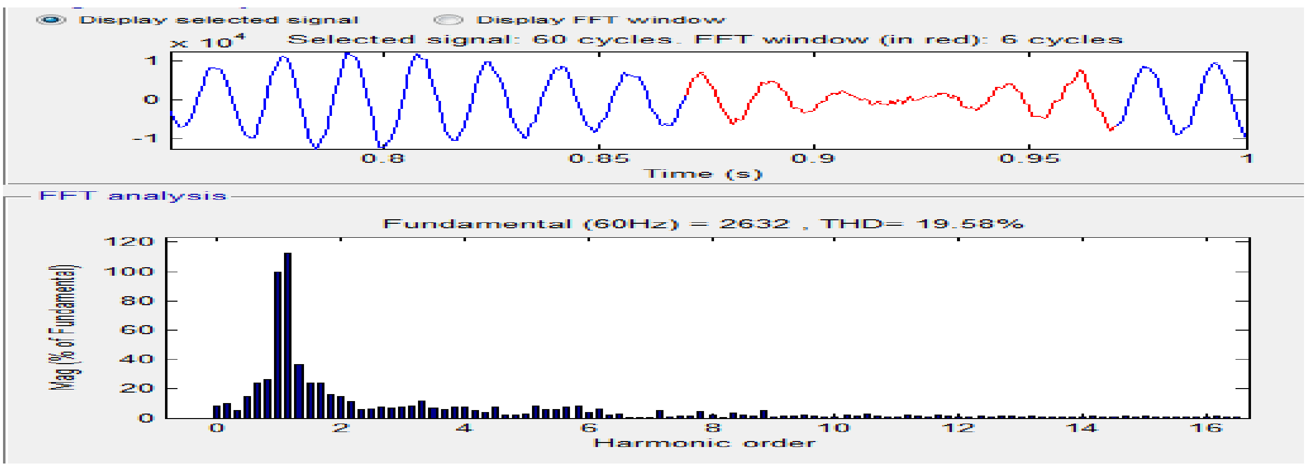


Fig 11 THD of current at source

The THD of current wave at source side are 19.58% which confirms the poor waveform.

- **System with compensation**

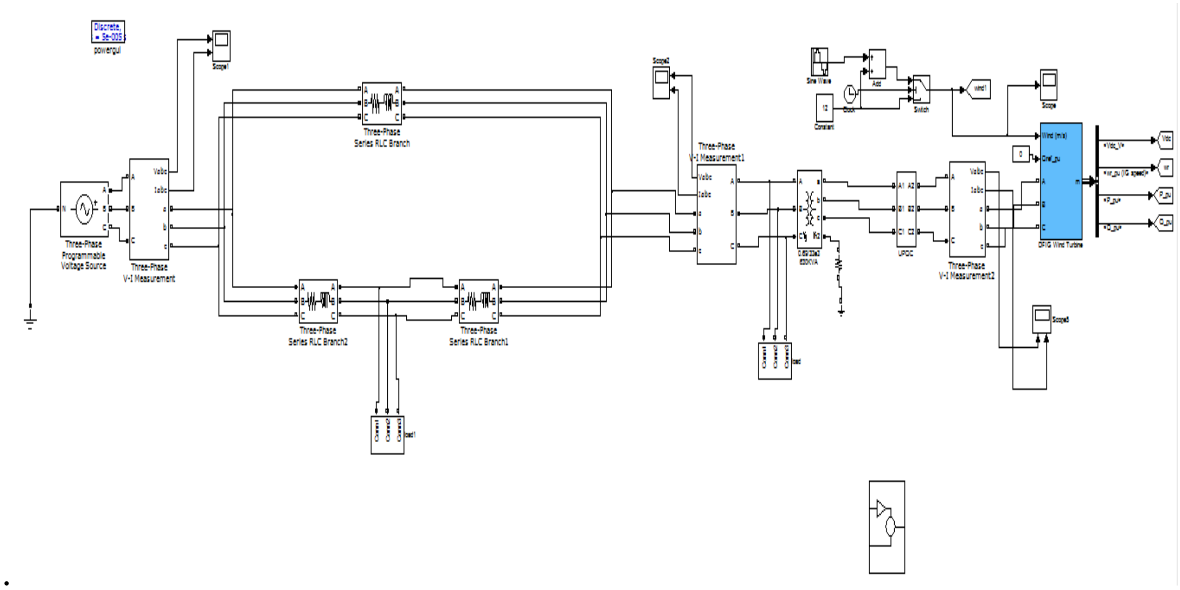


Fig 12 System with compensation

The above system is a wind farm connected to grid and a compensation device is used to enhance the power quality on the grid side.

