# Силовая электроника

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**Yu.S. Demchenko**
National Technical University of Ukraine "Kyiv Polytechnic Institute",
st. Polytechnique, 16, Kiev, 03056, Ukraine.

## Investigation of the Energy Characteristics of High Frequency Power Factor Correctors

*In this paper the investigation of the energy characteristics of the active high-frequency power factor correctors for three control methods (borderline control, peak current control and average current control) is made. In MATLAB/Simulink environment models corresponding to each method of control were developed. Power factor correctors' energy performance under the nominal load condition, under reduced and increased load resistance was researched. For the peak and average current control methods two values of a switching frequency were used – 50 kHz and 100 kHz.* References 3, figure 1, tables 3.

**Keywords:** *power factor corrector, control method, model, energy performance, total harmonic distortion, efficiency*.

### Introduction

In recent years national and international standards were introduced (EN 61000-3-2), which impose restrictions on electricity consumers' emission of current higher harmonics in the supply network [1]. To meet the requirements of these standards in modern power converting devices power factor correction is widely used. This allows reducing the level of mains current harmonics and improving the power factor.

A typical active high frequency power factor corrector (PFC) based on a boost converter is shown in Fig. 1. The PFC is constructed so that the shape of the average input current waveform is close to the shape of the supply network voltage. Ideally, they have the same shape and are in-phase, herein the power factor is equal to one. Modern PFCs provide a power factor close to 0.99, which suggests consumers influence on supply network is insignificant [3].

In addition to improving the electromagnetic compatibility of a power supply, the use of the PFCs enables to provide the stabilized output voltage of a corrector, which simplifies the design of secondary power supplies, such as high-frequency inverters, DC voltage converters and regulators [3].

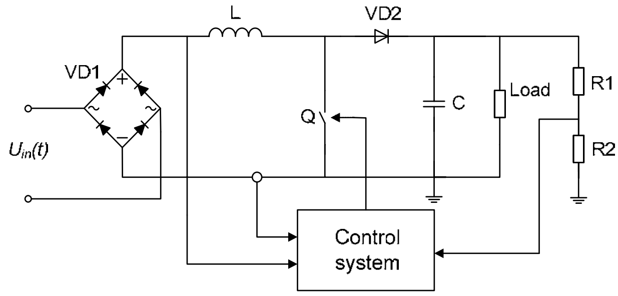


**Fig. 1. Power factor corrector based on a boost converter**

In this paper the following PFC control methods are considered: borderline control, peak current control and average current control methods. Description of these methods can be found in [2]. In MATLAB/Simulink environment the models of such correctors were developed and the electromagnetic processes in the PFCs were studied.

### The Energy Characteristics Investigation

The following energy performance rates were used for comparison: power factor χ, the cosine of the phase shift of the input voltage and the first input current harmonic (cosφ), total harmonic distortion (THD) of the input current and corrector efficiency η. The MATLAB/Simulink blocks were used to get the values of these parameters.

The energy characteristics investigation of the correctors was conducted for the nominal load condition $R_{Ln}$ = 700 ohms, for three times reduced load resistance and two times increased load resistance. Moreover, for the peak and average current control methods two values of a switching frequency were used – 50 kHz and 100 kHz.

The energy performance for the borderline control method is given in Table 1. Obtained results show that for this control the power factor and THD deteriorate with decreasing and increasing the load relative to the nominal value. Efficiency increases with decreasing the load resistance. The value of the THD can be improved by adding a high-frequency filter on the corrector input.

**Table 1. Energy performance for the borderline control method**

| Energy performance | RLn/3 | RLn | 2·RLn |
|---|---|---|---|
| χ | 0,826 | 0,838 | 0,819 |
| cosφ | 1 | 1 | 1 |
| THD, % | 68,2 | 65,2 | 70 |
| η | 0,972 | 0,867 | 0,817 |

Table 2 shows the energy performance for the peak and average current control methods with a switching frequency $f_s$ = 50 kHz. The best rates were obtained for the load resistance $R_{Ln}/3$, while the worst for $2 \cdot R_{Ln}$.

