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THREE-PHASED INVERTER ANALYSIS IN LINEAR MODULATED REGIME WITH WEAK INDUCTIVE CHARGE IN TRIANGLE CONNECTION

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INTRODUCTION

The inverters are power electronic circuits that convert the energy of direct current in the energy of alternative current. They are used as uninterruptible power supply by some consumers (telecommunication systems, air and marine traffic controllers, computers, etc) or they are components of frequency static converters used in the adjustable electrical drives with alternative current motors.

In this paper, the weak inductive charge has a power factor, cosφ >0,55 (this means X_L<1,51 R).

The inverter functions in modulated regime if the rectangular wave of voltage of a tact (an interval from a period) is divided in several pulses, either of the same width and equidistant (called regime of linear modulation), or with the width modulated after a sinusoidal function (called regime of sinusoidal modulation). The splitting of a tact into a succession of conduction – non conduction (corresponding to non null pulse – null pulse of voltage) allows the adjustment of the effective value of the output voltage of the inverter, correlated with the frequency, by modifying the width of the pulse and the number pulses/tact. The harmonic content of the output voltage is better (smaller number of low harmonics and of smaller amplitude) than for the inverter in non-modulated regime. This is why the inverter in modulated regime is used in the adjustable electrical drives with alternative current motors. The frequency static converter which contains an inverter in modulated regime is supplied with a constant direct voltage, because the inverter regulates not only the effective value of the voltage but also the frequency.

In this paper I investigate, based on mathematical models of the circuits configured in the pulses of tact, the functioning of the three-phased inverter in linear modulation regime with weak inductive charge in triangle connection and I prove them with numerical results.

ANALYSIS OF THE TRANSIENT REGIME FOR THE INVERTER- CHARGE CIRCUITS

The general schema of a three-phased inverter with weak inductive charge in a triangle connection is given in figure 1. The inverter consists of three-phased bridge with thyristors $T_1 \ldots T_6$, and the three-phased bridge with diodes $D_1 \ldots D_6$ in ant parallel connection.

The time when a thyristor is in the conduction state is *T*/2 (*T* is the period of the output voltage), meaning that in each moment of time three thyristors are in the conduction state. The time interval when a group of three thyristors, of the inverter in non-modulated regime, is in the conduction state is equal to *T*/6 and it one names *tact*; a period has six tacts.

When passing from tact to another, the thyristors on the same phase (but in different groups) commutate (the thyristor with an odd index together with the thyristor with an even index, and vice versa).

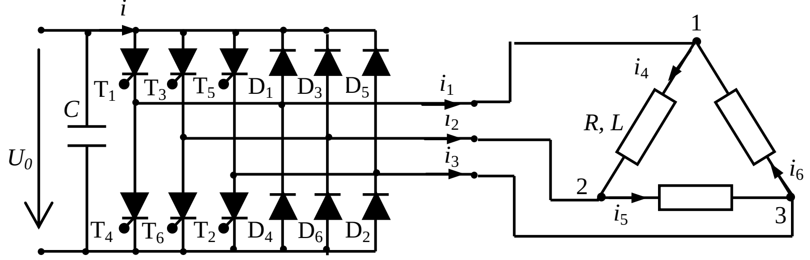

Figure 1. Inverter with charge in a triangle connection.

The output voltage is linearly modulated in an odd number n of pulses per tact. The non null pulses of voltage correspond to the conduction state of the semiconductor devices (thyristors, or thyristors and diodes) contained in the two groups of bridges (devices with odd and even indexes), and the null pulses correspond to the conduction state of the semiconductor components belonging to a single group of bridges (devices with odd or even indexes).

In the case of a resistive-inductive charge, when thyristors commute for passing from a tact to another, or from a non null pulse to a null pulse, one of the diodes from the phase of the blocking thyristor (that one directly polarized) begins conducting; the reactive energy stored in the inductance of the charge discharges through it, thus maintaining the same sense of the line current of the charge. The discharge currents close between phases, either through the condenser C, or through the source of direct current (if this is possible). Because the energy can come back from the charge to the direct current source, the diodes $D_1 \ldots D_6$ are called recovery diodes. The discharge line current is decreasing and zeroes in non null pulses after a time t_D, called *recovery time*. After the time t_D, the line current changes its sense through the thyristor ordered to conduct, and increases in time.

