"Effect of Harmonic Injection in AC-DC converter"

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***Abstract* –The paper basically deals with harmonic injection. The paper concentrates on understanding what harmonics are in general and in electric circuits particularly. The paper gives a detailed overview about the main sources of harmonics, their disadvantages and the steps to curb it specifically in the electric circuits.**

I. INTRODUCTION - Harmonics

A harmonic refers to a sine wave which has a frequency as a whole number multiple of a wave/signal's fundamental frequency. A series of all harmonics of a particular frequency is called it's harmonic series. Harmonics are seen in musical instruments, in electric circuits and signal processing, in quantum mechanics, and even in neuroscience. Harmonics are analysed by considering them as a superposition of waves and applying the concepts of Fourier series and Fourier transforms.

II. Fourier analysis of electric circuits

Fourier analysis is an approximation of general functions as a sum of simpler trigonometric functions.

$$f(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty}\left(a_n cos\frac{n\pi x}{L} + b_n sin\frac{n\pi x}{L}\right)$$

$$a_0 = \frac{1}{L}\int_{-L}^{+L} f(x)dx$$

$$a_n = \frac{1}{L}\int_{-L}^{+L} f(x)cos(\frac{n\pi x}{L})dx$$

$$b_n = \frac{1}{L}\int_{-L}^{+L} f(x)sin(\frac{n\pi x}{L})dx$$

Fig. 1. Fourier series

Thus they are used in circuits driven by non-sinusoidal periodic functions. The circuits are solved in a series of steps-

- Expressing the excitation(independent source) as a Fourier series
- Laplace transform of the circuit from time domain to frequency domain
- Finding response required by using superposition theorem.

III. Harmonics in electrical circuits

Electrical AC power generation only produces voltage waveform of a single frequency which is the wave's fundamental frequency. Linear loads like purely resistive loads which obey ohm's law do not induce harmonics into a system. But non-linear loads draw currents which are not sinusoidal in nature thus injecting odd-harmonics in the wave (current/voltage). The main sources of harmonic current are rectifiers, inverters, ballasts in fluorescent lights and transformers. This results in an "impure" waveform instead of the "pure" sinusoidal input given to these equipments.

IV. Disadvantages of harmonic injection

Presence of harmonics in a network lowers the quality of power due to the following factors

- Excessive neutral current – 3 phase connections use the fact that addition of the 3 phases produces a neutral to decrease the wiring. But the presence of the 3rd harmonic in the wave causes a net neutral current (as the 3rd harmonic adds up in phase) which causes the neutral wire to be overheated.

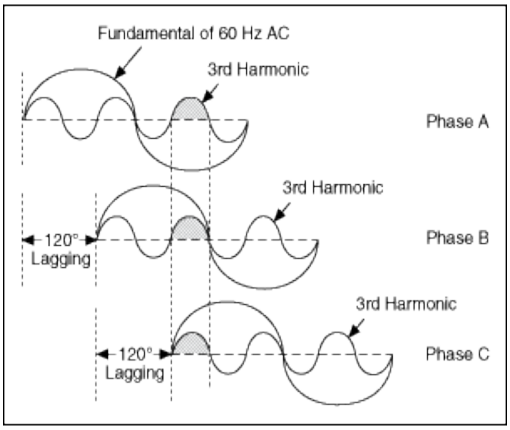

Fig. 2. 3rd harmonic in 3 phase circuits

- Incorrect readings- Harmonics are a cause of incorrect readings in induction watt meters and averaging type current meters.
- Failure of equipment – it causes lighting to flicker, fuse to blow, false tripping of relays and UPS, heating from increased losses in a transformer and motor.

V. Harmonic injection in electric circuits

Worldwide a huge amount of power conversion devices use non-linear components like diodes, thyristors, MOSFET and their usage is on a steady increase with the increasing electrical connectivity. These devices largely affect the harmonics of the whole grid by generating pulsating picky input currents in the utility grid leading to a poor power factor which judges it's quality.

$$POWER\ FACTOR = \frac{(REAL\ POWER)}{APPARENT\ POWER}$$

$$POWER\ FACTOR = P.F. = \frac{(VI_1)}{V \cdot I} \cdot \cos(\theta^{v} \sim \theta^{I_1})$$

$$P.F. = \Big(\underbrace{\frac{I_1}{I}}_{\text{DISTORTION FACTOR}} \cdot \underbrace{\cos(\theta^{v} \sim \theta^{I_1})}_{\text{DISPLACEMENT FACTOR}}\Big)$$

Fig.3 Power factor

The distortion factor gives the magnitude relation between the instantaneous current at fundamental frequency and the net current, while the displacement factor gives the phase relation between the fundamental current and voltage. The net effect of these 2 factor show the loss in power due to the presence of harmonics.

