A SIMULATION RESEARCH ON PASSIVE HARMONIC FILTERS FOR VARIABLE FREQUENCIES

MÔ PHỎNG BỘ LỌC SÓNG HÀI THỤ ĐỘNG VỚI TẦN SỐ BIẾN ĐỔI

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Abstract:

This article presents the principle of passive harmonic filters with variable frequency based on a nonlinear harmonic reducer depending on working characteristics. A schematic diagram of a harmonic filter with variable frequencies will be proposed. By simulating the operation principle of the device, this paper demonstrates the effectiveness of this device compared with conventional passive harmonic filters including low price, compact size, but the harmonic filtering quality is still the same.

Keywords:

Harmonics, harmonic filters, power quality, power losses.

Tóm tắt:

Bài báo trình bày nguyên lý làm việc của bộ lọc sóng hài thụ động với tần số biến đổi dựa trên một thiết bị phi tuyến phát thải sóng hài theo đặc tính làm việc. Sơ đồ nguyên lý hoạt động của thiết bị lọc sóng hài thụ động với tần số biến đổi sẽ được đề xuất. Thông qua việc mô phỏng nguyên lý hoạt động của thiết bị sẽ chứng minh được tính hiệu quả của thiết bị này so với các thiết bị lọc sóng hài thụ động thông thường như: giá thành rẻ, kích thước gọn nhẹ nhưng tính năng lọc sóng hài không thay đổi.

Từ khóa:

Sóng hài bậc cao, bộ lọc sóng hài, chất lượng điện năng, tổn thất điện năng.

1. INTRODUCTION

At present, harmonics filtering in electrical systems is one of the most important issues to improve power quality, to increase efficiency and lifespan of electrical appliances, to reduce power losses in electrical systems. In fact, high-power nonlinear devices are being used extensively in power grid such as: single phase or three-phase rectifiers and inverters, SVC,… In many countries, the percentage of nonlinear loads can be as high as 80-90% [2].

These nonlinear devices often cause harmonic spectrum which varies both in amplitude and in frequency [1], [2].

Therefore, in order to put harmonics within the limits [3] we need to use harmonic filters. If using classical harmonic filters (single frequency filters), it will need to use a lot of filters to reduce the impact of different harmonic frequencies. This leads to an increase of the equipment cost. Therefore, a variable frequency harmonic filter can reduce the cost of production and improve the efficiency of harmonic filter.

In this article, the simulation results of the passive harmonic filter with variable frequencies will be present. It is used for a harmonics reduction system depending on working characteristics of a compensating device using smooth - adjust thyristor system - by MATLAB - Simulink program. The simulation results introduce the harmonic filtering efficiency of this device which is more effective than the common passive harmonic filters.

2. CIRCUIT DIAGRAM USING HARMONIC FILTER WITH VARIABLE FREQUENCIES

2.1. Circuit principle

A schematic diagram of a harmonic filter with variable frequencies is used to filter harmonics for a single-phase turbo scroller (TCR) as shown in Fig.1. The inductor X0 has a capacity of 100 kVAr, thyristor T0 pairs anti-parallels.

The working principle of this device can be described as follows: By determining and changing the firing angle α, from 90^o to 180^o, it is possible to smoothly adjust the reactive power of the inductor X0 from 100 kVAr to 0 kVAr.

The change in the reactive power of the inductor X0 is determined by the formula [4]:

$$Q_1 = \frac{E^2}{\pi^2 \omega L}\left(2\pi - 2\alpha + \sin 2\alpha\right)^2 = \frac{Q_L}{\pi^2}\left(2\pi - 2\alpha + \sin 2\alpha\right)^2 \quad (1)$$

QL is the rated power of the inductor; α is the firing angle of the thyristor (in radians).