In the case of a charge weak inductive, the recovery time is smaller than a tact, $t_D < T/6$. The circuits inverter-charge configured during the pulses of tact are, function of time:

– for the first interval, $t \le t_D$:

- during the odd (non null) pulses two thyristors and a diode are conducting;
- during the even (null) pulses one thyristor and two diodes are conducting;

– for the second interval, $t \ge t_D$:

- during the odd (non null) pulses three thyristors are conducting;
- during the even (null) pulses two thyristors and a diode are conducting.

The commutation program for the semiconductor devices for one period is given in table 1.

In order to determine the voltages and the currents, the transient regime of the circuits formed during the first tact, from figure 2, is analysed. I consider the currents being positive when they have the senses displayed in figure 1 (absorbed by the charge).

Before commuting from 6^{th} tact to first tact, the thyristors T_4, T_5, T_6 are conducting. During commutation, the thyristor T_4 blocks, and thyristor T_1 receives the command for entering the conduction state; the signs of the currents are: $i_1<0$, $i_2<0$, $i_3>0$, $i_4<0$, $i_5<0$,
$i_6>0$. The circuits formed in first tact are given in the figures:

– 2,*a*, for the odd pulses (k=1, 3, …n) of the first interval;

– 2,*b*, for the odd pulses (k=1, 3, …n) of the second interval;

– 2,*d*, for the even pulses (k=2, 4, …n – 1) of the first interval;

– 2,*c*, for the even pulses (k=2, 4, …n – 1) of the second interval.

The equations of the formed circuits during the odd pulses are:

Table 1 - The commutation program

Tact	Pulse	Thyristors in conduction	Diodes in conduction	Semiconductor devices in conduction	
				first interval	second interval
1	Odd	T_5, T_6, T_1	D_1	T_5, T_6, D_1	T_5, T_6, T_1
	Even	T_5, T_3, T_1	D_1, D_3	T_5, D_3, D_1	T_5, D_3, T_1
2	Odd	T_6, T_1, T_2	D_2	T_6, T_1, D_2	T_6, T_1, T_2
	Even	T_6, T_4, T_2	D_2, D_4	T_6, D_4, D_2	T_6, D_4, T_2
3	Odd	T_1, T_2, T_3	D_3	T_1, T_2, D_3	T_1, T_2, T_3
	Even	T_1, T_5, T_3	D_3, D_5	T_1, D_5, D_3	T_1, D_5, T_3
4	odd	T_2, T_3, T_4	D_4	T_2, T_3, D_4	T_2, T_3, T_4
	even	T_2, T_6, T_4	D_4, D_6	T_2, D_6, D_4	T_2, D_6, T_4
	odd	T_3, T_4, T_5	D_5	T_3, T_4, D_5	T_3, T_4, T_5

5	even	T_3, T_1, T_5	D_5, D_1	T_3, D_1, D_5	T_3, D_1, T_5
6	odd	T_4, T_5, T_6	D_6	T_4, T_5, D_6	T_4, T_5, T_6
	even	T_4, T_2, T_6	D_6, D_2	T_4, D_2, D_6	T_4, D_2, T_6

