Abstract—In this paper, a compensator unit is presented that removes the entire harmonic generated by phase cutting devices such as dimmers and dimming controlled DC motor. The presented dynamic compensator, which has been designed and implemented, is very low cost and furthermore it has a very exact operation to reduce the total harmonic distortion (THD). The experimental results are presented to validate the theoretically results.

Keywords—Compensator, Harmonic, Phase Cutting Devices.

I. INTRODUCTION

As we know electrical energy is expensive and there are many devices such as dimmers, DC controlled motors which operate based on the phase cutting process. These devices produce a lot of harmonics generated by cutting the input electrical sine-wave. The harmonic distortion in the input current has harmful outcomes on the power electrical networks and will not also comply with international standards such as IEC 61000-3-2 (class C equipments) [1],[2],[3],[4],[5]. Recently, harmonic reduction of phase cutting dimmers has attracted considerable attentions [6],[7],[8],[9],[10]. In this paper, the presented harmonic compensator is located as the parallel element with the main system. In order to economize the electrical energy, the output of compensator is connected to resistance (elements) of the water heaters or boilers in houses or industrial centers.

II. HARMONIC COMPENSATOR

As shown in Fig. 1, the harmonic compensator is parallel with the phase cutting device, so the total current of the system is the sum of the device current and the compensator current. The implemented circuit of the harmonic compensator for one phase cutting device is shown in Fig. 2. It can be seen that the compensator is dynamic type and Gate turn-off thyristor (GTO) has been used. For economizing the electrical energy, the load of the compensator is the resistance (element) of the water heater or boiler in houses or industrial centers. Note that, in order to remove all of the harmonic distortion, the load of each compensator must be equal to the input resistance of phase cutting device.

The experimental results including the currents of the total system, the phase cutting device and the harmonic compensator using phase cutting angle equal to 90° (α = 90°) are shown in Fig. 3. As we see the total current of the system is completely sinusoidal form. Thus, the system does not generate any harmonic distortion.

III. QUANTITY OF THE REMOVED THD

Suppose that, the compensator of the system has been removed from the system. For the THD of the system (without compensator), we have

\[ THD = \sqrt{\sum_{n=2}^{\infty} \frac{|A_n|^2}{|A_1|^2}} \]  

where

\[ |A_n|^2 = \frac{1}{2\pi} \int_{-\pi/2}^{\pi/2} \sin(n\alpha) \cos(n\alpha) dx + \frac{1}{2\pi} \int_{-\pi/2}^{\pi/2} \sin(n\alpha) \sin(n\alpha) dx \]

So, we have

\[ |A_n|^2 = \frac{1}{4\pi^2} \left( \frac{1}{n+1}^2 + \frac{1}{n-1}^2 + \left( \frac{n-2}{n^2-1} \right)^2 - \frac{2}{n^2-1} \cos(2\alpha) \right) \]

\[ + \frac{4}{(n^2-1)(n+1)} \cos(n+1)\alpha - \frac{4}{(n^2-1)(n-1)} \cos(n-1)\alpha \]

for \( n \geq 2 \)

and

\[ |A_n|^2 = \frac{1}{8\pi^2} (1 - \cos 2\alpha) + (1 - \frac{\alpha}{2\pi})^2 + \frac{1}{2\pi} (1 - \frac{\alpha}{2\pi}) \sin 2\alpha \]

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\[ THD = \frac{1}{2\pi} \sum \left[ \left( \frac{1}{n+1} \right)^2 + \left( \frac{1}{n-1} \right)^2 + \left( \frac{2}{n^2-1} \right)^2 - \frac{2}{n^2-1} \cos(2\alpha) + \frac{4}{(n-1)(n+1)} \cos((n+1)\alpha) - \frac{4}{(n-1)(n-1)} \cos((n-1)\alpha) \right] \]

So, equation (5) presents the THD of the system that has been removed using the proposed harmonic compensator.

IV. A Practical Application

In this section, a DC motor, which is controlled by a phase cutting dimming controller, is presented as an application of the proposed compensator. The block diagram and circuit of the dimming controlled DC motor is shown in Fig. 4. Since the rectifier located in the input of the DC motor acts as a half wave rectifier, a diode (D1) is added to the proposed compensator in order to compensate the negative half cycle of the AC input.

V. Conclusion

In this paper, a dynamic compensator unit was presented that removes the entire harmonic generated by phase cutting devices such as dimming controlled DC motor. A practical application of the proposed compensator was presented. The experimental results of the implemented compensator validated the exact operation of the proposed compensator.

REFERENCES


