THREE -PHASE BRIDGE UNIDIRECTIONAL RECTIFIER WITH HIGH POWER FACTOR

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A b s t r a c t

In this report a method for output direct voltage control is proposed, which is based on an investigated theoretical model of the consumed from three-phase bridge unidirectional rectifier input current. By making use of this method a high power factor is reached as well as the even harmonics at the input of the considered power convertor are eliminated.

Introduction

The advantages of the three phase bridge unidirectional rectifier determine its application in the development of rectifier devices for different purposes. But this circuit has some disadvantages and the most important is the generation of even harmonics, exept the typical for the three-phase symmetrical rectifier odd harmonics [2, 3, 4, 6]. Some methods with phase control of the rectifiered voltage in case of ideally smooth load current of three-phase bridge circuits are co nsidered in [1]. They contribute to the power factor improvement but the even harmonics remain in the current consumed by the three-phase bridge unsymmetrical curcuit. A method is proposed [5] for obtaining the power factor as well as the harnonics of the input current consumed by everyone power electronic line connected convertor.

In this report a method for output direct voltage control is proposed, which is based on an investigated theoretical model of the consumed from three-phase bridge unidirectional rectifier input current. By making use of this method a high power factor is reached as well as the even harmonics at the input of the considered power convertor are eliminated.

Description of the method

A power circuit of three-phase bridge unidirectional rectifier with GTO thyristors is given on fig.1. In this case GTO are used instead of the standard thyristors in order to be able to realize prectically the proposed theoretical models of the comsumed by the convertor current. The investigation is carried out accrding to the following assumptions: ideal thyristors and diodes, ideally smoothed load current, unlimited power of the line, efc

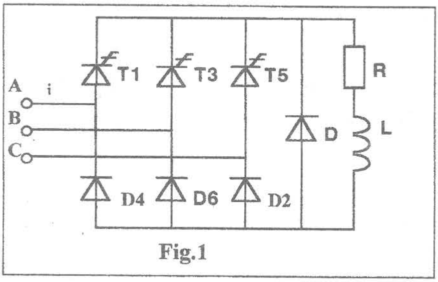


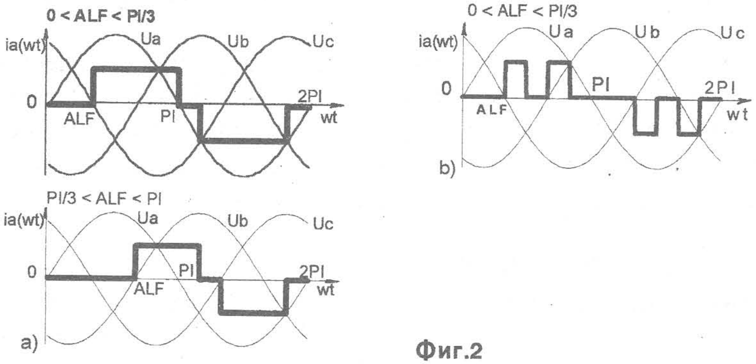
Fig.1

The thoretical models of the consumed by three-phase bridge unidirectional rectifier input current are developed for the following cases:

1. Phase control.
2. Phase control with two thyristor commutations per half cycle of the line voltage.

The first model has been known from the theory of rectifier convertors [1.2] but there is not information in the specialized literature about all the power factors and harmonics obtained at the input of the considered convertor. The latter serves as a basis for comparison with the proposed in the next section new model of phase control with two commutations per half period of the line voltage where the current conducting time of given phase that is equal to 120^0 for the uncontroled rectifier is devided in two equal intervals. The first one begins from the point of the thyritors real possible turn on ($(\alpha = 0)$) and finishes at $\alpha = 60^0$. This is the beginning of the second interval which has the same duration as the first one. In both intervals a phase control is used where the maximum of the control angle is 60^0 .

The variation of the convertor input current for control angles from 0 to maximum of the described two models is shown on fig.2



Фиг.2

The variation of the phase current (for inst. of the phase A) for the first model with phase control is demonstrated on fig. 2a. It could be presented in the interval $(0 - 2\pi)$ with the folloing equations:

at $(0 \le \alpha \le \pi/3)$

$$i_A = I_d\Big|_{\pi/6+\alpha}^{5\pi/6+\alpha} - I_d\Big|_{7\pi/6}^{11\pi/6}$$

at $(0 \le \alpha \le \pi)$

(1) $$i_A = I_d\Big|_{\pi/6+\alpha}^{7\pi/6} - I_d\Big|_{5\pi/6+\alpha}^{11\pi/6}$$

The variation of the curent input for the second proposed model of phase control with two commutations per half period is given on fig. 2b. When the control angle changes from 0 up to 60^0 , current i_A is described by eqs. 2

at $(0 \le \alpha \le \pi/3)$

(2) $$i_A = I_d\Big|_{\pi/6+\alpha}^{\pi/2} + I_d\Big|_{\pi/2+\alpha}^{5\pi/6} - I_d\Big|_{7\pi/6+\alpha}^{3\pi/2} - I_d\Big|_{3\pi/2+\alpha}^{11\pi/6}$$

The value of the input current of the considered three-phase bridge unidirectional rectifier for both models from fig. 2 ,not described by equations (1,2), is equal to zero.