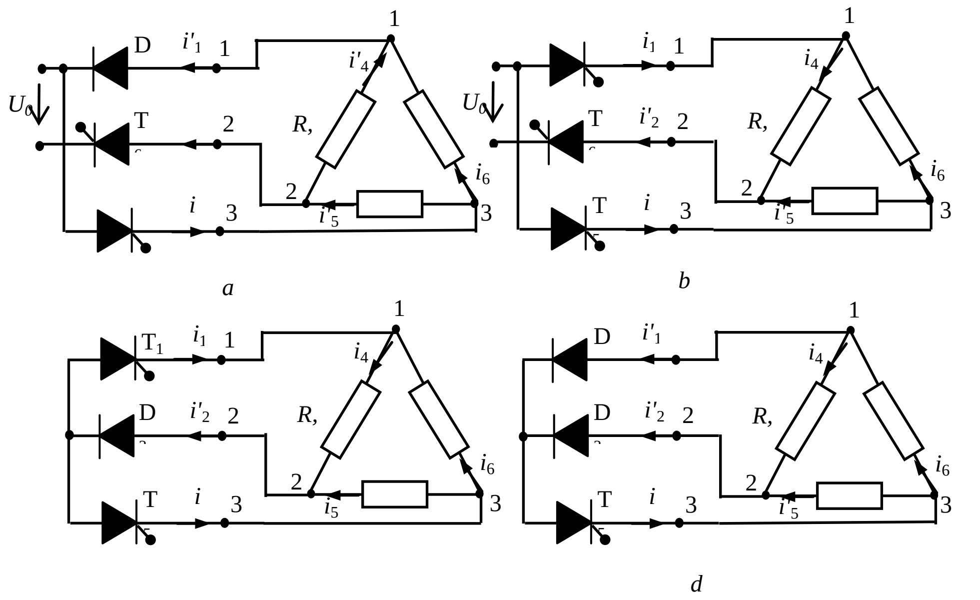

Figure 2 - The circuits inverter-charge in first tact

$$\begin{cases} L\dfrac{\mathbf{d}i_4^{'}}{\mathbf{d}t} + R i_4^{'} = -u_{12} = -U_0 \\ L\dfrac{\mathbf{d}i_5^{'}}{\mathbf{d}t} + R i_5^{'} = -u_{23} = U_0 \\ L\dfrac{\mathbf{d}i_6}{\mathbf{d}t} + R i_6 = u_{31} = 0 \end{cases} \qquad (1)$$

where $i_4 = -i_4^{'}$, $i_5 = -i_5^{'}$; the initial conditions: $i_4(0)=I_{4k}$, $i_5(0)=I_{5k}$, $i_6(0)=I_{6k}$, $k = 1, 3, \ldots, n$.

From equations (1) the phase and the line currents are inferred:

$$\begin{cases} i_4 = \left(-\dfrac{U_0}{R} + I_{4k}\right)\mathbf{e}^{-t/\tau} + \dfrac{U_0}{R} \\ i_5 = \left(\dfrac{U_0}{R} + I_{5k}\right)\mathbf{e}^{-t/\tau} - \dfrac{U_0}{R} \\ i_6 = I_{6k}\,\mathbf{e}^{-t/\tau} \end{cases}, \quad \begin{cases} i_1 = i_4 - i_6 = \left(-\dfrac{U_0}{R} + I_{1k}\right)\mathbf{e}^{-t/\tau} + \dfrac{U_0}{R} \\ i_2 = i_5 - i_4 = \left(\dfrac{2U_0}{R} + I_{2k}\right)\mathbf{e}^{-t/\tau} - \dfrac{2U_0}{R}, \\ i_3 = i_6 - i_5 = \left(-\dfrac{U_0}{R} + I_{3k}\right)\mathbf{e}^{-t/\tau} + \dfrac{U_0}{R} \end{cases} \qquad (2)$$

where: $I_{1k} = I_{4k} - I_{6k}$, $I_{2k} = I_{5k} - I_{4k}$, $I_{3k} = I_{6k} - I_{5k}$; $\tau = L/R$ is the time constant.

The equations of the circuits formed during the even pulses are:

$$\begin{cases} L\frac{\mathbf{d}i_4}{\mathbf{d}t}+Ri_4=u_{12}=0 \\ L\frac{\mathbf{d}i_5^{'}}{\mathbf{d}t}+Ri_5^{'}=-u_{23}=0 \\ L\frac{\mathbf{d}i_6}{\mathbf{d}t}+Ri_6=u_{31}=0 \end{cases} \tag{3}$$

where $i_5=-i_5^{'}$ and the initial conditions: $i_4(0)=I_{4k}$, $i_5(0)=I_{5k}$, $i_6(0)=I_{6k}$, $k=2,4,6,\dots,n-1$.

From equations (3) the phase and the line currents are inferred:

$$\begin{cases} i_4=I_{4k}\ \mathbf{e}^{-t/\tau} \\ i_5=I_{5k}\ \mathbf{e}^{-t/\tau} \\ i_6=I_{6k}\ \mathbf{e}^{-t/\tau} \end{cases},\quad \begin{cases} i_1=i_4-i_6=I_{1k}\ \mathbf{e}^{-t/\tau} \\ i_2=i_5-i_4=I_{2k}\ \mathbf{e}^{-t/\tau} \\ i_3=i_6-i_5=I_{3k}\ \mathbf{e}^{-t/\tau} \end{cases} \tag{4}$$

where: $I_{1k}=I_{4k}-I_{6k}$, $I_{2k}=I_{5k}-I_{4k}$, $I_{3k}=I_{6k}-I_{5k}$.