A vital factor which helps in quantifying harmonic injection is Total Harmonic Distortion (THD). It is a measure of the harmonic distortion and is found by normalizing the currents or voltages at all frequencies.

$$THD_V = \frac{\sqrt{\sum_{n=2} V_n^2}}{V_1}$$

$$THD_I = \frac{\sqrt{\sum_{n=2} I_n^2}}{I_1}$$

Fig. 4. Total Harmonic Distortion

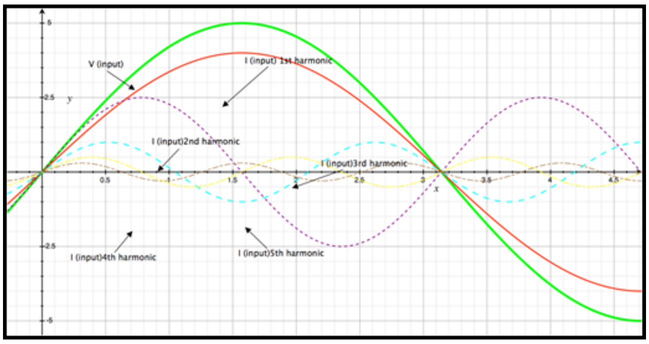

Fig. 5. Individual harmonics in a signal

VI. Circuit simulation

In this paper we are simulating a Bridge type full wave rectifier.. We have used Simulink and done Fast-Fourier Transform (FFT) of the output waveforms. We have measured the input and output voltages and currents and shown the analysis as follows.

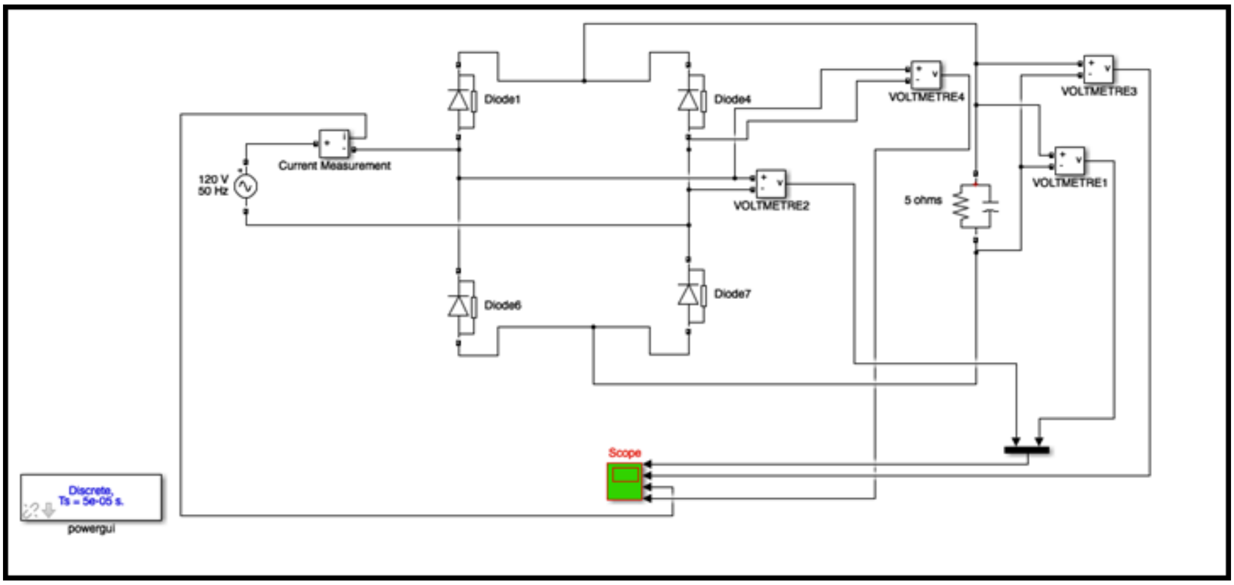

Fig..6. Simulink circuit of a bridge rectifier with a filter

Fig 6 is the circuit of the bridge rectifier used for analysis. The load is connected in parallel with a capacitor whose value is initially set to 0 (i.e. analysing the circuit without a filter), produces the following output voltage and current waveforms.

