A Novel and Fast Technique for Harmonic Reduction Based on Wavelet Analysis and Active Filter in Wind Farms

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Abstract—**The paper analyzes the effects of harmonics in wind turbines by presenting a useful technique to reduce the effects of harmonics. In this paper by using a harmonic model of wind turbine, and using a harmonic reduction technique, the power quality of network will be improved and the number of harmonics decrease. The technique is combination of wavelet analysis and active filters. The results show the correctness of the presented method.**

Keywords- shunt active filter; wavelet transform, harmonic, wind turbine.

I. INTRODUCTION

As always, the main objective of the power system would be generation of electrical energy to the end user. Also, associated with power system generation is the term power quality. Ref [1] presents the results for the performance of passive and active power filter to reduce harmonics in the distribution system. Also, bidirectional switching is used as a strategy control in active power filter. Representative result of circuit simulations is carried out. The results show that the active power filter can simultaneously attenuate various frequencies and are compared with passive filter which is only filtering an individual harmonics.ref [2] present a controller is also responsible for activating selected CSC filter module(s) to the electric grid. The automated activation of the corresponding filter module(s) is based on the decisionmaking rules in accordance with the current total harmonic distortion (THD_i) and the harmonic factor (HF) levels set by the IEEE 519-1992 standard. A special 3-level PWM switching strategy is proposed for the filter modules which results in a 50% reduction in the overall switching losses compared with the 2-level method. Ref [3] presents a combined system with a passive filter and a small-rated active filter, both connected in series with each other. In [4] a newly developed control algorithm using a neural network theory for an active AC harmonic filter system to reduce the harmonic voltage distortion in an electrical power system is presented. In [5], a method is presented that simultaneously both active power filters bring their own characteristic advantages, i.e., the feedback filter improves the steady-state performance of the harmonic mitigation and the feed forward filter improves the dynamic response. In [6], the proposed active compensation technique is based in a series active filter composed by two single-phase inverters sharing the same DC bus, and is suitable for current harmonics and reactive power compensation generated by static converters. Ref [7] describes the control and parallel operation of two active power filters. The filters are coupled in a combined topology in which one filter is connected in a feedback loop and the other is in a feed forward loop for harmonic compensation. Thus, both active power filters bring their own characteristic advantages i.e. the feedback filter improves the steady-state performance of the harmonic mitigation and the feed forward filter improves the stability and the dynamics.ref [8] describes how a single phase PWM current source inverter connected in the DC link of a current source drive may be used to filter out AC side current inter harmonic components. In [9], the harmonic components in the current from the VSC has larger peak than expected for the fundamental component. Therefore, active filter action to eliminate these harmonic components in the current from the VSC is investigated in this paper.

In an inverter DC voltage is converted into an AC output. During this transformation from DC to AC, harmonics affect the power quality a lot, so using wavelet as a detection method for harmonics, and then using active filters, the harmonic performance of the wind farms will be improved.

II. HARMONICS

A. Active harmonic filter

Where reactive power requirement is low, active harmonic filters are used for low voltages. In this way, the output load with the voltage waveform is obtained by boosting the voltage throughout each half cycle by the filter. After that, the voltage tends to rectifiers in the power supply to gain current. Depending on the active harmonic filter used, the output distortion is reduced. So, current which is produced due to load is monitored by the harmonic filter and generates a waveform which coincides with the exact shape of the nonlinear portion of the load current.

B. Passive harmonic filter

Passive harmonic filters are used for different voltage levels. In this regard, the harmonics are reduced by using series or parallel resonant filters. In this method, a filter connected in parallel with the load and in series with inductance and capacitance is a current acceptor. In fact, a current acceptor is a parallel filter which is in parallel with the load and is in series with the inductance and capacitance. This filter provides maximum attenuation. The filter passes as much current as the harmonic voltage nears the filter resonant point. So, the passive filters eliminate the harmonics. If the individual load requirement is more than that of the input load, the harmonic current should be eliminated. For example, a capacitor in series with an inductance is a passive filter. The reduced harmonic frequency must be equal to the resonant frequency of the circuit. The impedance of the network and the low impedance of the filter thus eliminate the harmonic current. Figure 1 and Figure 2 shows three phase passive filter for shunt and series configuration respectively. Normally, more than 3 filters are connected in a system to reduce the harmonics. Sinusoidal Pulse Width Modulation is a bit different compared to the Sinusoidal Pulse Width Modulation. In case of sinusoidal pulse width modulation, all the pulses are modulated individually. Each and every pulse is compared to a reference sinusoidal pulse and then they are modulated accordingly to produce a waveform which is equal to the reference sinusoidal waveform. Thus, sinusoidal pulse width modulation modulates the pulse width sinusoidal.