At the end of each pulse, the currents have the following values:

$$\begin{cases} \begin{cases} i_4\left(kT/6n\right)=I_{4,k+1}=b+a\,I_{4k} \\ i_5\left(kT/6n\right)=I_{5,k+1}=-b+a\,I_{5k} \\ i_6\left(kT/6n\right)=I_{6,k+1}=a\,I_{6k} \end{cases} \\ \mathbf{for}\,k=1,3,5,\dots,n;\ i_4(T/6)=I_{4,n+1}=-I_{51}, \\ i_5(T/6)=I_{5,n+1}=-I_{61},\ i_6(T/6)=I_{6,n+1}=-I_{41}; \\ \begin{cases} i_4\left(kT/6n\right)=I_{4,k+1}=a\,I_{4k} \\ i_5\left(kT/6n\right)=I_{5,k+1}=a\,I_{5k} \\ i_6\left(kT/6n\right)=I_{6,k+1}=a\,I_{6k} \end{cases} \\ \mathbf{for}\quad k=2,4,6,\dots,n-1; \end{cases}$$

$$\begin{cases} \begin{cases} i_1\left(kT/6n\right)=I_{1,k+1}=b+a\,I_{1k} \\ i_2\left(kT/6n\right)=I_{2,k+1}=-2b+a\,I_{2k} \\ i_3\left(kT/6n\right)=I_{3,k+1}=b+a\,I_{3k} \end{cases} \\ \mathbf{for}\,k=1,3,5,\dots,n;\ i_1(T/6)=I_{1,n+1}=-I_{21}, \\ i_2(T/6)=I_{2,n+1}=-I_{31}, i_3(T/6)=I_{3,n+1}=-I_{11}; \\ \begin{cases} i_1\left(kT/6n\right)=I_{1,k+1}=a\,I_{1k} \\ i_2\left(kT/6n\right)=I_{2,k+1}=a\,I_{2k} \\ i_3\left(kT/6n\right)=I_{3,k+1}=a\,I_{3k} \end{cases} \\ \mathbf{for}\quad k=2,4,6,\dots,n-1; \end{cases} \tag{5}$$

where: $a=\mathbf{e}^{-T/6n\tau}$, $b=\frac{U_0}{3R}(1-a)$.

The systems of equations, written in a matrix form, are:

$$AI_f = B_f$$

$$AI = B,$$

where:

$$I_f^T(1,3n) = \begin{bmatrix} I_{41} & I_{42} & I_{43} \ldots\ldots I_{4n} & I_{51} & I_{52} & I_{53} \ldots\ldots I_{5n} & I_{61} & I_{62} & I_{63} \ldots\ldots I_{6n} \end{bmatrix}$$
$$I^T(1,3n) = \begin{bmatrix} I_{11} & I_{12} & I_{13} \ldots\ldots I_{1n} & I_{21} & I_{22} & I_{23} \ldots\ldots I_{2n} & I_{31} & I_{32} & I_{33} \ldots\ldots I_{3n} \end{bmatrix},$$
$$B_f^T(1,3n) = \begin{bmatrix} 1 & 0 & 1 \ldots\ldots 1 & 1 & 0 & 1 \ldots\ldots 1 & 0 & 0 & 0 \ldots\ldots 0 \end{bmatrix}$$
$$B^T(1,3n) = \begin{bmatrix} 1 & 0 & 1 \ldots\ldots 1 & 2 & 0 & 2 \ldots\ldots 2 & 1 & 0 & 1 \ldots\ldots 1 \end{bmatrix}$$