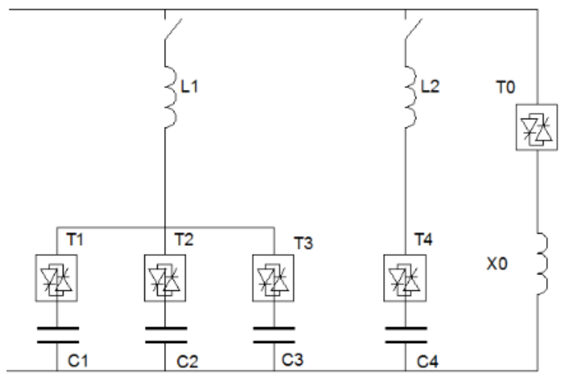

Fig.1. The principle of the proposed harmonic filter with variable frequencies

However, during the control process, the harmonics generated is very large and the amplitude of the harmonics is highly dependent on the firing angle α of the thyristor (see Table 1).

From Table 1, in the TCR device, harmonics focus mainly on order 3, 5, 7 and 9. The values of these harmonics depend on the angle α. If using classical passive filter, 04 sets should be used. However, in this case, we will consider to install two harmonic filters, one with fixed frequency for filtering 3 harmonic order. The other has 3 filter frequencies, including orders 5, 7, and 9. The change in filter frequency will be achieved by closing or opening the capacitor system using thyristors T1, T2 and T3.

Table 1. Harmonics amplitude depending on firing angle α [4]

α (°)	90	120	135	150	180
I_3,A	0	19.9	15.3	6.6	0
I_5,A	0	4.0	3.1	4.0	0
I_7,A	0	1.4	2.2	1.4	0
I_9,A	0	2.0	1.0	0.2	0
I_{11},A	0	0.7	0.8	0.7	0
I_{13},A	0	0.4	0.5	0.4	0
I_{15},A	0	0.7	0.4	0.0	0
I_{17},A	0	0.3	0.3	0.3	0
I_{19},A	0	0.2	0.3	0.2	0

2.2. Calculation method for selecting the capacity of passive harmonic filters with variable frequencies

The filter in Fig.1 consists of three capacitors C1, C2, C3, which have different capacitances, each capacitor is controlled by two parallel thyristors. The resonance frequency of the device when closing a capacitor as follows [5], [6]:

$$\nu_1 = \sqrt{\frac{X_{C1}}{X_{L1}}} \tag{2}$$

When the second capacitor is connected, the equivalent capacitance of two parallel capacitors as follows:

$$X_{Ctd2} = \frac{1}{\frac{1}{X_{C1}} + \frac{1}{X_{C2}}}$$

The resonance frequency will be:

$$\nu_2 = \sqrt{\frac{X_{Ctd2}}{X_{L1}}} = \sqrt{\frac{\frac{1}{\frac{1}{X_{C1}} + \frac{1}{X_{C2}}}}{X_{L1}}} \tag{3}$$

Similarly, when the third capacitor is connected, the resonance frequency of the device will be:

$$\nu_3 = \sqrt{\frac{X_{Ctd3}}{X_{L1}}} = \sqrt{\frac{\frac{1}{\frac{1}{X_{C1}} + \frac{1}{X_{C2}} + \frac{1}{X_{C3}}}}{X_{L1}}} \tag{4}$$

The value of X_{C1}, X_{C2}, X_{C3} and X_{L1} will be selected to match the harmonic amplitude caused by the change in load power.

3. SIMULATION RESULTS

Simulation results were recorded with different angles α and calculated in 2 cases, as follows:

- Case 1: Do not use filters.
- Case 2: Use a fixed frequency filter for harmonic order 3 and a variable frequency filter for harmonic orders 5, 7 and 9.

The simulation schematic is shown in Fig.2.

