УДК 621.314

CONTROL OF THREE PHASE MATRIX FREQUENCY CONVERTERS ON BASE OF FIRST HARMONICS METHOD IN SPACE WITH TWO TIME VARIABLES

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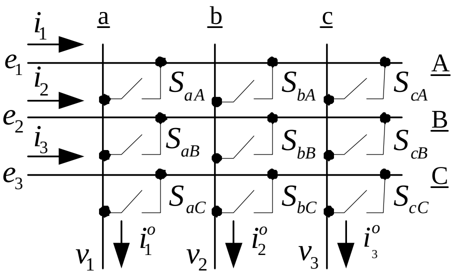
A procedure for the synthesis of control signals for three phase matrix frequency converters is presented. The procedure is based on extension of the space of one time variable to the space with two time variables. An expansion of control signals in Fourier series is use. References 2, figure 1.

Key words: control synthesis, matrix frequency converter, first harmonic method, two time variables.

Let us consider a three phase matrix frequency converter (MFC) presented in Figure.



The switches $S_{aA} \ldots S_{cC}$ shown in Figure are ideal. They are turned on and off periodically with durations defined by a matrix

$$\mathbf{M}(t) = \begin{pmatrix} d_{aA} & d_{aB} & d_{aC} \\ d_{bA} & d_{bB} & d_{bC} \\ d_{cA} & d_{cB} & d_{cC} \end{pmatrix}.$$

The best known strategies used for control of such MFC are developed [1].

It has been shown [2] that the above mentioned control strategy is not single-valued. In this article we consider method based on extension of the space of one time variable to the space with two time variables and control signals expansion in Fourier series. A synthesis of control signals is realized using their presentation as sum of steady components and first harmonics.

Coupling between input and output voltages describes the equation

$$\mathbf{V} = \mathbf{M}(t)\mathbf{E} \tag{1}$$

and between output and input currents the relation

$$\mathbf{I} = \mathbf{M}^T(t)\mathbf{I}^o, \tag{2}$$

where

$$\mathbf{E} = \begin{pmatrix} E_i \cos\omega t \\ E_i \cos(\omega t + 2\pi/3) \\ E_i \cos(\omega t + 4\pi/3) \end{pmatrix}, \mathbf{V} = \begin{pmatrix} V_o \cos(\omega_L t + \sigma) \\ V_o \cos(\omega_L t + 2\pi/3 + \sigma) \\ V_o \cos(\omega_L t + 4\pi/3 + \sigma) \end{pmatrix}, \mathbf{I} = \begin{pmatrix} I_i \cos(\omega t + \nu) \\ I_i \cos(\omega t + 2\pi/3 + \nu) \\ I_i \cos(\omega t + 4\pi/3 + \nu) \end{pmatrix}, \mathbf{I}^o = \begin{pmatrix} I_o \cos(\omega_L t + \rho) \\ I_o \cos(\omega_L t + 2\pi/3 + \rho) \\ I_o \cos(\omega_L t + 4\pi/3 + \rho) \end{pmatrix} -$$

are vectors of input and output voltages and currents with ω and ω_L as frequencies of input and output signals. Since the above cosines functions depend on three variables ω, ω_L and t identically, we could replace them in the following way

$$t \to \Omega,\ \omega \to t,\ \omega_L \to \tau. \tag{3}$$

Let us assume that coefficients of the matrix $\mathbf{M}(t)$ are periodical and are described by steady components and first harmonics $m_{1k} = m_{1k}^0 + m_{1k}^s \sin(\Omega t) + m_{1k}^c \cos(\Omega t)$, where coefficients m_{1k}^0, m_{1k}^s, m_{1k}^c might depend on time τ, $k = 1,2,3$.

In order to find these coefficients let us multiply first row of matrix $\mathbf{M}(t)$ by the vector $\mathbf{E}$ and expand the result in Fourier series. We obtain in this way four equations. Two further equations result using conditions that input circuits should not be shorted and output circuits cannot be opened, i.e. $\mathbf{1} = \mathbf{M}(t)\mathbf{1}$ (where $\mathbf{1}$ is the unit vector). After solving of these equations we get

$$m_{11}^0 = \frac{1}{3}; \qquad m_{11}^s = \frac{-6m_{13}^s(\sqrt{3} + tg\rho) + 2cs_1(3+\sqrt{3})\sec\rho}{(\sqrt{3} - 3tg\rho)(3+\sqrt{3})}; \qquad m_{11}^c = \frac{-2(\sqrt{3}\cos\rho + \sin\rho)(-cs_1 + 3m_{13}^s seq\rho)}{3\sqrt{3}\cos 2\rho - 3\sin 2\rho}.$$

The variables cs_1, cs_2 and cs_3 in above coefficients are elements of the vector $\mathbf{V}$ and depend on time τ. We can determine all other coefficients m_{nk} in the same way. These coefficients depend on m_{23}^s, cs_2 and m_{33}^s, cs_3.