$$A(3n,3n) = \begin{bmatrix}
-a & 1 & 0 \ldots\ldots 0 & 0 & 0 & 0 \ldots\ldots 0 & 0 & 0 & 0 \ldots\ldots 0 \\
0 & -a & 1 \ldots\ldots 0 & 0 & 0 & 0 \ldots\ldots 0 & 0 & 0 & 0 \ldots\ldots 0 \\
0 & 0 & -a \ldots\ldots 0 & 0 & 0 & 0 \ldots\ldots 0 & 0 & 0 & 0 \ldots\ldots 0 \\
. & & & & & & & & \\
0 & 0 & 0 \ldots\ldots -a & -1 & 0 & 0 \ldots\ldots 0 & 0 & 0 & 0 \ldots\ldots 0 \\
0 & 0 & 0 \ldots\ldots 0 & a & -1 & 0 \ldots\ldots 0 & 0 & 0 & 0 \ldots\ldots 0 \\
0 & 0 & 0 \ldots\ldots 0 & 0 & a & -1 \ldots\ldots 0 & 0 & 0 & 0 \ldots\ldots 0 \\
0 & 0 & 0 \ldots\ldots 0 & 0 & 0 & a \ldots\ldots 0 & 0 & 0 & 0 \ldots\ldots 0 \\
. & & & & & & & & \\
0 & 0 & 0 \ldots\ldots 0 & 0 & 0 & 0 \ldots\ldots a & 1 & 0 & 0 \ldots\ldots 0 \\
0 & 0 & 0 \ldots\ldots 0 & 0 & 0 & 0 \ldots\ldots 0 & -a & 1 & 0 \ldots\ldots 0 \\
0 & 0 & 0 \ldots\ldots 0 & 0 & 0 & 0 \ldots\ldots 0 & 0 & -a & 1 \ldots\ldots 0 \\
0 & 0 & 0 \ldots\ldots 0 & 0 & 0 & 0 \ldots\ldots 0 & 0 & 0 & -a \ldots\ldots 0 \\
. & & & & & & & & \\
-1 & 0 & 0 \ldots\ldots 0 & 0 & 0 & 0 \ldots\ldots 0 & 0 & 0 & 0 \ldots\ldots -a
\end{bmatrix};$$

By solving the systems of equations (6), the values of the currents at the end of each pulse are obtained. The changing in sign of two consecutive values of the current i_1 shows in which pulse it zeroes and the time of conduction for the diode D_1:

$$t_D = \frac{(k-1)T}{6n} + \tau \mathbf{ln}\left(1 + \frac{3R|I_{1k}|}{U_0}\right) < T/6 \qquad (7)$$

where: $I_{1k} < 0$, $I_{1,\,k+1} > 0$, $k = 1, 2, 3, \ldots, n$ and k is the number of the pulse during which the current i_1 nullifies.

The changing in sign of two consecutive values of the current i_4 shows in which pulse it zeroes and the duration t_d for the discharge of energy stored in first phase:

$$t_d = \frac{(k-1)T}{6n} + \tau \mathbf{ln}\left(1 + \frac{3R|I_{4k}|}{U_0}\right) < T/6 \qquad (8)$$

where: $I_{4k} < 0$, $I_{4,\,k+1} > 0$, $k = 1, 2, 3, \ldots, n$ and k is the number of the pulse during which the current i_4 nullifies.

The current in the intermediate circuit only exists during the non null pulses and has an exponential variation between the values I_{2k} and I_{2k+1}, according to the relation:

$$i=-i_2=-\left(\frac{2U_0}{3R}+I_{2k}\right)\mathbf{e}^{-t/\tau}+\frac{2U_0}{3R},\ k=1,3,5,\ldots,n \qquad (9)$$

The current i flowed out of the source is always positive, meaning that the energy given by the source to the charge is always greater than the energy recovered from first phase.

From the condition imposed for the recovery time, $t_D \le T/6$, it follows that $i_1(T/6)=-I_{21}\ge 0$. Using the Cramer rule, the current I_{21} is determined from the system of equations (6):

$$I_{21}=\frac{\Delta I_{21}}{\Delta A}=\frac{\frac{U_0}{3R}(1-a)(a^n+1)(2a^n-1)\left(\sum_{j=1}^{(n+1)/2}a^{n-(2j-1)}\right)}{a^{3n}+1}, \qquad (10)$$

and the inequality results:

$$\frac{\frac{U_0}{3R}(1-a)(2a^n-1)\left(\sum_{j=1}^{(n+1)/2}a^{n-(2j-1)}\right)}{a^{2n}-a^n+1}\le 0, \qquad (11)$$

where $a=\mathbf{e}^{-T/6n\tau}$, with the domain of definition $0\le a\le 1$.

