Propagation and Filtering of Harmonics in Electrical Networks

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Abstract_In recent years, harmonics are considered as one of the most essential problems in electrical power systems, Even though, this new highly efficient electronic technology provides improved product quality with increased productivity by the use of smaller and lighter electrical components but they are the sources of harmonics. As a result, the perfect sinusoidal voltage and current waveform are very much distorted. To solve this problem, a simple and practical approach to reduce harmonics current in power distribution system is proposed. The using of LC filter will reduce the harmonic problem in the system. This LC filter is depending on value of capacitor and inductor. This application also can improve power factor and reduced the total harmonic distortion (THD) system. Our application has been made on a section of the electrical network (35 KV). The proposed procedure is based primarily on optimizing filters used (cost and place); the results show the effectiveness of this method especially with the use multiple filtering.

Key words : Power Quality, Harmonics, Electrical Network ,Filtring

I. INTRODUCTION

Harmonic distortion is increasing in industrial and commercial power factor due to proliferation of nonlinear load and development of industry [2, 5]. Thus, reduction of harmonics is becoming an important topic among electric power engineers in these days [1, 3, and 6]. The electrical energy is usually distributed in sinusoidal three phase power system . One of the parameters of this system is the waveform which must be as close as possible to a sinusoid [10, 11]. The correction of the waveform is required if the deformation exceeds certain limits. More and more electrical receivers, in industry, services and even domestic, are non-linear loads [3, 4]. These types of loads absorb no sinusoidal currents, crossing the electrical lines between the feeder and customer node trough the impedance network, causes power quality problems [8, 9]. In this paper, a simple method for minimizing the harmonics distortion associated with a three-phase bridge rectifier is presented. The method employs the LC filter for minimizing harmonics currents and voltages.

II. MODEL SIMULATION

Figure 1 shows the principles of the system application is a distribution network (35 KV). The coupling of the transformer star- triangle is served to eliminate the harmonic of the order 3.

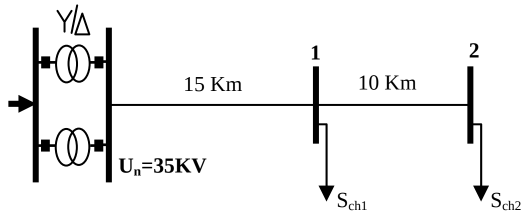


Fig. 1 Distribution network [12]

Where:

$$S_{ch1} = 6{,}1\angle 0{,}6435^{\circ}\ MVA$$
$$\cos\varphi = 0{,}8$$

And

$$S_{ch2} = 2{,}72\angle 0{,}5548^{\circ}\ MVA$$
$$\cos\varphi = 0{,}85$$

II.1. Parameters and loads

The loads are modelled as transversal impedance given in an operated rate:

$$Zch_1 = \frac{|U|^2}{\hat{S}_{ch1}} = \frac{35^2}{4{,}88 - j3{,}66} = 160{,}66 + j120{,}49\Omega$$

$$Zch_2 = \frac{|U|^2}{\hat{S}_{ch2}} = \frac{35^2}{2{,}312 - j1{,}4328} = 382{,}82 + j237{,}24\Omega$$

II.2 Harmonics consideration

we take the load at node 2 as no linear, for example a rectifier which injects harmonic currents, and we chose to study the first three harmonic amplitudes that have the greatest, and are the closest to the fundamental “5, 7, and 11”

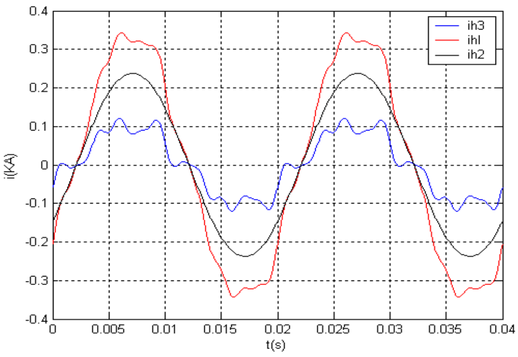


Fig. 2 Harmonics Currents

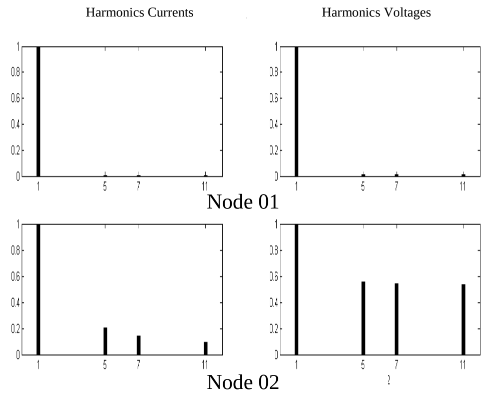
Where:

i_{h1}: harmonic current in the line.

i_{h2}: harmonic current in load 01.

i_{h3}: harmonic current in load 02.

II.3. Spectral representation



III. HARMONIC& FILTERING

LC filter is designed for the second-order passive filter, which contains two reactive components that are inductor and capacitor [7, 8]. When a capacitor and an inductor are placed in the same filter, there are two reactive devices responding in opposite ways to the changes of frequency [9]. The inductor blocks high frequencies and passes low frequencies, while the capacitor passes high frequencies but blocks low frequencies. The filtering action of resistor /capacitor filters are also dependent on the impedance that will vary the frequency. The impedance of a capacitor is inversely proportional to frequency or increasing frequency leads to reducing impedance [7, 9]. For an inductor, its impedance is directly proportional to the frequency. Increasing frequency leads to increasing impedance. So, with these two reactive components, most of the frequency can block and reduce the number of harmonic frequency that goes through the system. Because of this, it can reduce the current harmonics for phase and neutral conductor.

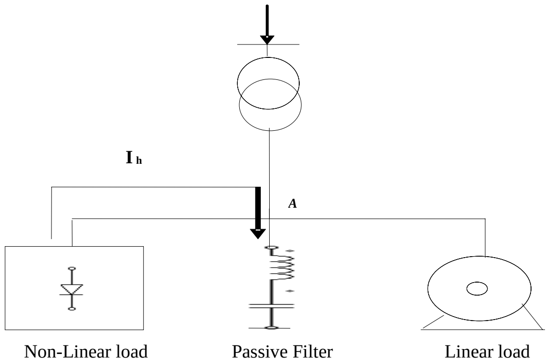


Fig. 3 Schemas of principle

III.1.Passive filters parameters

Before implementing the filter; we must first specify its L C parameter. Witch is the filter impedance

$$Z = j\left(L\omega - \frac{1}{C\omega}\right) \tag{1}$$

If resonance becomes the inductive reactance equals the capacitive reactance, and you can write:

$$L\omega_r = \frac{1}{C\omega_r} \tag{2}$$

ω_r : Is the resonant frequency, it is equal to

$$\omega_r = 2\pi F_r \tag{3}$$

$$F_r = \frac{\omega_r}{2\pi} = \frac{1}{2\pi\sqrt{LC}} \tag{4}$$

The capacitive or inductive reactance which correspond to the frequency is:

Hence: $\omega_r^2 .L.C = 1$

In harmonic regime:

$X_{Lh}=hX_L$ *and* $X_{Ch}=X_C/h$

In the case of resonance: $X_{Lh}= X_{Ch}$

$$X_r = L\omega_r = \frac{1}{C\omega_r} \tag{5}$$

Therefore: $hX_L= X_C/h$

Either $h^2=X_C/X_L$

Hence:

$$h = \sqrt{\frac{X_C}{X_L}} \tag{6}$$

But we can express in terms of reactive power “*Q*” and short-circuit power “S_{cc}”. As follows:

$$h = \sqrt{\frac{S_{cc}}{Q}} \tag{7}$$

With:

h: order harmonic resonance producing parallel

III.2. Single branch filter

The filter is turned to a specified rank harmonic rang (Ex: h = 5.7…). This branch is constituted by the elements LC, the resonance gives one relation

$$\omega h = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{\frac{X_{Lf}}{X_{Cf}}}} \tag{8}$$

So we must have a second equation to solve this system with 2 unknown parameters .our filter branch play in this case double rule: filtering and injection of reactive power

$$X_{Lf} - X_{Cf} = X_{ch} \tag{9}$$

With:

L, C: Are the parameters of the filter
H: The rank harmonic.
X_{Lf}: Inductive reactance filter agreement
X_{Cf}: Capacitive reactance filter agreement
X_{ch}: Reactance inductive load

After simplification we obtain capacitive and inductive reactance respectively as follows:

$$\begin{cases} X_{Lf-h} = \dfrac{X_{ch-h}}{(1-h^2)} & (10) \\ X_{Cf-h} = \dfrac{h^2 . X_{ch-h}}{(1-h^2)} & (11) \end{cases}$$

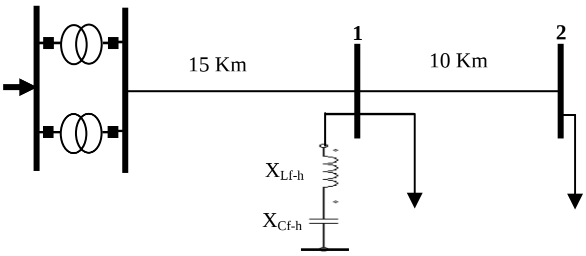


Fig. 4. Implantation of only one passive filter

TABLE I
FILTERING AT NODE 01

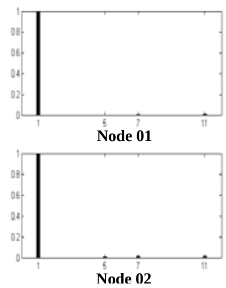
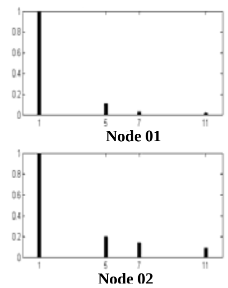
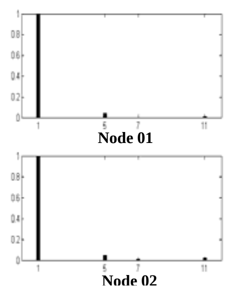
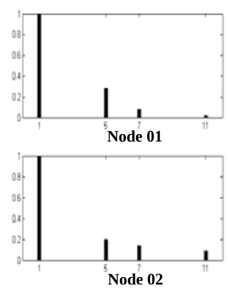
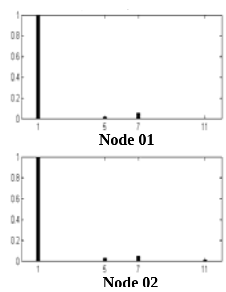
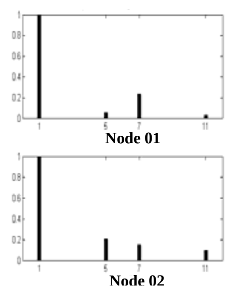
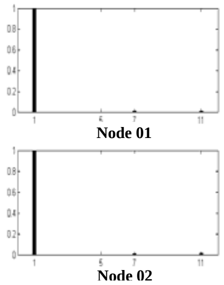
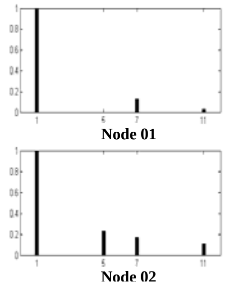
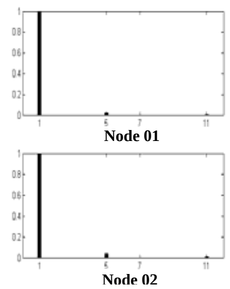
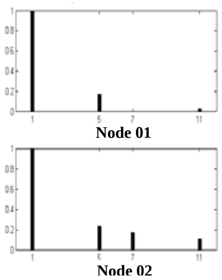
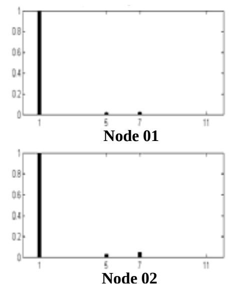
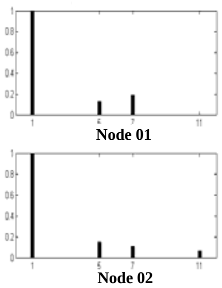
Filter 5	
Harmonics Voltages	*Harmonics Currents*
	