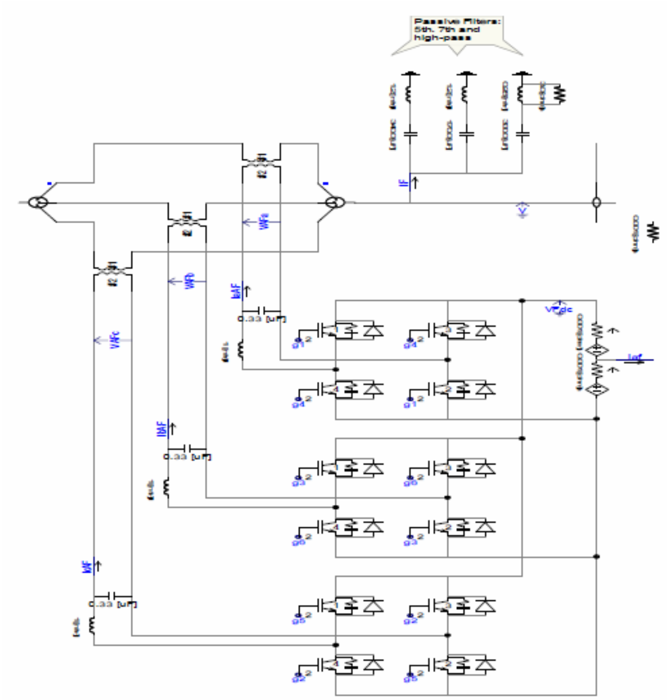


Figure 1. Three phase passive filter for shunt configuration

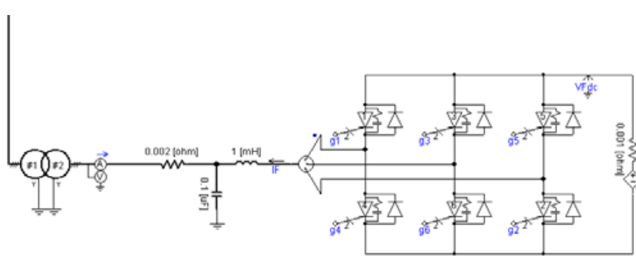


Figure 2. Three phase passive filter for series configuration

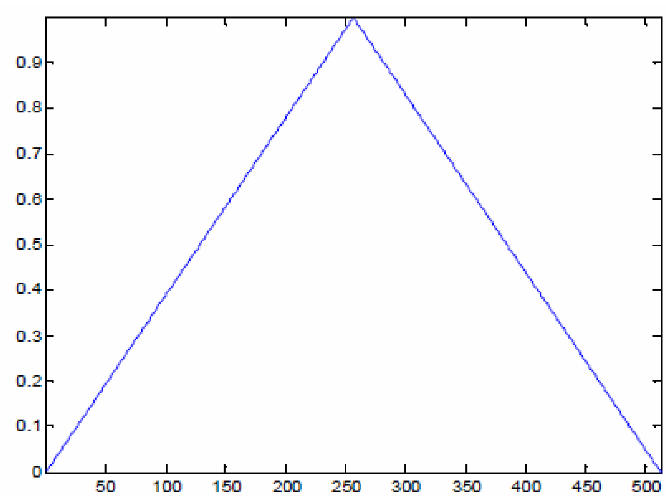
III. SIMULATION RESULTS

Nowadays, wavelet has much application in power systems. Brahma [13] introduces wavelet transform to reliably and quickly detect any fault during a power swing. A logic block based on the wavelet transform has been developed. Valsan and Swarup [12] present a novel wavelet transform based directional algorithm for bus bar protection Hong and Chen [11] studied a new method to locate the positions of the switching capacitors using discrete wavelet transform. Tarasuik [10] analyze the detection and evaluation of different kinds of waveform distortions such as harmonics; inter harmonics, transients and notching using hybrid-Fourier method. Another expert system developed by Reaz et al [14] which uses a different type of randomly optimized neural network combined with discrete wavelet transform and fuzzy logic to have better power quality disturbance classification accuracy. The need to analyze power quality signals to extract their distinctive features made Gargoom in [15] to use Hilbert transform and Clarke transform for the classification of power quality signals and compared the performance of these techniques with wavelet transform. Elkalashy