From the inequality (11), the conditions of definition for the weak inductive charge are:

$$\begin{aligned}&0\le a\le 1/\sqrt[n]{2},\quad T\ge 6\,\mathbf{ln}2\,\tau=4{,}1589\,\tau,\quad f[\mathbf{Hz}]\le 240{,}45\,\tau^{-1},\quad \tau\le T/4{,}1589,\\ &\mathbf{tg}\varphi_1\le 1{,}5108,\quad X_L\le 1{,}5108\,R,\quad \mathbf{cos}\varphi_1\ge 0{,}55,\quad \varphi_1\le 0{,}9861[\mathbf{rad}]=56{,}49^o.\end{aligned} \qquad (12)$$

The phase difference between the voltage and the phase current:

– as a sinusoidal sizes of order 1 is:

$$\varphi_1=\mathbf{arctg}\frac{X_L}{R}=\mathbf{arctg}\frac{2\pi}{T}\frac{L}{R}. \qquad (13)$$

– as non sinusoidal sizes is:

$$\varphi=\pi/6+\frac{2\pi}{T}t_d. \qquad (14)$$

During the other tacts, the voltages and the currents are determined using the recurrent relations from table 2. The voltages and the currents are doubly indexed: the superior index corresponds to the first tact and the inferior index corresponds to the phase.

Table 2 - The recurrent relations

Tact Size	1	2	3	4	5	6
u_{12}	$u_{12}^{(1)}$	$-u_{23}^{(1)}$	$u_{31}^{(1)}$	$-u_{12}^{(1)}$	$u_{23}^{(1)}$	$-u_{31}^{(1)}$
u_{23}	$u_{23}^{(1)}$	$-u_{31}^{(1)}$	$u_{12}^{(1)}$	$-u_{23}^{(1)}$	$u_{31}^{(1)}$	$-u_{12}^{(1)}$
u_{31}	$u_{31}^{(1)}$	$-u_{12}^{(1)}$	$u_{23}^{(1)}$	$-u_{31}^{(1)}$	$u_{12}^{(1)}$	$-u_{23}^{(1)}$
u_{10}	$u_{10}^{(1)}$	$-u_{20}^{(1)}$	$u_{30}^{(1)}$	$-u_{10}^{(1)}$	$u_{20}^{(1)}$	$-u_{30}^{(1)}$

Continue table 2

	1	2	3	4	5	6
u_{20}	$u_{20}^{(1)}$	$-u_{30}^{(1)}$	$u_{10}^{(1)}$	$-u_{20}^{(1)}$	$u_{30}^{(1)}$	$-u_{10}^{(1)}$
u_{30}	$u_{30}^{(1)}$	$-u_{10}^{(1)}$	$u_{20}^{(1)}$	$-u_{30}^{(1)}$	$u_{10}^{(1)}$	$-u_{20}^{(1)}$
i_1	$i_1^{(1)}$	$-i_2^{(1)}$	$i_3^{(1)}$	$-i_1^{(1)}$	$i_2^{(1)}$	$-i_3^{(1)}$
i_2	$i_2^{(1)}$	$-i_3^{(1)}$	$i_1^{(1)}$	$-i_2^{(1)}$	$i_3^{(1)}$	$-i_1^{(1)}$
i_3	$i_3^{(1)}$	$-i_1^{(1)}$	$i_2^{(1)}$	$-i_3^{(1)}$	$i_1^{(1)}$	$-i_2^{(1)}$
i	$i^{(1)}$	$i^{(1)}$	$i^{(1)}$	$i^{(1)}$	$i^{(1)}$	$i^{(1)}$

Table 3 - The numerical results of the simulation.