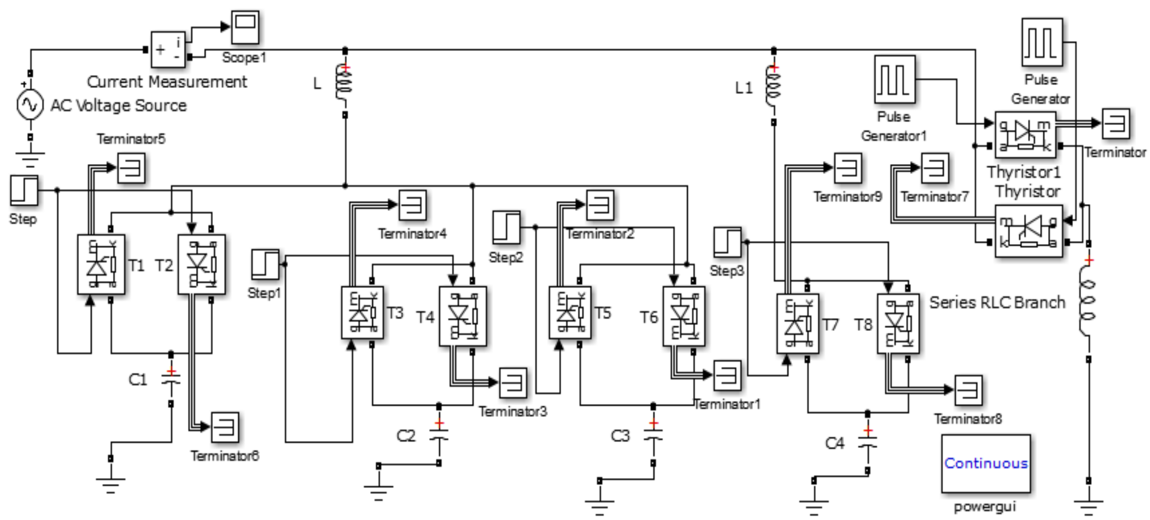

Fig.2. Matlab - Simulink simulation schematic of a passive filter with variable frequencies

3.1. When the angle α = 127°

- Case 1: Do not use filters.

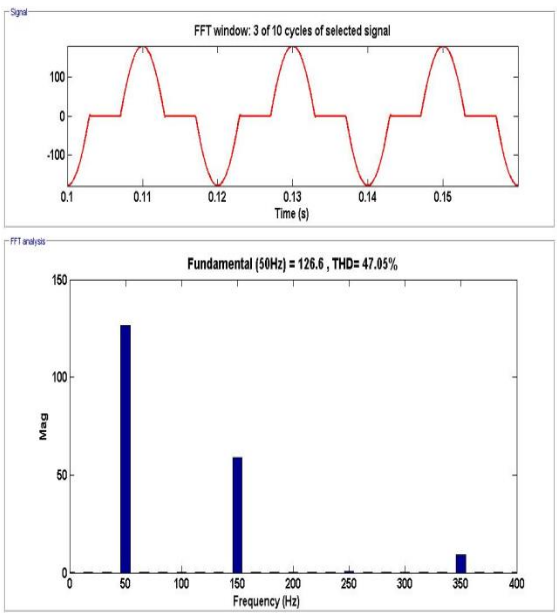

Fig.3. Waveform distortion and THD at α = 127°

In this case, the waveform of the current is shown in Fig.3. The harmonics are very high. The third - order and seventh - order harmonics are the highest. The THD index is 47.05% (see Fig.3).

- Case 2: Use a fixed frequency filter for harmonic order 3 and a variable frequency filter for harmonic order 7.

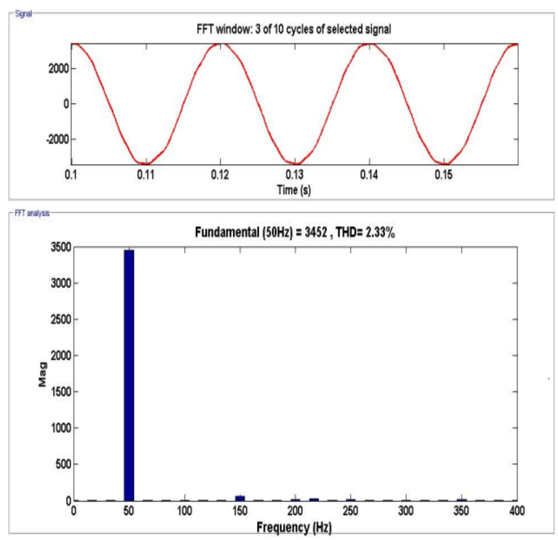

Fig.4. Waveform distortion and THD when using third - order and seven - order filters at α = 127°

When using filters to filter large harmonic frequencies, the waveform is corrected closer to the sinusoidal form (see Fig.4). The distortion rate is very small. The total THD level of the harmonics is 2.33%.