in [16] uses DWTs to detect high impedance faults due to leaning trees. Wireless sensors have been considered for processing the DWTs. Mishra in [17] presented an S transform based probabilistic neural network classifier for the recognition of power quality disturbances. Also Ref [18] claims that wavelet Daubechies at level of d4 to d8 presents the amount of harmonic and reference [19] shows that the level d8 exactly presents the amount of harmonic of a signal. So in this paper the average of Daubechies wavelet d8 and d4 is selected as harmonic detection technique. The result of this criterion ((d4+d8)/2) is presented in Fig.3. Another criterion for harmonic detection in this paper is the energy of wavelet coefficient. Introducing a threshold, we can detect the over harmonics of a signals. In fig we can see the signal and in Fig. 3 we can se the wavelet coefficient d4 and d8 in order to detect harmonics of that signal. So two below criterion are used as harmonic detectors in this paper:

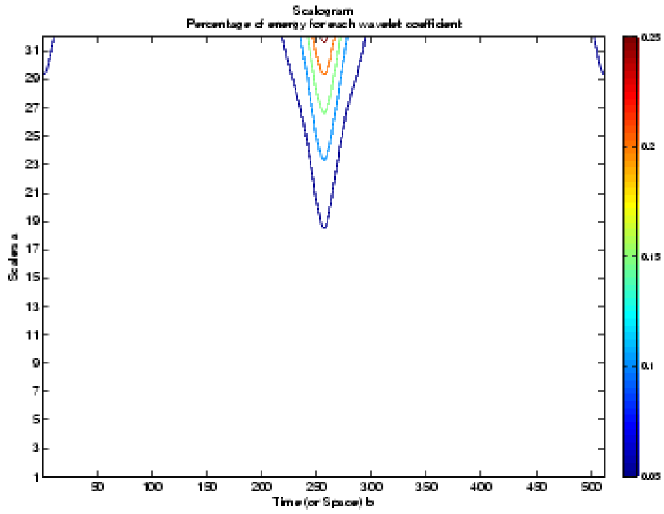
1- Average of d8+d4

2- The slop at wavelet coefficient signal energy

In the Fig. 4, the scale and levels of wavelet can ebe seen. In the Fig. 4(a) the original signal is shown and in theFig. 4(b) the energy of wavelet coefficient amont frequency spectrum can be seen.



(a)



(b)

Figure 3. (a) A sample signal, (b) Energy of wavelet coefficient among frequency spectrum