a. Current at PCC

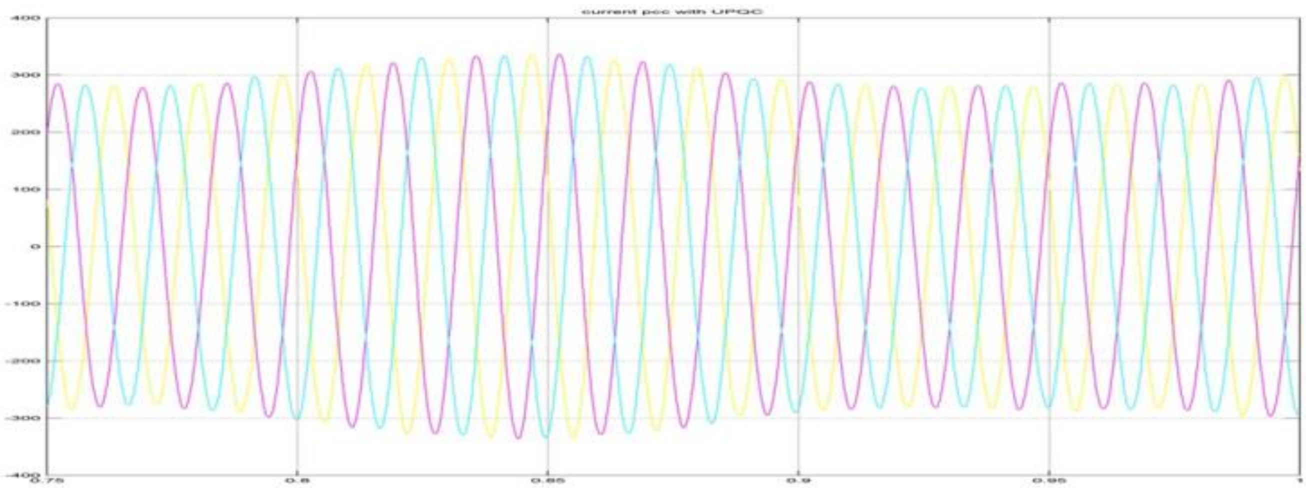


Fig 13 Current at PCC

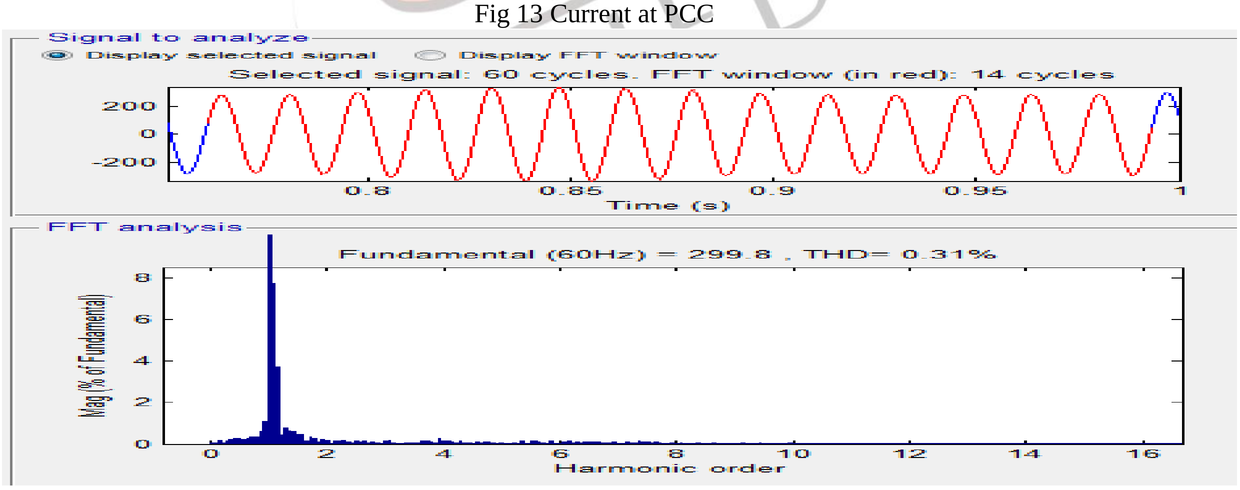


Fig 14 Current THD at PCC

The above figure shows the current waveform at the PCC and then the THD of the current is given which shows that the harmonics and the variation of the current at the PCC has reduced considerably. THD has reduces to .31% from 17.14%.

