Power Quality: Harmonics Case Study and Solution

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Abstract---This paper describes the basic power quality issues with the MATLAB analysis. There are different types of the PQ issues like voltage sag, voltage swell, interruption, harmonics, 3 phase unbalance, voltage fluctuation, noise etc. normally current harmonics is produced by the various nonlinear loads which will result the distorted voltage wave which produce the voltage harmonics so harmonics is present in both voltage as well as current. So harmonics as the power quality case study of industrial load is carried out by taking one nonlinear load and filter design is carried out to reduce the current harmonics.

I. Introduction

Power quality is mainly the customer driven issues so the power quality is defined as any power problem manifested in voltage, current or frequency deviation which will lead to the failure or disoperation of the equipment.

Power quality is simply the interaction of electrical power with the equipment. If electrical equipment operates correctly without being damaged or stressed, we would say that the electrical power quality is good. On the other hand, if the electrical equipment malfunctions or does not operate properly, is unreliable, or it is damaged during normal usage, we would suspect that the power quality is bad.

The concept of power quality is not properly defined. It varies with the requirements of the customer and the electrical characteristics of the load of the customer so there are however several phenomena that can cause problems of different magnitude for a grid connected user. These are harmonics, voltage variations, asymmetry between phases, frequency deviations etc. All of these phenomena describe states that in some way deviate from the nominal state of the electrical characteristics. One can therefore define power quality as the absence of these phenomena.

Generally the power quality is defined as the voltage quality in most of the cases. Because the current drawn by the load is depends on the load characteristics. Power supply utility can only control the quality of the voltage. So the standards in the PQ are also to maintain the supply voltage within the prescribe limit.

II. Power Quality Issues

The various types of the power quality issues are as follows

1. Voltage sags (or dips)
2. Very short interruption
3. Long interruption
4. Voltage spike
5. Voltage swell
6. Harmonic distortion
7. Voltage fluctuation
8. Noise
9. Voltage unbalance

Voltage sags (or dips)

A decrease of the normal voltage level between 10 and 90% of the nominal rms voltage at the power frequency, for durations of 0.5 cycles to 1 minute [4].

Very short interruptions

Total interruption of electrical supply for duration from few milliseconds to one or two seconds [4].

Long interruptions

Total interruption of electrical supply for duration greater than 1 to 2 seconds. An *interruption* occurs when the supply voltage or load current decreases to less than 0.1 Pu for a period of time not exceeding 1 min [4].

Voltage spike

Very fast variation of the voltage value for durations from a several microseconds to few milliseconds. These variations may reach thousands of volts, even in low voltage [4].

Voltage swell

Momentary increase of the voltage, at the power frequency, outside the normal tolerances, with duration of more than one cycle and typically less than a few seconds [4].

Harmonic distortion

Voltage or current waveforms assume non-sinusoidal shape. The waveform corresponds to the sum of different sine-waves with different magnitude and phase, having frequencies that are multiples of power-system frequency [4].

Voltage fluctuation

Oscillation of voltage value, amplitude modulated by a signal with frequency of 0 to 30 Hz [4].

Noise

Superimposing of high frequency signals on the waveform of the power-system frequency [4].

Voltage Unbalance

A voltage variation in a three-phase system in which the three voltage magnitudes or the phase angle differences Between them are not equal [4].

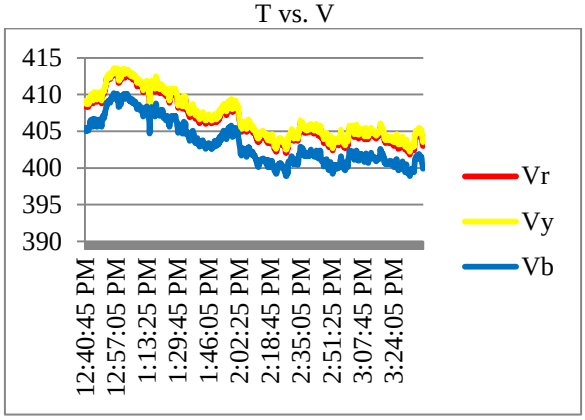
III. Harmonics Analysis With Case Study

The real data of the air compressor (which is the major source of the harmonics in the industries) will be taken in between 12:40PM to 03:39 PM at an interval of 10 Sec. by using power quality analyzer and up to 50th order the harmonics is recorded.