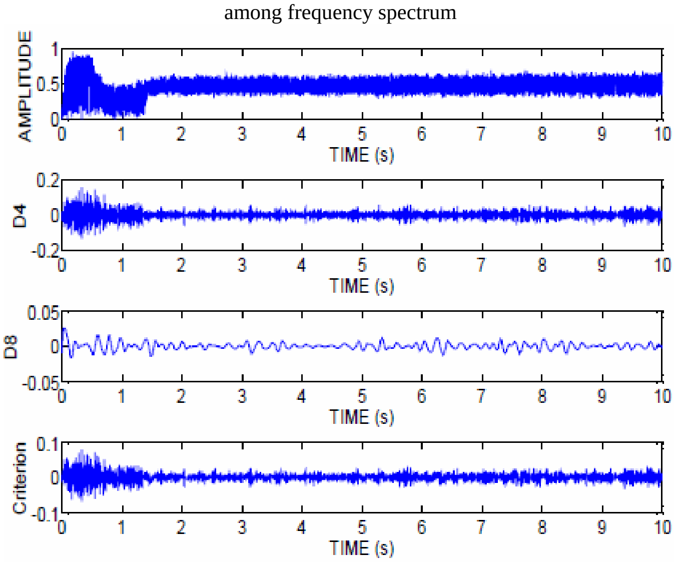
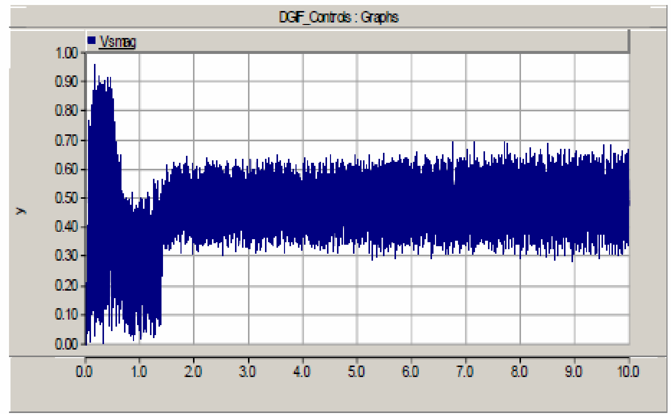
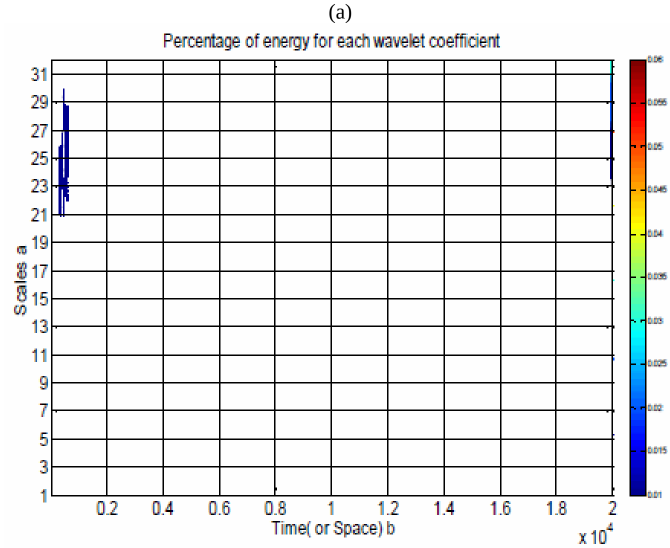


Figure 4. Voltage at PCC point and the presented criterion

The slop at wavelet coefficient energy curve can be a good criterion in order to detect harmonics of signals. In fact in these levels, the energy of wavelet that changes to ohmic loss are shown. Fig. 3. (a) shows a sample signal, and Fig (b) shows energy of wavelet coefficient among frequency spectrum. It is seen that in Fig. 3(b), by using a threshold, we can detects harmonics of signal. In the Fig .4, the voltage of system at PCC point can be seen. In the Fig. 4, using a step disturbance, the voltage at PCC point can be seen plus the presented criterion. After harmonic detection of the signal, the shunt active filter will be connected in parallel form in order improve the harmonics of the signals. Fig. 5. (a) shows voltage at PCC point voltage and Fig (b) shows voltage at PCC point energy coefficients. It is found that similar to Fig.3(b), by using a threshold, we can detect the harmonics of a signal. Fig. 6 shows current harmonic components of d axis before using active filter. This figure is related to the voltage at PCC point. For the conditions where both voltage and current are leading to a deterioration in power system, more complex filters are used which are made up of combination of active and passive filters. Such filters are called as Hybrid Filters



(a)



(b)

Figure 5. (a)Voltage at PCC point voltage, (b) Voltage at PCC point energy coefficients