b. Voltage at PCC

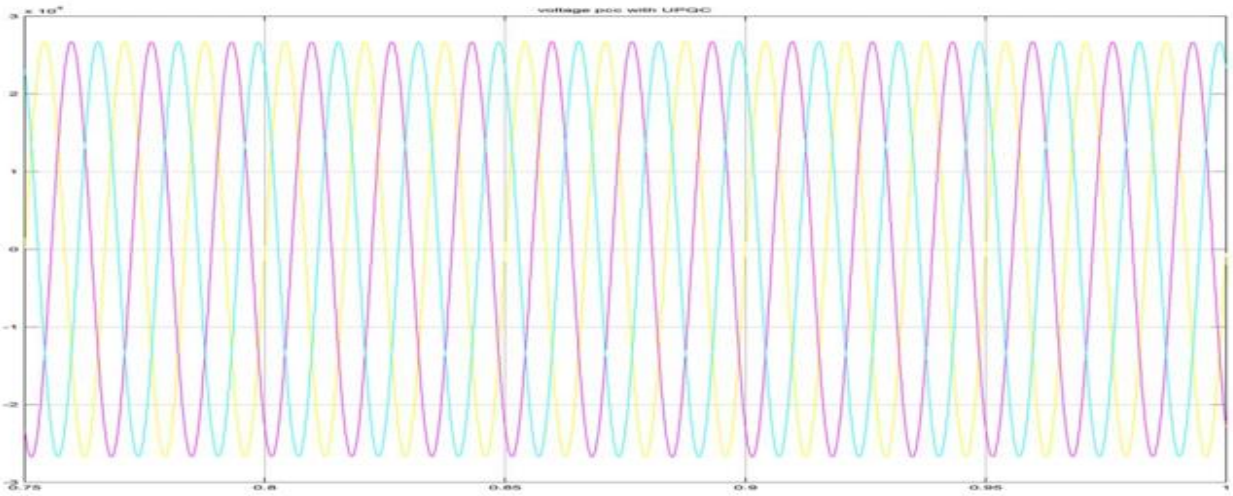


Fig 15 Voltage at PCC

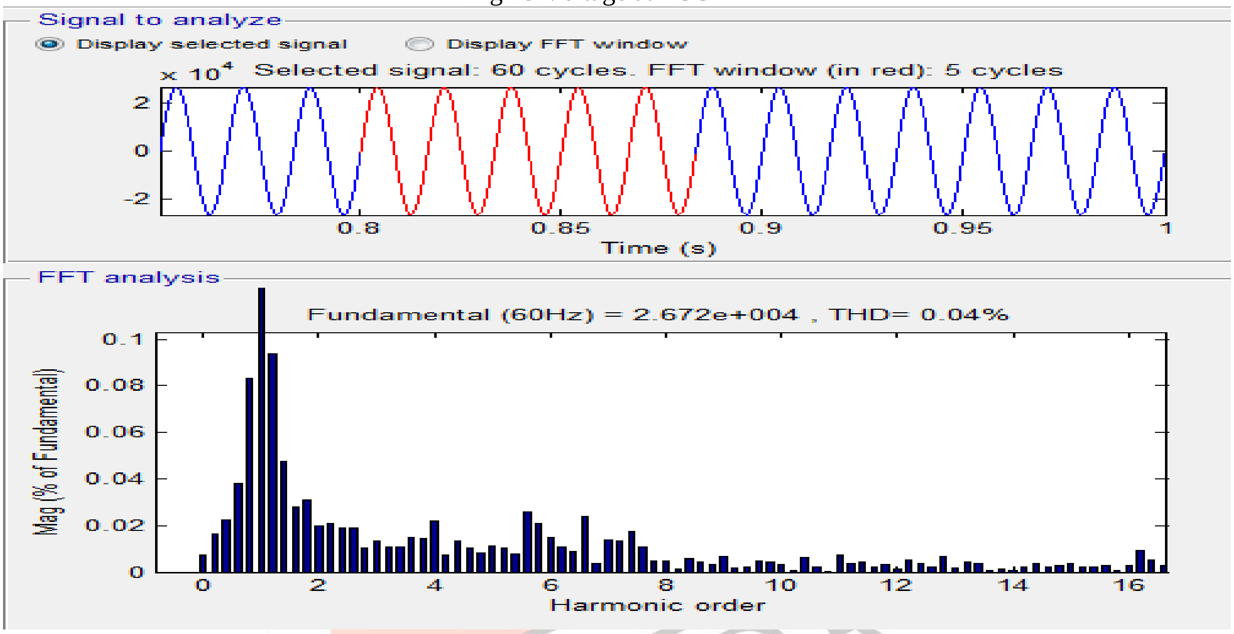


Fig 16 THD of Voltage at PCC

From the above figures it is analyzed the voltage at the PCC gets enhanced with the help of UPQC. Hence the series APF provides the compensation to voltage