THDv (%)	THDi (%)
0,9691 2,2085	3,2681 11,551 25,822
Filter 7	
Harmonics Voltages	*Harmonics Currents*
	
THDv (%)	THDi (%)
4,1261 5,3657	25,911 29,322 25,822
Filter 11	
Harmonics Voltages	*Harmonics Currents*
	
THDv (%)	THDi (%)
5,3775 5,2220	23,2068 24,0015 26,5923

TABLE II
FILTERING AT NODE 02

Filter 5	
Harmonics Voltages	*Harmonics Currents*
	
THDv (%)	THDi (%)
1,1083 1,9066	8,2572 13,0547 30,5300
Filter 7	
Harmonics Voltages	*Harmonics Currents*
	
THDv (%)	THDi (%)
2,2254 3,8280	8,1768 17,4521 30,5300
Filter 11	
Harmonics Voltages	*Harmonics Currents*
	
THDv (%)	THDi (%)
2,8529 5,5255	8,9289 23,0613 19,5471

III. 3. Multiple harmonic filtering

The filters are placed at node 2 and turned to two harmonics rang (Example (h, h '); 5 and 7 or 7 and 11….

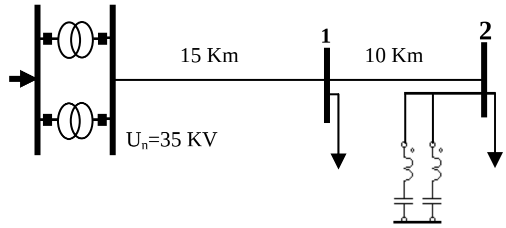


Fig. 5. Implantation of two passives filters

This method requires several conditions to achieve:

$$h^2 = \frac{X_{Cf-h}}{X_{Lf-h}} \quad (12)$$

$$h^{2'} = \frac{X_{Cf-h'}}{X_{Lf-h'}} \quad (13)$$

$$\frac{U^2}{X_{Cf-h} - X_{Lf-h}} + \frac{U^2}{X_{Cf-h'} - X_{Lf-h'}} = Q_{ch2} \quad (14)$$

$$Z_{f-h}' = \frac{h'}{h}.Z_{f-h} \quad (15)$$

- ✓ After simplification we found

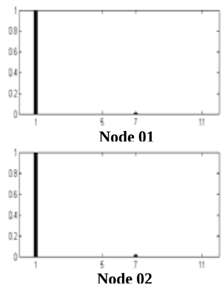
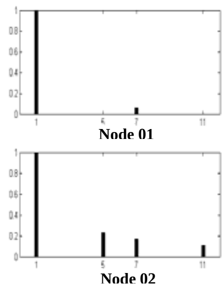
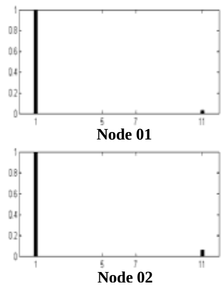
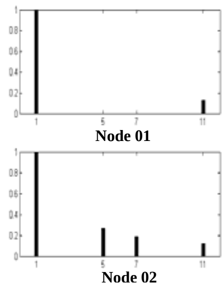
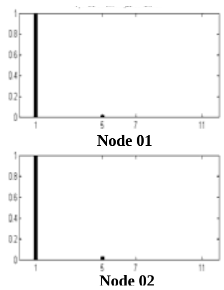
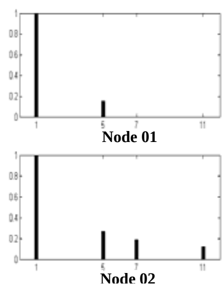
$$X_{Lf-h} = \frac{(h+h').U^2}{(h^2-1).h'Q_{ch2}} \quad (16)$$

$$X_{Cf-h} = \frac{h^2(h+h').U^2}{(h^2-1).h^2Q_{ch2}} \quad (17)$$

$$X_{Lf-h'} = \frac{(h+h').U^2}{(h^{2'}-1).hQ_{ch2}} \quad (18)$$

$$X_{Cf-h'} = \frac{h^{2'}(h+h').U^2}{(h^{2'}-1).hQ_{ch2}} \quad (19)$$

TABLE III
MULTIPLE FILTERING

Filter 5 and 11	
Harmonics Voltages	*Harmonics Currents*
	
THDv (%)	THDi (%)
1,0040 1,7273	7,3139 5,8129 30,5300
Filter 5 and 7	
Harmonics Voltages	*Harmonics Currents*
	