**Table 2. Energy performance for the peak and average current control methods with a switching frequency $f_s$= 50 kHz**

| Energy performance | Load resistance | Peak current control | Average current control |
|---|---|---|---|
| χ | 3 times reduced | 0,985 | 0,986 |
| | nominal | 0,971 | 0,975 |
| | 2 times increased | 0,959 | 0,966 |
| cosφ | 3 times reduced | 0,999 | 0,998 |
| | nominal | 1 | 0,999 |
| | 2 times increased | 1 | 1 |
| THD, % | 3 times reduced | 17,4 | 15,8 |
| | nominal | 24,5 | 22,3 |
| | 2 times increased | 29,6 | 26,5 |
| η | 3 times reduced | 0,895 | 0,895 |
| | nominal | 0,768 | 0,768 |
| | 2 times increased | 0,643 | 0,639 |

Table 3 shows the energy performance for the peak and average current control methods with a switching frequency $f_s$ = 100 kHz. Evidently, increasing the frequency improves the power factor and THD, but the efficiency falls.

**Table 3. Energy performance for the peak and average current control methods with a switching frequency $f_s$ = 100 kHz**

| Energy performance | Load resistance | Peak current control | Average current control |
|---|---|---|---|
| χ | 3 times reduced | 0,994 | 0,999 |
| | nominal | 0,994 | 0,997 |
| | 2 times increased | 0,984 | 0,989 |
| cosφ | 3 times reduced | 1 | 0,999 |
| | nominal | 1 | 0,999 |
| | 2 times increased | 1 | 0,999 |
| THD, % | 3 times reduced | 11,1 | 4,1 |
| | nominal | 11,1 | 6,7 |
| | 2 times increased | 18,1 | 14,3 |
| η | 3 times reduced | 0,813 | 0,817 |
| | nominal | 0,628 | 0,61 |
| | 2 times increased | 0,477 | 0,52 |

## Conclusion

In this paper the research of the energy performance of three different high-frequency PFC control methods was conducted. In MATLAB/Simulink environment the models for each control method were constructed and the reaction of these models to a load change was studied.

Based on the results obtained the following conclusion can be made: the average control method has the best power factor value while borderline control method has the worst. The borderline control has higher efficiency than the peak and average current control. The cosine of the phase shift of the considered methods is close to unity and almost independent of the load resistance change. The best THD was obtained for the average current control, and the worst for the borderline control. Taking into consideration that for the PFC the key indicators are the power factor and the total harmonic distortion, we can conclude that among the considered correction techniques the best performance is produced using the average current control method.

Also it was found that the power factor and THD are better at higher frequencies. Meanwhile, the efficiency deteriorates with increasing the frequency

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**Ю.С. Демченко**

Національний технічний університет України "Київський політехнічний інститут",

вул. Політехнічна, 16, корпус 12, м. Київ, 03056, Україна.

## Дослідження енергетичних характеристик високочастотних коректорів коефіцієнта потужності

*У даній статті проведено дослідження енергетичних характеристик активних високочастотних коректорів коефіцієнта потужності для трьох методів керування (граничного керування, керування по піковому струму та по середньому струму). У середовищі MATLAB/Simulink були розроблені відповідні моделі для кожного методу керування. Досліджені енергетичні показники коректорів коефіцієнта потужності при роботі на номінальне навантаження, при зменшеному та при збільшеному опорі навантаження. Для методів керування по піковому та по середньому струму використано два значення частоти комутації – 50 кГц та 100 кГц.* Бібл. 3, рис. 1, табл. 3.

**Ключові слова:** *коректор коефіцієнта потужності, метод керування, модель, енергетичні показники, коефіцієнт сумарних гармонічних спотворень, коефіцієнт корисної дії.*

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**Ю.С. Демченко**

Национальный технический университет Украины "Киевский политехнический институт",

ул. Политехническая, 16, корпус 12, г. Киев, 03056, Украина.

## Исследование энергетических характеристик высокочастотных корректоров коэффициента мощности

*В данной статье проведено исследование энергетических характеристик активных высокочастотных корректоров коэффициента мощности для трех методов управления (граничного управления, управления по пиковому току и по среднему току). В среде MATLAB/Simulink были разработаны соответствующие модели для каждого метода управления. Исследованы энергетические показатели корректоров коэффициента мощности при работе на номинальную нагрузку, при уменьшенном и при увеличенном сопротивлении нагрузки. Для методов управления по пиковому и по среднему току использовано два значения частоты коммутации - 50 кГц и 100 кГц.* Библ. 3, рис. 1, табл. 3.

**Ключевые слова:** *корректор коэффициента мощности, метод управления, модель, энергетические показатели, коэффициент суммарных гармонических искажений, коэффициент полезного действия.*

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