System data

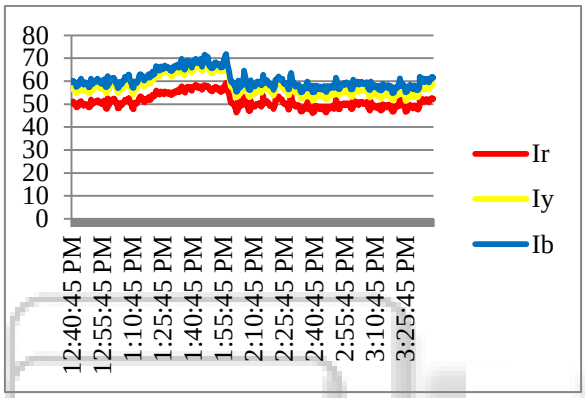
Average active power	33705.71 W
Average reactive power	21077.6 VAR
Average current	60.54353 A
Average voltage	405.6764 V

T vs. V



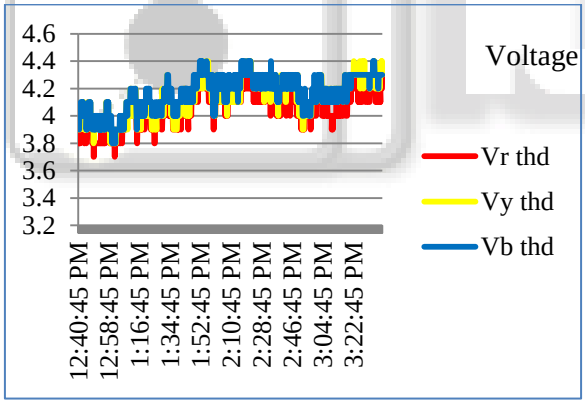
The average value of the voltage is 405.6764 V

T vs. I



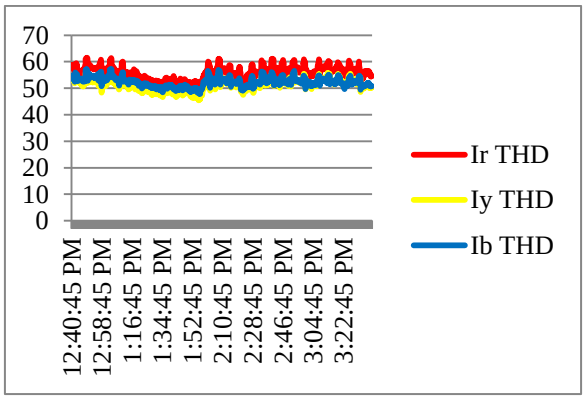
The average value of the current is 60.54353 A

T vs. V THD



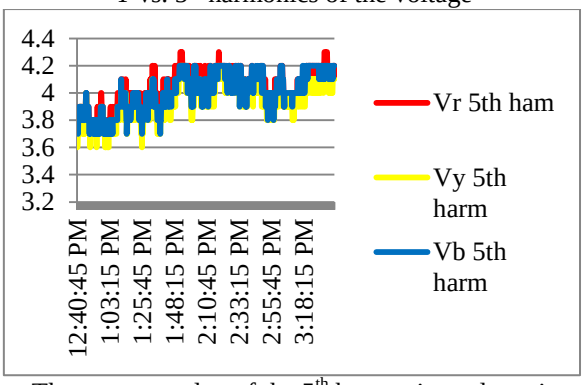
The average value of the voltage harmonics is 4.16307%

T vs. I THD



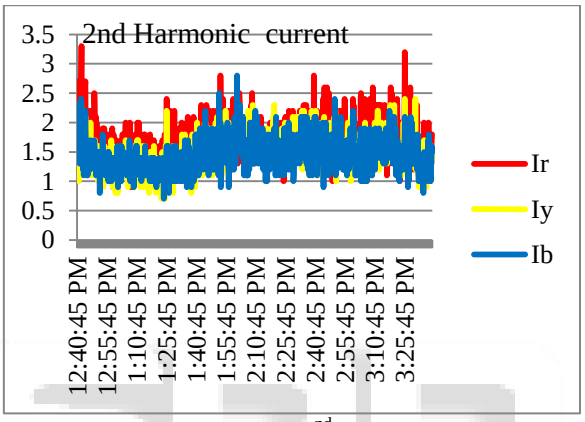
The average value of the THD of current is 52.30056%

