ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 7, Issue 2 , February 2020

Higher harmonics of the primary current of rectifiers for control with double switching ON/ OFF valves

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ABSTRACT: This article discusses the main problems with double inclusion valves for converters with natural commutation, as well as adverse harmonic compositions of the primary current.

KEYWORDS: Valves, natural commutation, double switching, primary current three-phase bridge converter.

I. INTRODUCTION

Electric power in industrial production is used in electric drive, various electrical installations.
Consequently, various converter devices are needed to meet the power generation needs of different types and parameters and to effectively control its distribution.
Semiconductor converters best satisfy the above requirements. They have small dimensions and weight, consume very low control power, have high speed, and their versatility allows to create a wide variety of devices. All these qualities offer a wide range of opportunities for their application.

II. METHODOLOGY

The control method with double activation of valves for natural switched converters was proposed by O.A. Maevskii. This method was further extended to forced switched converters.
The authors analyzed the harmonic composition of the primary current of the three-phase bridge converter (Fig.1 a) with forced double actuation of valves and investigated ways of reducing distortion power.
Decomposition of the primary current curve (Fig. 1 b) under forced double-switching control of the valves of the three-phase bridge converter gives the following expression for the amplitudes of the various harmonic components of the primary current:

$$I_1(k)_m = \frac{8Id}{k\pi} sin^2 \frac{k\pi}{2} cos \frac{k\pi}{6} \sin\left(\frac{\pi}{6} - \alpha\right) \quad , \qquad (1)$$

Where α-angle of delay at the first actuation of valves (the second time valves are switched on with delay equal to 240 ° -α)

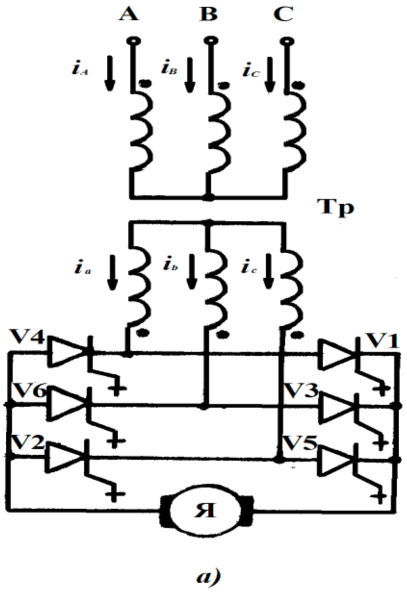

Fig. 1 a: Three-phase bridge converter with forced double switching on of valves

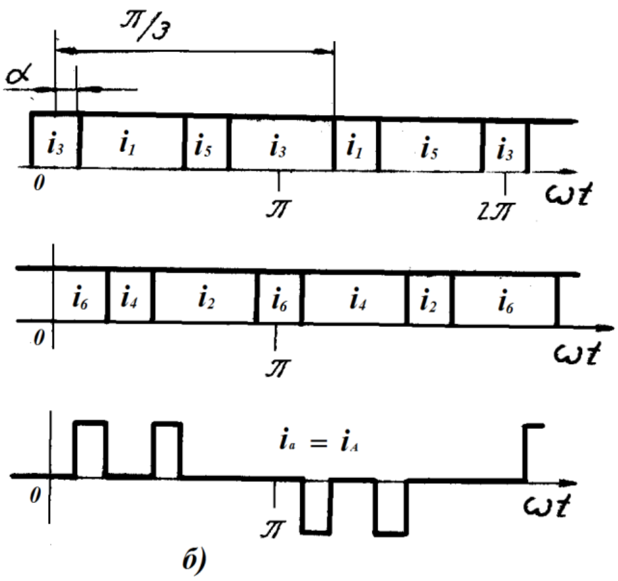

Fig. 1 b: Decomposition of primary current curve.