Harmonic analysis and power factors

The effectiveness of the electrical energy convertion for each above mentioned models is estimated through the described in [5] method based on the harmonic analysis of the consumed current curve, on the components of the total power and the developed program modules in FORTRAN. In order to make a comparative analysic of these models and the corresponding to them methods for phase control of the smoothed voltage of the considered rectifier circuit, it is necessary to transform the given bellow koefficients and factors in dimensionless form deviding the current value on the maximal one (it is obtained at the three-phase uncontroled bridge circuit)

Relative value factor of k-th current harmonic

(3) $$K_{IKM} = \frac{\pi\sqrt{3}}{6}\sqrt{A_k^2 + B_k^2} \quad ,$$

where $$A_{(k)} = \frac{1}{\pi}\int_0^{2\pi} i(\omega t)\cos k\omega t\, d\omega t \ , \quad B_{(k)} = \frac{1}{\pi}\int_0^{2\pi} i(\omega t)\sin k\omega t\, d\omega t \ , \quad k = 0,1,2,\ldots N$$

In the abovementioned expressions the amplitudes of the first and higher harmonics are divided by the maximum value $2\sqrt{3}\,I_d/\pi$ .of the current first harmonic.

Relative R.M.S. value factor of input current

(4) $$K_I = \sqrt{\frac{3}{4\pi}\int_0^{2\pi} i^2(\omega t)\, d\omega t}$$

The maximum R.M.S. value of the input current, consumed from the considered rectifier is equal to $2\sqrt{3}\, I_d / 3$

Distortion factor

(5) $$\nu = \frac{3}{\pi} \bullet \frac{K_{I\,1M}}{K_I}$$

Cosine of the phase between voltage and the current fundamental

(6) $$\cos\varphi_{(1)} = \pi\, B_{(1)} / 2\sqrt{3} K_{I\,1M}$$

Power factor

(7) $$\chi = \nu \bullet \cos\varphi_{(1)}$$

Takig into account the requirements of the used method for assessmant of the power factors and harmonics of the consumed by the convertor current, the input functions for the used programs are described according to eqs. (1, 2) relating the current value i_A to the value I_d .

Analysis of the obtained results

The results are obtained in tables that allow to plot the diagrams of the power factor, distortion factor, the relative values of the first and higher harmonics amplitudes, etc., from the relative effective value of the input current, from the control angle and s.o.

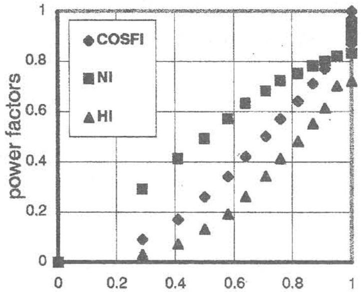


Fig.3

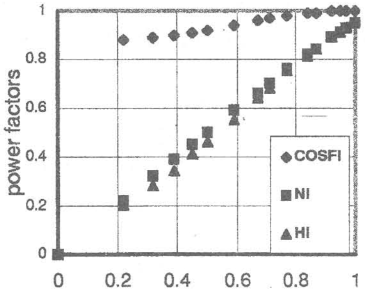


Fig.4

On fig.3 are shown the relationships of the distortion factor, cosine of the phase between current first harmonic and the line voltage, power factor from the relative effective value of the consumed current for the first model of phase control aat ideally smoothed load current. This figure illustrates the well known from the theory of rectifiers dependance , that at variation of the control angle in the interval (0 - 60^0) , the values of these factors change by the line $K_I = 1$. From the values of COSFI = 0.866, NI = 0.827 and HI = 0.716 these factors decrease with the diminution of the control range KI to zero and the power factor in all the control range remains low.

On fig.4 are given the results from the calculations of the proposed model for phase control with two commutations per half period of the line voltage at ideally smoothed load current. It is seen that the curves of the cosine of phase between the first harmonic of the consumed current and the line voltage as well as the power factor of the proposed model are to a considerable extent higher than those shown on fig.3 (typical for the well known case of phase control). Also it follows that the second component of the power factor has little lower values at the proposed model at the expence of higher harmonics.

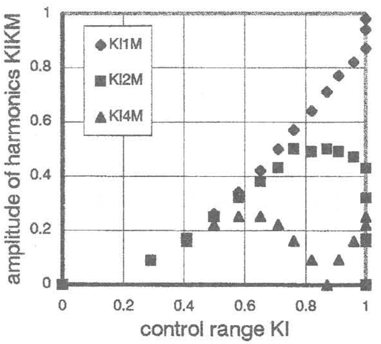


Fig.5

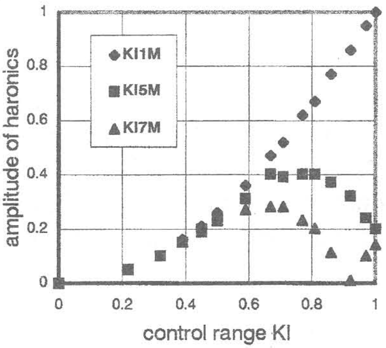


Fig.6

This is illustrated on fig. 5 and fig.6. Comparing the results of these figures it is seen that the even harmonics (second and the fourth) in the input current of the three-phase bridge unidirectional circuit, always considered as its most important disadvantage, are missing in the proposed second model. There, the first high harmonic in the current consumed is fifth as it is in the three-phase bridge rectifier. This is the greatest advantage of the proposed model for smoothed voltage control through three-phase bridge unidirectional rectifier.

Conclusions:

1. On the basis of the proposed model with two commutations per half period, a corresponding method can be developed for output voltage control of the three -phase bridge unidirectional rectifier, that will provide more effective electrical convertion.
2. This model is a basis for power circuit development of the considered rectifier and of its control system.

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