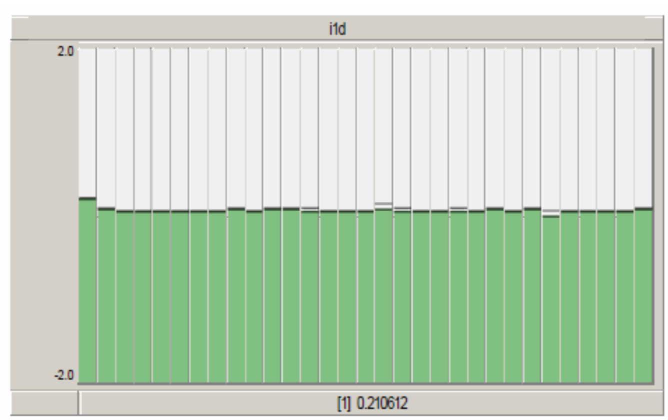


Figure 6. Current harmonic components of d axis before using active filter

[9]. Fig.7 shows frequency impedance in capacitor bus before using active filter and also Fig. 8 shows current of load phase an after using active filter.

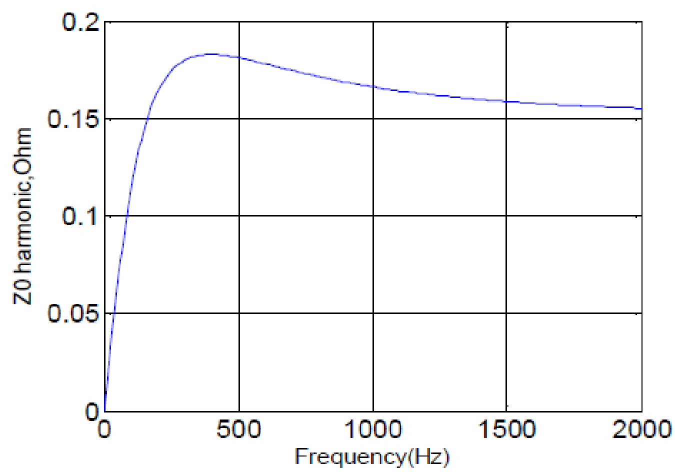


Figure 7. Frequency impedance in capacitor bus before using active filter

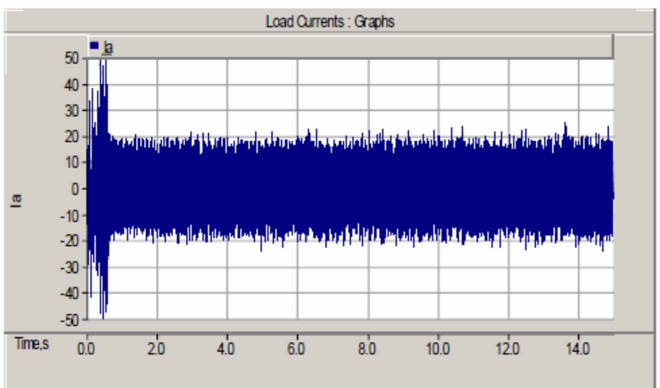


Figure 8. Current of load phase a after using active filter

In the below chart, the results are shown during using the active filter described former. Fig.9 shows controlled torquesand speed after using active filter using a step disturbance atspeed at 0.5 sec and Fig.10 shows current harmoni ccomponents after using active filter. It is obvious that using active filters, the amount of harmonic critically decrease, so the results show the correctness of the proposed technique.