At α = 0, as with symmetric control, we get

$$I_1(k)_{m_0} = \frac{8Id}{k\pi} sin^2\frac{k\pi}{2} cos\frac{k\pi}{6} sin\frac{k\pi}{6} \quad (2)$$

Dividing (1) by (2),

$$\frac{I_1(k)_m}{I_1(k)_{m_0}} = \frac{sink\,(\frac{\pi}{6}-\alpha)}{sin\frac{k\pi}{6}} \quad (3)$$

You can find that the maximum value is

$$I_1(k)_m max = 2I_1(k)_{m_0} \quad (4)$$

Higher harmonic reaches at angles equal to

$$\alpha_{kp} = \frac{\pi}{6} * \frac{k-3}{k} \quad (5)$$

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Thus, from the expressions (1) and (3) it follows that when controlling with double forced actuation of valves in consumed three-phase bridge converter, current contains only canonical, for this scheme higher harmonic.

For comparison we will consider harmonious structure of primary current of the three-phase bridge converter at serial management under the law $\alpha_k = \alpha_a = \alpha$ (where α_a and α_k-the angles of management of gates of anode and cathode groups of gates respectively).

Decomposition of primary current curve (Fig.1v) under $\alpha_k = -\alpha_a$ a law control allows to obtain the following expression for amplitudes of harmonic components

$$I_{1(k)m} = \frac{4I_d}{k\pi} sin\frac{k\pi}{3} sink(\frac{\pi}{2} - \alpha) \qquad (6)$$

Analysis of the expression (6) shows that in the curve of the current consumed from the network there are only 3 and all multiples of it harmonic. During adjustment of rectified voltage, harmonic amplitudes change, reaching their maximum value at certain values α and decreasing to zero at others. From (1) follows that harmonious, initial for the three-phase bridge scheme, changing in the course of regulation of the straightened tension, do not go beyond I_ values $I_{1(k)m_0}$ which they have in the three-phase bridge converter at usual (symmetric) management. However at $\alpha \neq 0$ in a curve consumed by the converter current appear even harmonious, not multiple we rub which cause the low power factor of the converter.

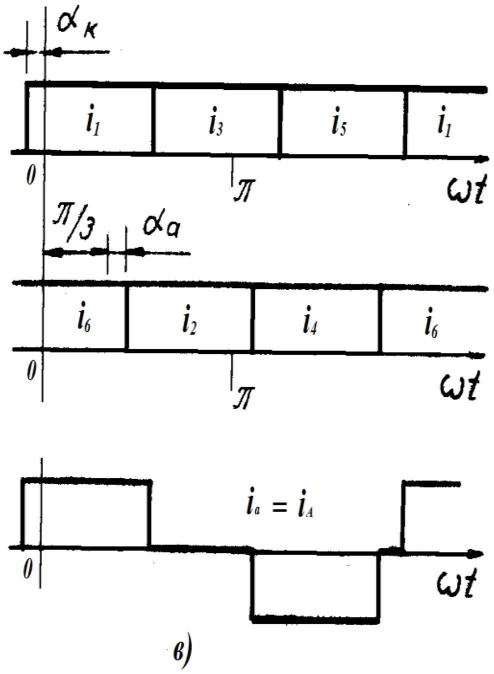

Fig. 1 v: Decomposition of primary current curve.

Power factor of three-phase bridge rectifier at forced double actuation of valves of Fig.1g (curve 2) is not much higher than at control of valve groups according to the law $\alpha_k = -\alpha_a$ Fig.1g (curve 1), but harmonic composition of current consumed from the network is more favorable: It contains only canonical harmonics for the phase bridge circuit, and the relatively small effect in increasing the power factor is due to the fact that in control with double switching on the valves the maximum amplitudes of the higher harmonics are twice as high as in normal (symmetrical) control.

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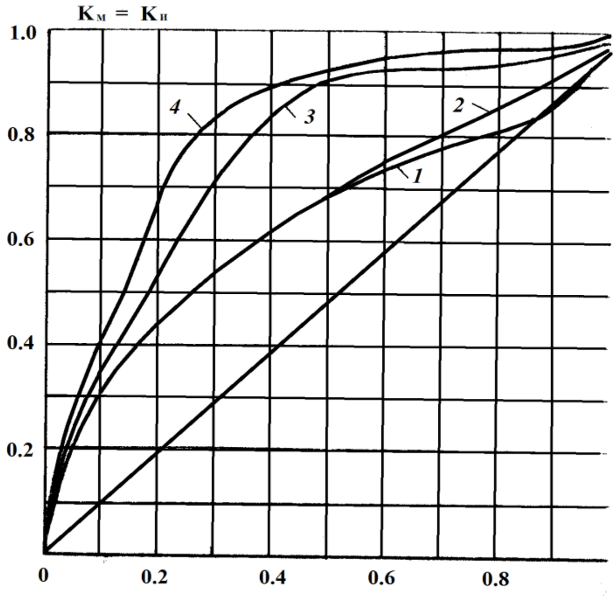

Fig. 1 g: Power factor of three-phase bridge rectifier at forced double actuation of valves.