3.2. The angle α = 110^0

- Case 1: Do not use filters.

The total harmonic level of the harmonics is 23.41%, where the harmonic order 3 and 5 are the largest (see Fig.5).

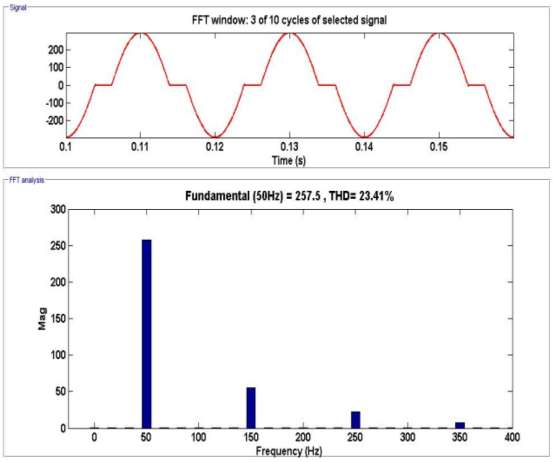

Fig.5. Waveform distortion and THD when not using filter at α = 110^0

- Case 2: Use a fixed frequency filter for harmonic order 3 and a variable frequency filter for harmonic order 5.

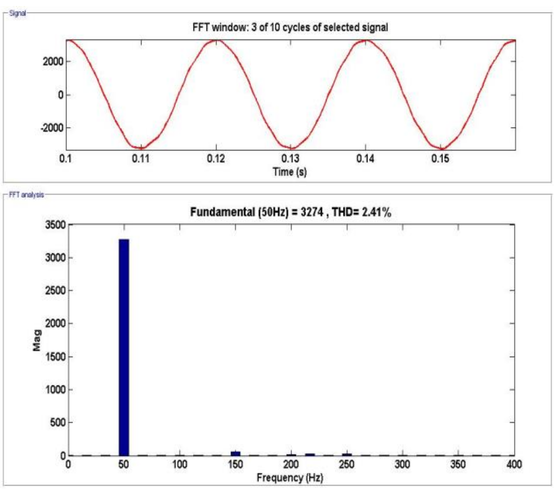

Fig.6. Waveform distortion and THD when using filters 3 and 5 - order frequencies at α = 110^0

Since the third harmonic is the largest, then to the fifth harmonic. Two harmonics filters with frequency orders of 3 and 5 are used. Thus, wave distortion is much reduced compared to the case do not use filters and the THD index in this case drops to 2.41% (see Fig.6).

Through the simulation results for two firing α of the inductance, when the width of angle changes, the amplitude of the harmonics also changes. And the use of passive harmonic filters with variable frequencies will be more effective than using single frequency filters (in case 1).

4. CONCLUSION AND DISCUSSION

The use of nonlinear loads has many advantages compared with previous electrical and electronic equipment. However, beside these advantages, these nonlinear devices generate harmonics that reduce the power quality. This results in increasing power losses, reducing lifespan, especially for electronic devices. Through this paper, the author introduced a solution using harmonic filters with variable frequencies.

The working principle of this device is explained based on the analysis and calculation of the harmonics emission of a typical non-linear load. The efficiency of harmonic filters with variable frequencies is indicated clearly through simulation. Simulation results show that, at some time, variable frequencies harmonic filters offer greater efficiency than conventional single frequency harmonic filters. In addition, this solution also reduces the investment cost and the device is lighter than the classical filter.

These harmonics filters are well suited to variable nonlinear loads. And we can completely research and produce this device.

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Biography:

Anh Tuan Bui, received the B.S and M.Sc. degrees in electrical engineering from Hanoi University of Science and Technology, Vietnam in 2001 and 2006, respectively. He received the Ph.D. degree in electrical materials from Ampere University, Lyon, France in 2011. He is the lecturer at the Faculty of Electrical Engineering, Electric Power University, Vietnam.

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