Input data Output data	U = 144 [V] R = 6 [Ω] L = 30 [mH] τ = 5 [ms] n = 7 pulses/tact								
	T[ms]	200	150	100	72	50	36	27	20,8
1	*2*	3	4	5	6	7	8	9	10
Line cur - Rents [A]	I_{11}	- 5,7846	- 5,4254	- 5,1756	- 5,2042	- 5,3463	- 5,3402	- 5,0701	- 4,5942
	I_{12}	2,6814	1,4277	- 0,1840	- 1,3716	- 2,5186	- 3,2386	- 3,4932	- 3,4066
	I_{13}	1,0346	0,6989	- 0,1143	- 0,9735	- 1,9849	- 2,7284	- 3,0718	- 3,0853
	I_{14}	5,3126	4,4258	2,9599	1,6312	0,1306	- 1,0382	- 1,7360	- 2,0400
	I_{15}	2,0497	2,1666	1,8385	1,1577	0,1029	- 0,8747	- 1,5265	- 1,8476
	I_{16}	5,7043	5,1443	4,1728	3,1438	1,7761	0,5234	- 0,3772	- 0,9190
	I_{17}	2,2008	2,5184	2,5919	2,2312	1,3998	0,4410	- 0,3316	- 0,8328
	I_{21}	- 5,7626	- 5,3165	- 4,6408	- 3,9057	- 2,7982	- 1,6318	- 0,6736	- 0,0006
	I_{22}	-12,0502	-10,7700	- 8,9443	- 7,4162	- 5,5953	- 3,8954	- 2,5227	- 1,5093
	I_{23}	- 4,6492	- 5,2724	- 5,5557	- 5,2636	- 4,4098	- 3,2817	- 2,2183	- 1,3670
	I_{24}	-11,6206	-10,7484	- 9,5126	- 8,3799	- 6,8654	- 5,2853	- 3,8811	- 2,7469
	I_{25}	- 4,4835	- 5,2618	- 5,9087	- 5,9476	- 5,4108	- 4,4527	- 3,418	- 2,4879
	I_{26}	-11,5567	-10,7432	- 9,7318	- 8,8654	- 7,6544	- 6,2718	- 4,9315	- 3,7621
	I_{27}	- 4,4588	- 5,2592	- 6,0449	- 6,2921	- 6,0326	- 5,2838	- 4,3365	- 3,4073
	I_{31}	11,5472	10,7420	9,8164	9,1099	8,1444	6,9720	5,7437	4,5948
	I_{32}	9,3686	9,3423	9,1283	8,7878	8,1138	7,1340	6,0159	4,9159
	I_{33}	3,6146	4,5734	5,6700	6,2370	6,3947	6,0101	5,2901	4,4523
	I_{34}	6,3080	6,3226	6,5527	6,7487	6,7349	6,3236	5,6170	4,7869
	I_{35}	2,4338	3,0952	4,0702	4,7899	5,3079	5,3274	4,9393	4,3355
	I_{36}	5,8524	5,5989	5,5590	5,7216	5,8783	5,7484	5,3086	4,6810
	I_{37}	2,2580	2,7409	3,4530	4,0609	4,6329	4,8428	4,6681	4,2396

Continue table 3

1	*2*	3	4	5	6	7	8	9	10
	I_{41}	- 0,0074	- 0,0363	- 0,1783	- 0,4329	- 0,8494	- 1,2361	- 1,4655	- 1,5312
	I_{42}	4,9106	4,0659	2,9201	2,0149	1,0256	0,2189	- 0,3235	- 0,6324
	I_{43}	1,8946	1,9904	1,8138	1,4300	0,8083	0,1844	- 0,2845	- 0,5728
	I_{44}	5,6444	5,0581	4,1575	3,3370	2,3320	1,4157	0,7150	0,2356