From the above it can be concluded that the highest energy values without deterioration of other operating properties can be obtained in a rectifier with forced double actuation of valves,

When installing the 5th and 7th harmonics filters, the effective value of the current consumed from the network in relative units can be determined by the formula

$$\frac{\acute{I}_1}{I_{10}} = \acute{K}_v = \sqrt{1 - \frac{6\alpha}{\pi} - \frac{36}{\pi^2}\left[\frac{1}{25} sin^2 5\left(\frac{\pi}{6} - \alpha\right) + \frac{1}{49} sin^2 7\left(\frac{\pi}{6} - \alpha\right)\right]}$$

The power factor can be calculated using the formula

$$K_M = K_и = \frac{6}{\pi} * \frac{\sin\left(\frac{\pi}{6} - \alpha\right)}{\acute{K}_v} \qquad (8)$$

This constraint is based on Figure 1 (3 curve). Comparing it with a similar dependence on Figure 1 (2 curve) without filters of higher harmonics, it can be concluded that a three-phase bridge rectifier with forced double actuation of valves and filters of the 5th and 7th harmonics has a sufficiently high power factor. The power factor in this case can be calculated by the formula

$$K_M = K_и = \frac{6}{\pi} * \frac{\sin\left(\frac{\pi}{6} - \alpha\right)}{\sqrt{1 - \frac{6\alpha}{\pi} - \frac{36}{\pi^2}\left[\frac{1}{25} sin^2 5\left(\frac{\pi}{6} - \alpha\right) + \frac{1}{49} sin^2 7\left(\frac{\pi}{6} - \alpha\right) + \frac{1}{14} sin^2 11\left(\frac{\pi}{6} - \alpha\right) + \frac{1}{169} sin^2 \beta\left(\frac{\pi}{6} - \alpha\right)\right]}} \qquad (9)$$

This dependence is also represented in fig. 1g (a curve 4), and on average the power factor of the recipient in this case is higher, than in the three-phase two bridge rectifier at control of gates of certain bridges under the law $\alpha_{k=} - \alpha_{a}$.

III. EXPERIMENTAL RESULTS

Thus, the most promising application of control of valves of three-phase bridge with their forced double activation at simultaneous installation on AC side of resonance inductive-capacitive filters of the most powerful higher harmonics should be considered. Such a method of increasing the energy performance of three-phase bridge rectifiers is much more efficient than using thyristor reactive power sources, since in both cases it is necessary to install filters of higher harmonics of approximately the same power, but when controlling the valves of the bridge with forced double activation, no controlled reactive power source is required, the dimensions of which are commensurate with the dimensions of the rectifier itself.

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IV. CONCLUSION AND FUTURE WORK

Development of power converter technology is stimulated by continuous growth of consumed electric power using devices operating on direct current and devices using AC electric power with different parameters in frequency different from generated 50-60 Hz.
Solid-state semiconductor devices based on lockable thyristors (GTO, IGCT), powerful field transistors with lockable gate (IGBT) allowed to dramatically increase the unit power to several megawoltampers, as well as improve their dynamic performance by the times of power circuits switching on and off.
All this allowed to create powerful converter substations for power supply of electric transport, powerful electric drives of rolling mills, electro technological plants and other consumers.
Along with powerful consumers, there are numerous local consumers where direct current is used (medicine, electroplating, household appliances).
In order to properly design any converter device, it is necessary to meet a number of requirements to ensure certain technological characteristics, energy and other indicators (as consumers of electricity from the AC power system).
The proposed article will provide the necessary answers on the choice of converter circuit, selection of elementary base, determination of energy characteristics, influence of converter plants on the supply network and development of measures to ensure electromagnetic compatibility.

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ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
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