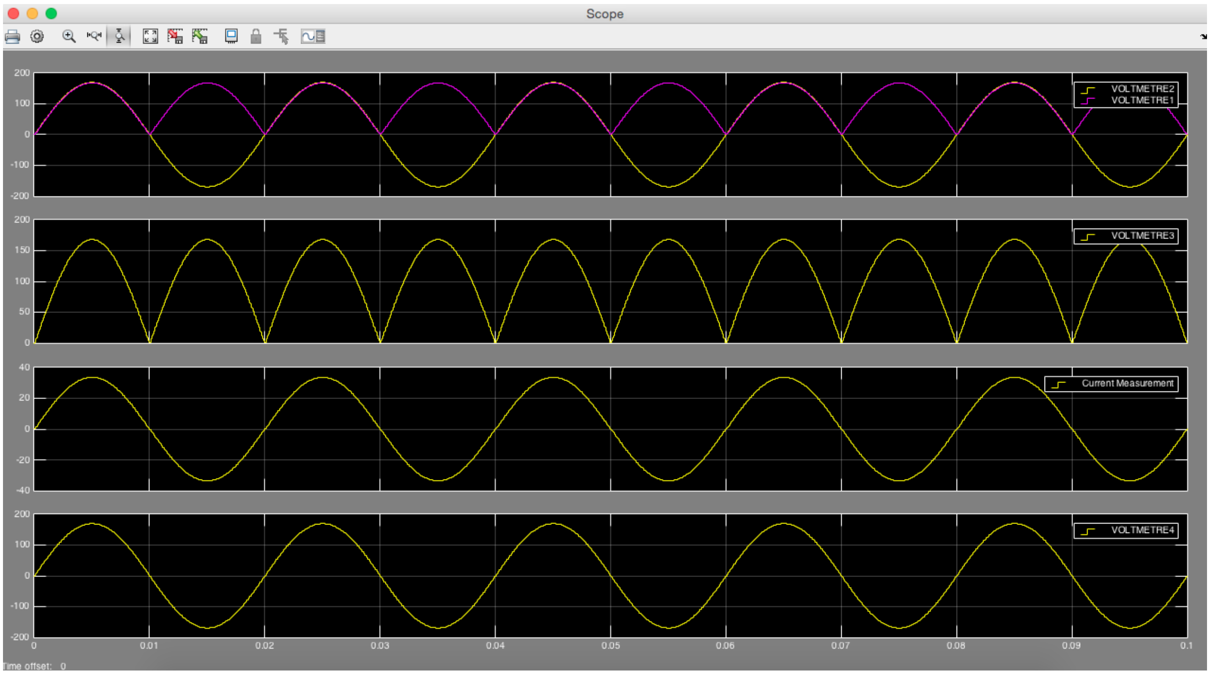

Fig. 7. (top to bottom) Input voltage, rectified output voltage, Output current, Input voltage

After having a value of capacitance to filter the output voltage, the output becomes,

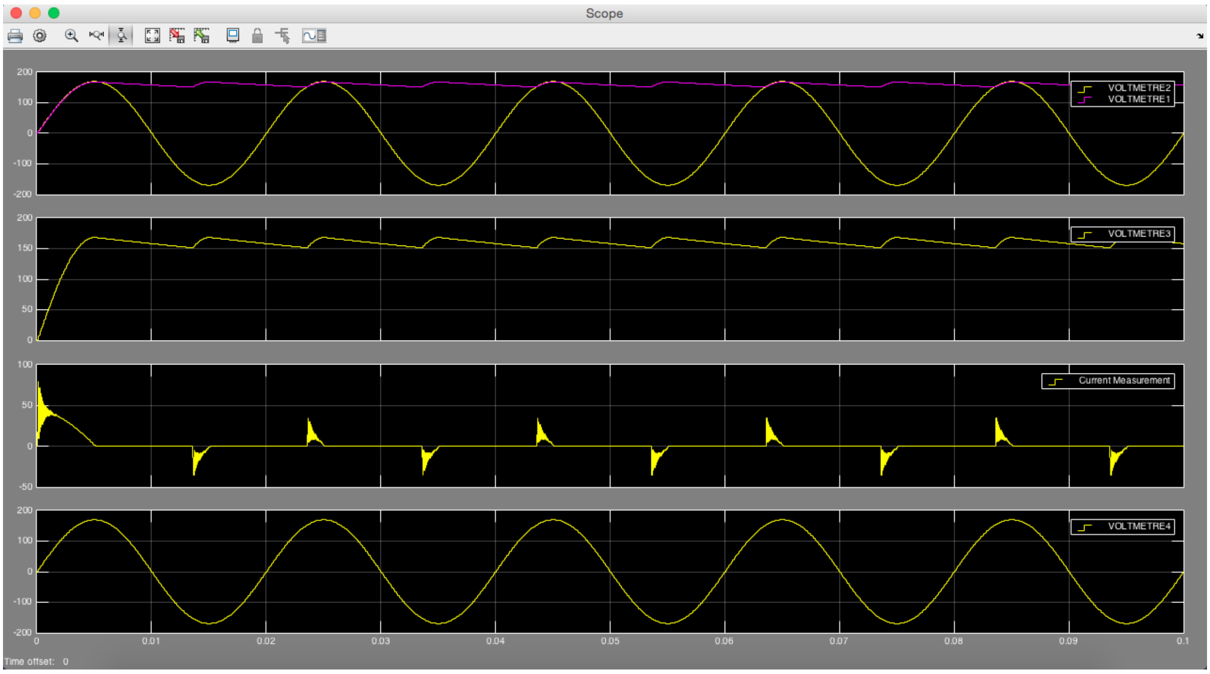

Fig. 8. (top to bottom) Input voltage, Output voltage, Output current, Input voltage

The output current as we can see has lots of sharp pulses. These occur due to the presence of higher order harmonics. Thus a FFT of the analysis is done to isolate individual harmonics.