T vs. 5th harmonics of the voltage



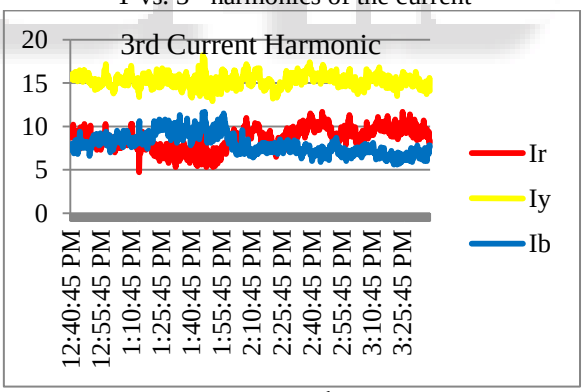
The average value of the 5th harmonics voltage is 4.001674%

T vs. 2nd harmonics of the current



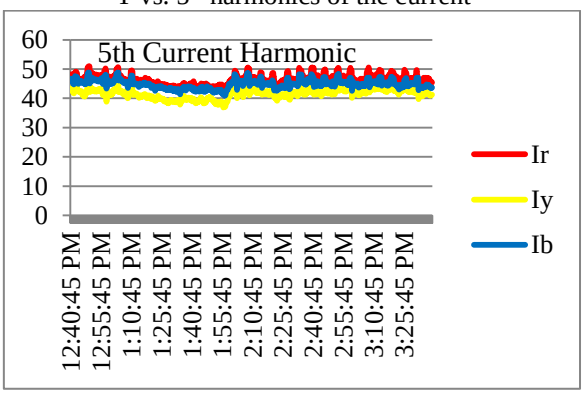
The average value of the 2nd harmonics current is 1.436093%

T vs. 3rd harmonics of the current



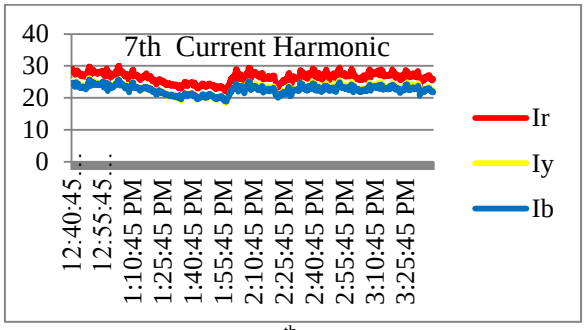
The average value of the 3rd harmonics current is 7.951442%

T vs. 5th harmonics of the current



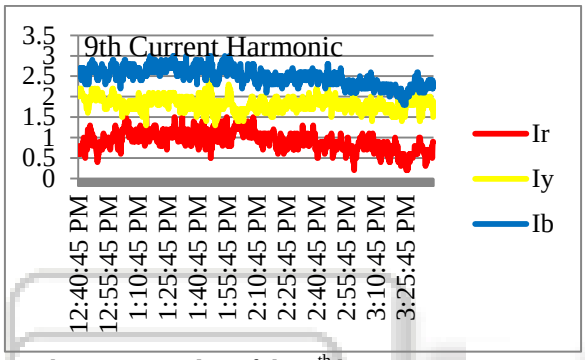
The average value of the 5th harmonics of the current is 44.86577%

T vs. 7th harmonics of the current



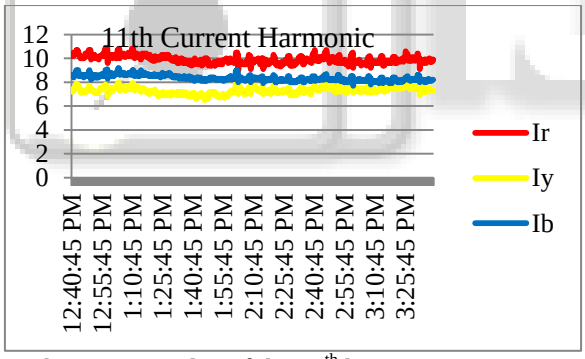
The average value of the 7th harmonics of the current is 22.54009%

T vs. 9th harmonics of the current



The average value of the 9th harmonics current is 1.824558%

T vs. 11th harmonics of the current



The average value of the 11th harmonics current is 7.319349%

So from the above results we will observe that the voltage harmonics contents presents in the air compressor is 4.16307% which is within the specified limits of <5%. But the total current harmonics presents in the system is 52.30056% which is very much higher than the specified limits of the <5% so it needs to be filter out by using any kind of the filtering techniques.so in this air compressor system the level of the 3rd, 5th, 7th, and 11th harmonics is outside the specified limit.