In order to find the coefficients m_{13}^s, m_{23}^s and m_{33}^s one uses (2) and after additional analyses they could be chosen as follows $m_{n3}^s = \mu cs_n / \sqrt{3}$. After substitution one obtain the following expressions

$$m_{11} = \left\{1 + 2q\cos(\Omega\tau + \sigma)\left[\cos(\lambda - \Omega t) + \sqrt{3}(\mu - 1)\sin(\lambda - \Omega t)\right]\right\}/3;$$

$$m_{12} = \left\{1 + q\cos(\Omega\tau + \sigma)\left[(3\mu - 2)\cos(\lambda - \Omega t) + \sqrt{3}(\mu - 2)\sin(\lambda - \Omega t)\right]\right\}/3;$$

$$m_{13} = \left\{1 + q\cos(\Omega\tau + \sigma)\left[(3\mu - 4)\cos(\lambda - \Omega t) - \sqrt{3}\mu\sin(\lambda - \Omega t)\right]\right\}/3.$$

Other coefficients can be written by shifting the argument of cosines in the following way $\sigma \to \sigma + 2\pi/3$, $\sigma \to \sigma + 4\pi/3$. Then first elements of the vectors of the output voltage $\mathbf{V}$ calculated by (1) have the form $q\left[\cos\lambda + \sqrt{3}(\mu - 1)\sin\lambda\right]\cos(\Omega\tau + \sigma)$, and the input current $\mathbf{I}$ calculated by (2) is as follows $q\cos(\rho - \sigma)\times$ $\times\left[\cos(\lambda - \Omega t) + \sqrt{3}(\mu - 1)\sin(\lambda - \Omega t)\right]$. Other elements of the vectors $\mathbf{V}$ and $\mathbf{I}$ are obtained by similar shifting of arguments $\sigma \to \sigma + 2\pi/3$, $\sigma \to \sigma + 4\pi/3$ and $\lambda \to \lambda - 2\pi/3$, $\lambda \to \lambda - 4\pi/3$. We can transform parts of these expressions in the following way $\cos\lambda + \sqrt{3}(\mu - 1)\sin\lambda = \sqrt{1 + 3(\mu - 1)^2}\cos(\lambda - \phi)$, $\cos(\lambda - \Omega t) + \sqrt{3}(\mu - 1)\sin(\lambda - \Omega t) =$ $= \sqrt{1 + 3(\mu - 1)^2}\cos(\lambda - \phi - \Omega t)$, where $\phi = arctg\left[\sqrt{3}(\mu - 1)\right]$.

Multiplying input and output vectors of current and voltage one finds input and output power of MFC

$$3q\sqrt{1 + 3(\mu - 1)^2}\cos(\rho - \sigma)\cos(\lambda - \phi)/2.$$

In order to obtain signals in the space of one time variable we use the substitution opposite to (3).

The synthesized control could change both the amplitude of output voltages and the amplitude and phase shift of input currents. The power factor equal 1.0 could be obtained.

It should be noted that obtained expressions could be also transformed in expressions given in [1].

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УПРАВЛЕНИЕ ТРЕХФАЗНЫМИ МАТРИЧНЫМИ ПРЕОБРАЗОВАТЕЛЯМИ ЧАСТОТЫ НА ОСНОВЕ МЕТОДА ПЕРВЫХ ГАРМОНИК В ПРОСТРАНСТВЕ С ДВУМЯ ФУНКЦИЯМИ ВРЕМЕНИ

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В статье рассмотрен процесс синтеза управляющих сигналов для 3-фазных матричных преобразователей частоты. Процесс основан на расширении пространства одной функции времени до пространства с двумя функциями времени. Используется расширение управляющих сигналов в ряду Фурье. Библ. 2, рис. 1.

Ключевые слова: управление синтезом, матричный преобразователь частоты, метод первой гармоники, функции времени.

УПРАВЛІННЯ 3-ФАЗНИМИ МАТРИЧНИМИ ПЕРЕТВОРЮВАЧАМИ ЧАСТОТИ НА ОСНОВІ МЕТОДУ ПЕРШИХ ГАРМОНІК У ПРОСТОРІ З ДВОМА ФУНКЦІЯМИ ЧАСУ

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У статті розглянуто процес синтезу сигналів керування для 3-фазних матричних перетворювачів частоти. Процес оснований на розширенні простору однієї функції часу до простору з двома функціями часу. В ряду Фур'є використовуються розширення сигналів керування. Бібл. 2, рис. 1.

Ключові слова: керування синтезом, матричний перетворювач частоти, метод першої гармоніки, функції часу.

Надійшла 20.12.2011
Received 20.12.2011