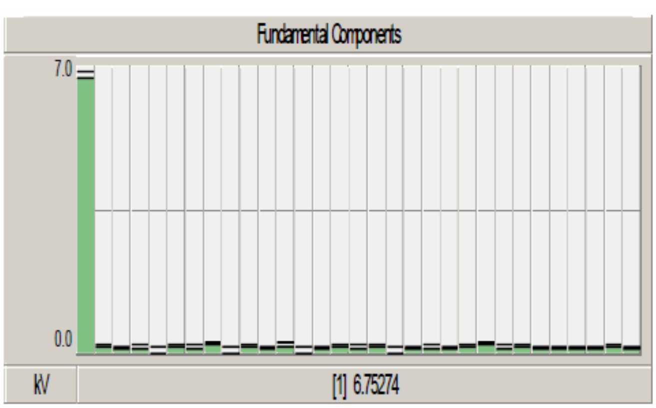


Figure 10. Current harmonic components after using active filter

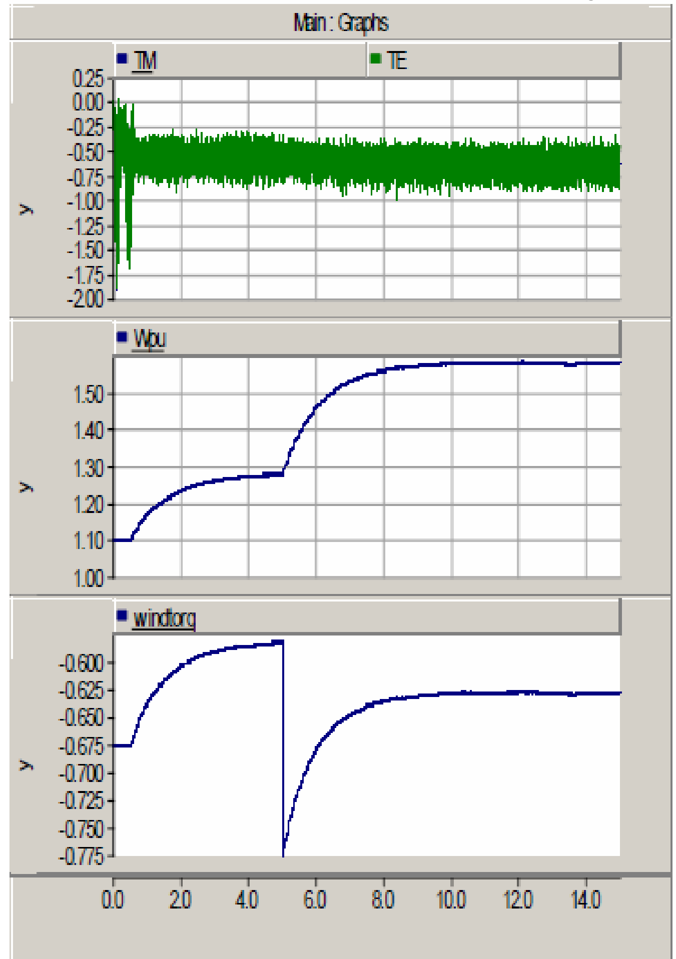


Figure 9. Controlled torques and speed after using active filter using a step disturbance at speed at 0.5 sec