- **Current at source**

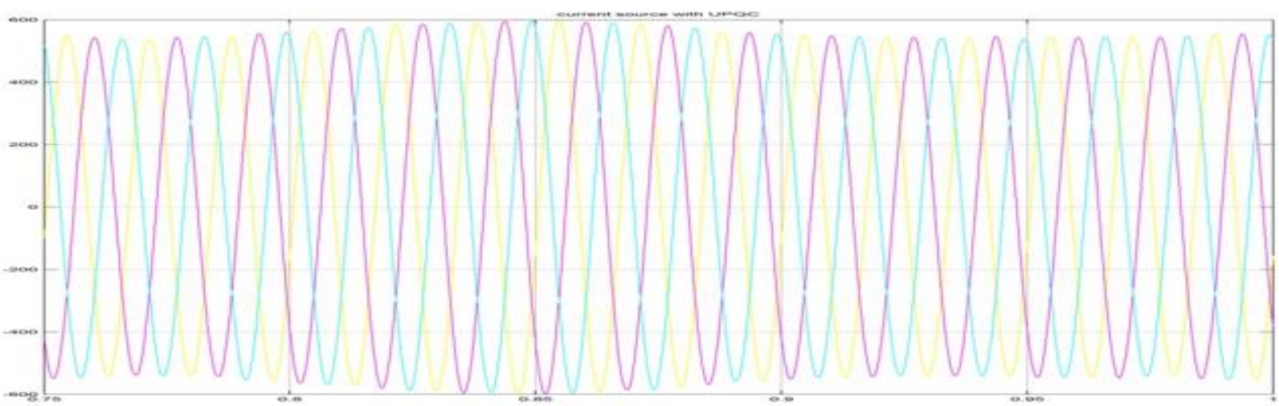
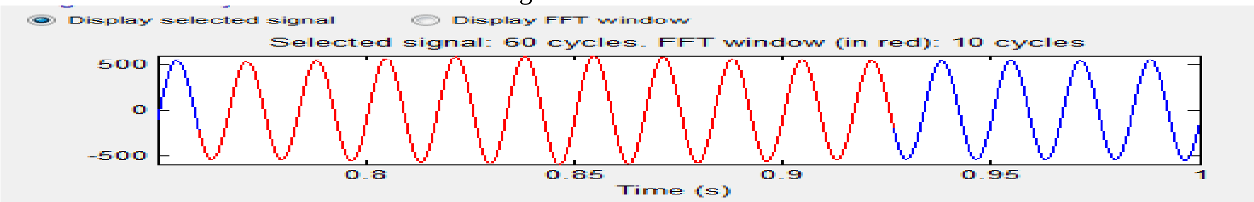


Fig 17 Current at source



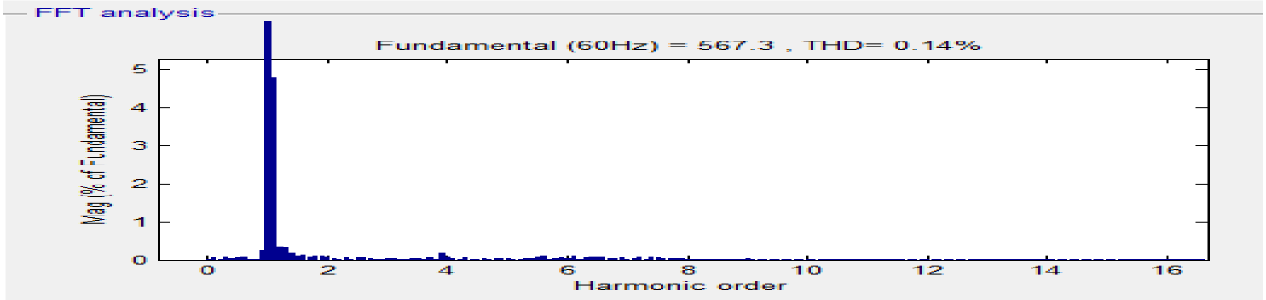


Fig 18 Current THD at source

It is confirmed from the above figures that the waveform of current gets corrected when we apply UPQC, and the THD of the current reduces to 0.14% from 19.38%. which means that the shunt APF provides the reactive and desired current in order to correct the waveform of the current.

VI. CONCLUSION

In the above chapter of results and discussion it confirms that the UPQC is very helpful in mitigating the harmonics and transients in the voltage and current waveforms ads hence enhance the power quality of the system. As we can see that at the source and PCC the current harmonics has been reduced to 0.14% and 0.31% from 19.58% and 17.14% respectively. The voltage THD has also been detected as 0.04% which shows that the voltage is conditioned too. This show that the UPQC improves the supply from wind side when it is injected in the grid by improving both current and voltage profile with the help of series and shunt APFs.

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