THDv (%)	THDi (%)
3,3885 5,8355	10,4689 12,5064 34,8575
Filter 7 and 11	
Harmonics Voltages	*Harmonics Currents*
	
THDv (%)	THDi (%)
1,8835 3,2440	7,5013 15,1785 34,8575

The following figures summaries the filtering results at node 2 with and without filter branch

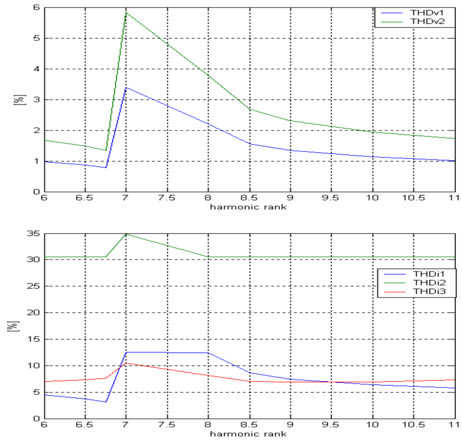


Fig.6. Variation of THD at node 2 with filter 5 & different filters

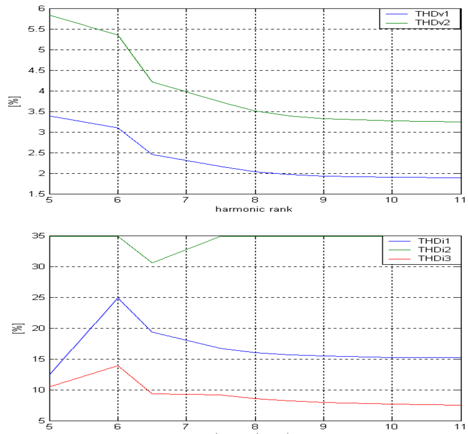


Fig.7. Variation of THD at node 2 with filter 7 & different filters

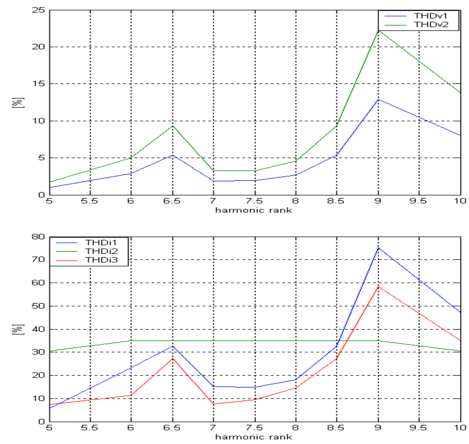


Fig. 8.Variation of THD at node 2 with filter 11 & different filters

According to the figures "6, 7 and 8", we can pull the frequencies of resonances that make an amplification of the THDv and THDi therefore it counsel to avoid connecting some filters on these frequencies.

we note that according to the figure " 6 ", that we have the values of the THDv and THDi are predominant to the rank of the filter 7, therefore we avoid to connect the filters of the ranks (5 and 7) in the same node, and according to the figure "8" we avoid connecting the filter of the rank 11 with the filter of the rank 9, or of the rank 6,5.

IV. CONCLUSION

The experimental results show the effectiveness of the method presented. The application of the proposed procedure hearts the uses of passive filters to reduce harmonics, and the offsetting deficit of reactive power. The model can be drawn from the following concepts:

- Acceptable results given by a specific harmonic filtering, requires a prior study of its design.
- The multiple harmonic filtering provides are eliminated. The location of filters must be carefully selected, in order to avoid dangerous oscillation, and sensitivity of filter parameters to supply frequency deviation.
- Our study lead to the implantation of two filters "5 and 11" is better than other, this choice has yielded good results in terms of network performance (technical) and economic (cost), more this method assures offsetting the deficit in reactive power.

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