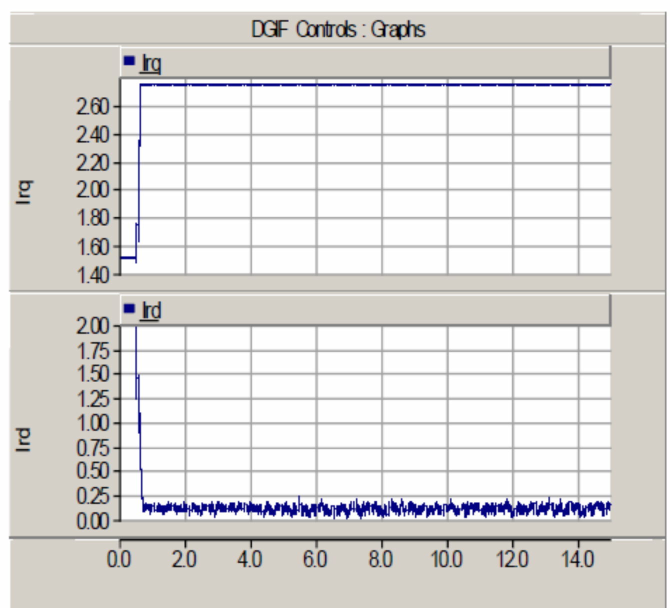


Figure 11. D and Q axis current using active filters

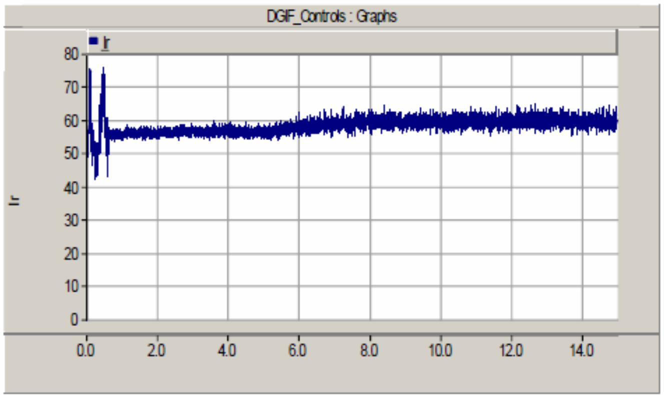


Figure 12. Rotor current using active filters

Form figs it is obviously determined that the amount of harmonics decrease. It is seen that by reducing the voltage distortion due to the 3 Rd, 5 Th, and 7 Th harmonics the harmonics of signal reduces and THD criterion significantly decreases. Non-linear devices such as power electronics converters can inject harmonics alternating currents (AC) in the electrical power system. To maintain the quality limits proposed by standards to protect the sensitive loads, it is necessary to include some form of filtering device to the power system. Harmonics also increases overall reactive power demanded by equivalent load. Filters have been devised to achieve an optimal control strategy for harmonic alleviation problems. In this paper, using an active filter, the amount of harmonic of power converter decrease and the power quality examine based on a harmonic model of system.

IV. Conclusion

A combined method presented in this paper in order to reduce the harmonic of of wind farms. At first after presenting the harmonic model of wind turbine, introduce two criterions in order to detect the harmonic components. After that using an active filter, improve the performance of wind farms. The simulation results show the power of the introduced technique. These benefits provide some further practical incentives for the use of active filters with traction systems.

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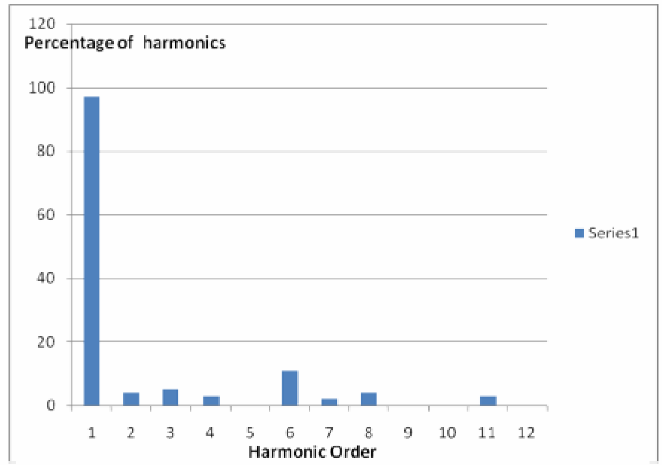

Figure 13. Voltage at PCC point energy before using active Filters

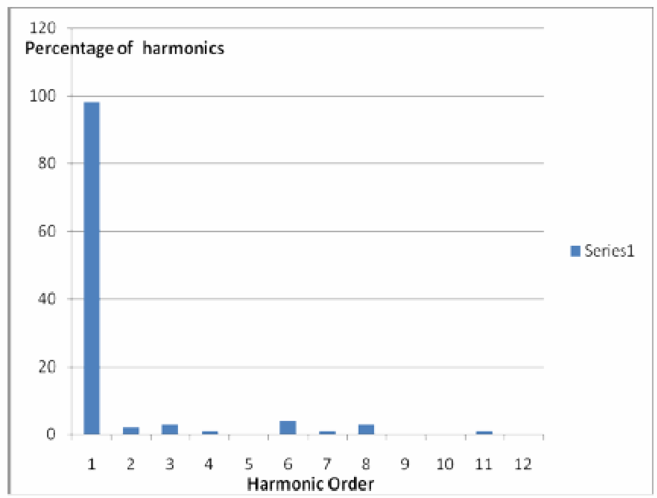

Figure 14. Voltage at PCC point energy before after active filters

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