Hear in this paper the design of the passive tuned filter is carried out to filter out the major harmonics present in the air compressor.

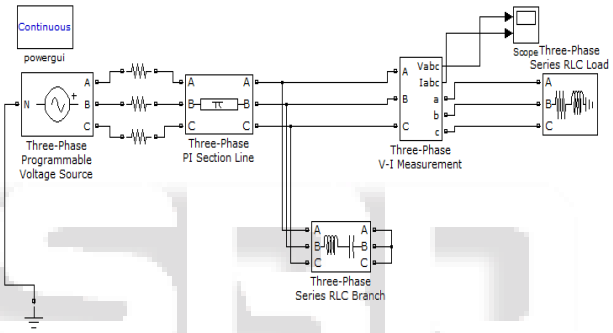
IV. Design Procedure Of The Passive Filter

1. Select the tuned frequency for the filter.
2. Find capacitor bank size and the resonant frequency.
3. Find filter reactor size
4. Calculate filter duty requirements.
5. Calculate of fundamental duty requirements.
6. Find the harmonic duty requirements
7. Evaluate total rms current and peak voltage requirements.
8. Evaluate capacitor rating limits.
9. Evaluate filter frequency response.
10. Evaluate the effect of filter parameter variations within specified tolerance.

Calculation of L and C for the tuned passive filter

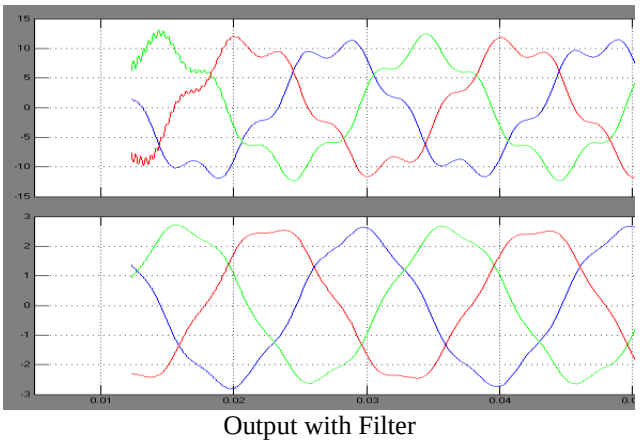
For 3rd harmonic
Xl=0.984129989, Xc= 7.873039911
L=3.13417*10^-6 C=0.000404509
For 5th harmonics
Xl=0.325332228, Xc=8.133305693
L=0.00103609, C=0.000391564
For 7th harmonics
Xl=0.162666114, Xc=7.970639597
L=5.18045*10^-7, C=0.000399556
For 11th harmonics
Xl=0.065066446, Xc=7.873039911
L=2.07218*10^-7, C=0.000404509

Simulation Results using MATLAB Simulink

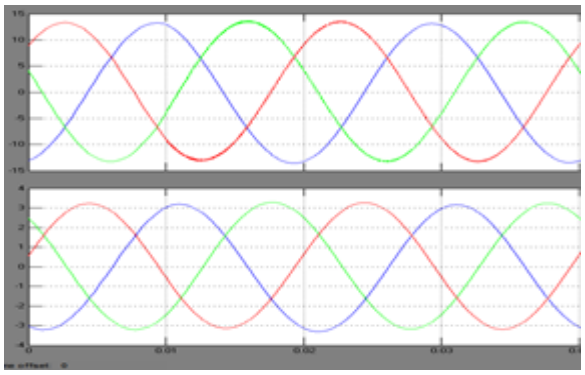


Block parameters

Voltage source with 5th harmonics generation
Load phase to phase voltage = 405.6764
Active power of the load = 33705W
Inductive reactive power = 21077VAR
Filter inductance = 0.001036H (for 5th harmonics)
Filter capacitance = 0.00039156F (for 5th harmonics)
Output without filter (for 5th harmonics generation)



Output with Filter



V. CONCLUSION

The detailed study is completed on the harmonics spectrum by using the power quality analyzer. It is found that the harmonics level up to the 11th order is higher than the IEEE standard present in the system so filter design is carried out to reduce the harmonics level below the IEEE standards. The real measured data is used in MATLAB Simulink and calculated value of the parameter of the harmonics filter is inserted in the simulation in MATLAB. So it is found that the harmonics are reduced as per the IEEE standards.

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