But an analysis of the output with a filter shows the presence of multiple harmonics superimposed upon one other as shown in Fig. 9.

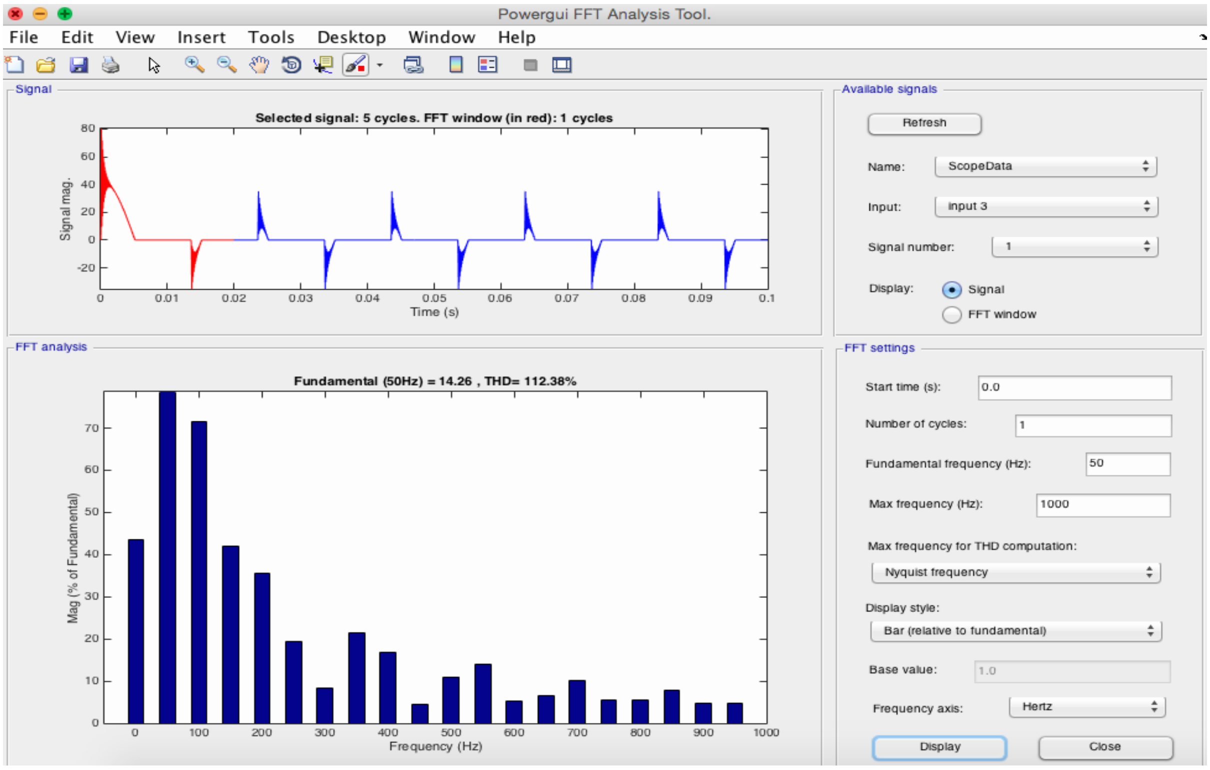

Fig. 9. FFT of output current with filter

VII. Solutions

The most common solution to reduce the harmonic injection is to use filters.
We can use “active filters” or “passive filters”.
Active filters are generally used in the input side and to eliminate higher order harmonics.
Passive filters can be used both in the input or the output side of the AC to DC converter. These can be of the type band-pass or low-pass or high-pass filters. But the main problem associated with these passive filters is their bulky nature. They also tend to create problems in controlled circuits due to their inertia property.

VIII. Conclusion

According to electric power research institute (EPRI) by the year 2020 almost 90% utility power will be processed through some form of power electronics equipment. Thus power quality disruption in electronic devices like diodes, and thyristors is a major concern which needs a lot of importance.

IX. References

1)HARMONICS-Understanding the facts – by Richard P.Bingham

2)State of art seminar on ”Power Factor Improvement In AC-DC Switching Converters” – by Ramaprasad Panda