Phase cur - Rents [A]	I_{45}	2,1777	2,4761	2,5824	2,3684	1,8379	1,1927	0,6288	0,2134
	I_{46}	5,7536	2,2958	4,6348	4,0030	3,1435	2,2651	1,5181	0,9477
	I_{47}	2,2199	2,5925	2,8789	2,8411	2,4775	1,9083	1,3349	0,8583
	I_{51}	- 5,7699	- 5,3528	- 4,8191	- 4,3385	- 3,6475	- 2,8679	- 2,1391	- 1,5318
	I_{52}	- 7,1396	- 6,7041	- 6,0242	- 5,4013	- 4,5697	- 3,6764	- 2,8462	- 2,1417
	I_{53}	- 2,7546	- 3,2819	- 3,7419	- 3,8335	- 3,6015	- 3,0973	- 2,5028	- 1,9398
	I_{54}	- 5,9762	- 5,6903	- 5,3551	- 5,0429	- 4,5334	- 3,8696	- 3,1660	- 2,5113
	I_{55}	- 2,3058	- 2,7856	- 3,3263	- 3,5791	- 3,5729	- 3,2600	- 2,7841	- 2,2744
	I_{56}	- 5,8030	- 5,7444	- 5,0969	- 4,8623	- 4,5109	- 4,0068	- 3,4134	- 2,8144
	I_{57}	- 2,2389	- 2,6667	- 3,1659	- 3,4510	- 3,5552	- 3,3755	- 3,0015	- 2,5490
	I_{61}	5,7773	5,3891	4,9974	4,7414	4,4969	4,1041	3,6046	3,0630
	I_{62}	2,2290	2,6382	3,1041	3,3864	3,5441	3,4575	3,1697	2,7742
	I_{63}	0,8600	1,2915	1,9281	2,4035	2,7932	2,9128	2,7873	2,5126
	I_{64}	0,3318	0,6322	1,1976	1,7059	2,2014	2,4539	2,4510	2,2756
	I_{65}	0,1280	0,3095	0,7439	1,2107	1,7350	2,0673	2,1553	2,0610
	I_{66}	0,0494	0,1515	0,4621	0,8593	1,3674	1,7417	1,8953	1,8667
	I_{67}	0,0191	0,0742	0,2870	0,6099	1,0777	1,4673	1,6666	1,6906
Conduc time [ms]	t_D	2,7206	2,5886	4,8328	4,0027	3,4891	3,9474	4,0602	3,4663
Number of pulse	k	1	1	3	3	3	5	7	7
Nullify time [ms]	t_d	0,0046	0,0226	0,1102	0,2635	0,5045	0,7184	1,4604	1,3362
Phase differenc e harmo - Nic 1 [rad]	φ_1	0,1558	0,2065	0,3044	0,4114	0,5610	0,7175	0,8608	0,9860
Phase differ non sinusoi Dal [rad]	φ	0,5237	0,5242	0,5305	0,5466	0,5870	0,6490	0,8635	0,9272

NUMERICAL RESULTS

The functioning of a three-phased inverter in linear modulated regime with 7 pulses per tact, with charge weak inductive in triangle connection, is analyzed, considering the input data from table 3. For T > 4,1589 τ = 20,79 ms, the charge have character weak inductive and phase difference is φ_1<0,9861[radian]. The numerical results of the simulation are given in table 3.

For the numerical solving of the systems of equations (6) and for the graphical representation of voltages and currents, the Matlab toolbox is used. The recovery time, the number of pulse during which the currents nullify, the differences of phase are computed and the inequalities (12) are verified.

CONCLUSIONS

The inverter functions in linear modulated regime if the rectangular wave of voltage of a tact is split in several equidistant pulses of the same width, meaning that during the tact the groups of diodes and/or thyristors in conduction state follow each other at time intervals equal to $T/(6\ n)$, where n is the number of pulses per tact.

In the context of this paper, the weak inductive charge is defined, according to relation (12), for a power factor cosφ >0,55 (this means $X_L < 1{,}51\ R$). In this case, the reactive energy stored in the inductance of the charge is discharged through one of the recovery diodes. The recovery time is smaller than a tact, $t_D < T/6$.

For the inverter with 7 pulses per tact, the numerical results obtained through simulation are presented in table 3.

For the circuits configured in the pulses of the first tact, their equations, voltages and currents are determined for a weak inductive charge in a triangle connection. Based on recurrent relations, the waveforms of voltages and currents are deducted for an entire period; the variation in time of voltages has a shape of rectangular pulses, and that of currents is alternatively exponential.

ABSTRACT

The paper presents a framework for the analysis of the three-phased inverter functioning in linear modulated regime with weak inductive charge in triangle connection. The resistive – inductive charge with a power factor cosφ > 0,55 is defined as weak inductive. The recovery time of the reactive energy accumulated in the charge's inductances is smaller than tact (an interval from a period).

On the circuits configurated in the pulses of a tact one determines their equations in transitory regime and their solutions, and on the basis of some recurrent relations for the other tacts one determines the waveforms of the voltages and electric currents for a period.

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