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The Research of the Sinusoidal Three-phase Windings

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Introduction

The sinusoidal three-phase winding is the two-layer concentric winding of the alternating current, which consists of similar groups of sections. The number of the groups of sections in each phase winding is equal to the number of poles of this winding but the numbers of the turns of sections that form the groups and which are subdivided according to the sinusoid law from the adequate symmetry axes of these groups are different [1÷3]. Thus, the structure of the connection diagrams of the sinusoidal three-phase windings totally corresponds to the structure of the connection diagrams of the two-layer concentric three-phase windings. As it is seen from the definition, these windings are also formed from similar groups of sections the concentric sections of which are not of similar pitch that is the adjacent sections' pitches differ in two slot pitches in their groups. The sinusoidal three-phase windings differ from the two-layer concentric three-phase windings only in that that their sections in groups contain unequal numbers of turns $\left(N_1 \neq N_2 \neq \ldots \neq N_i \neq \neq \ldots \neq N_q\right)$.

The sinusoidal three-phase windings as well as the two-layer concentric windings may be of maximum or of average short-pitch according to the forming structure of the connection diagrams [1÷3]. The pitch of each group of sections of the maximum average pitch sinusoidal three-phase windings corresponds to the pole pitch τ (Fig. 1), while the pitch of the short-pitch average windings is smaller in one slot pitch (Fig. 2).

Both the maximum and the short-pitch average sinusoidal three-phase windings may be formed optimizing the pulsating magnetomotive forces that are formed by each phase winding or the rotational magnetomotive forces that are generally formed by all three phase windings. This depends on that which reference axis is used while dispensing the number of turns in sections that form groups of sections according to the sinusoid law. If the symmetry axis of any phase winding group of sections is chosen as the reference axis, thus, with reference to it while dispensing the numbers of turns of sections according to the sinusoid law the pulsating magnetomotive force is optimized [1÷3]. If the symmetry axis of the two adjacent groups of sections belonging to the same phase winding is chosen as the reference axis, then with reference to it while dispensing the numbers of turns of sections according to the sinusoid law the rotational magnetomotive force is optimized [1;3].

The aim of this article is to evaluate the true relative quantity of the number of all types sinusoidal three-phase turns of sections that are related with the concentrated three-phase windings according to the terms formed and to investigate and compare the magnetic circuit slot priming of these windings.

Optimizing the Pulsating and the Rotational Magnetomotive Forces of the Maximum and the Medium Short-Pitch Sinusoidal Three-phase Windings

In order to get the dimensional function that is made by any phase winding in the fixed time moment of the pulsating magnetomotive force and that is the closest to the sinusoid, the number of the turns of sections in the groups of sections must be allocated from the symmetry axes of these groups according to the sinusoid law because in the sections of any of these groups of sections the current of the same phase and quantity is flowing. Thus, the repartition form of the pulsating magnetomotive force is directly influenced by the number of sections in their groups and by the number of turns that are in them. Considering this, the values of the sinusoidal function of any section group of the position from the solid angles of the group's symmetry axis, expressed in electrical degrees, are found out. These values will correspond to the tentative relative quantities of the number of the turns of sections. Optimizing the pulsating magnetomotive force the tentative relative quantities of the turns of sections of the maximum average pitch sinusoidal three-phase windings are evaluated as follows:

$$\varphi_{p\,i}^{1} = \sin\left[\pi/2 - \beta\left(i-1\right)\right]; \tag{1}$$

where $\beta = 2\pi\, p\, /\, Z = \pi\, /\, \tau$ is the slot pitch in electrical degrees; p is the number of the pole pairs; Z is the number of the slots; τ is the pole pitch; $i = 1 \div q$ is the number of the section in the group; q is the number of sections that form the group of sections.

Continuing the theoretical analyses, the maximum average pitch sinusoidal three-phase winding is linked with the concentrated three-phase winding by recalculating the tentative relative quantities of the number of turns of sections that are derived from the expression (1) to the real ones:

$$N^{*1}_{p\,i} = \varphi^{1}_{p\,i} / C^{1}_{p}\,; \tag{2}$$

where C^{l}_{p} is the sum of the tentative relative quantities of the number of turns of sections that are derived from the (1) expression:

$$C^{1}_{p} = \sum_{i=1}^{q} \varphi^{1}_{p\,i}\,. \tag{3}$$

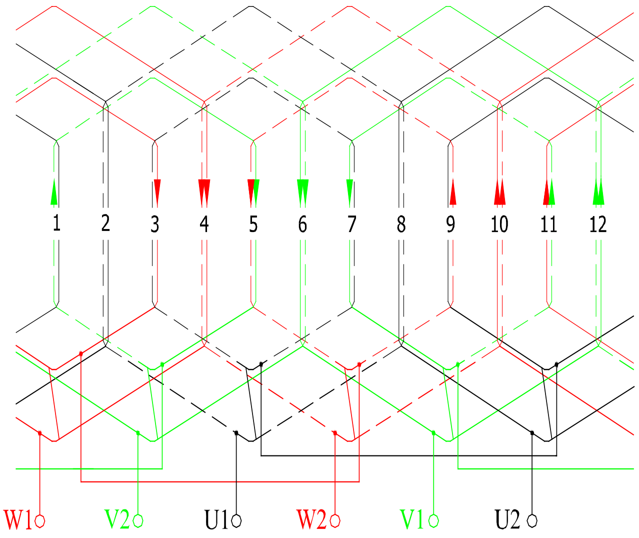

Fig. 1. The Maximum Average Pitch Sinusoidal Three-phase Winding, which $q = 2$

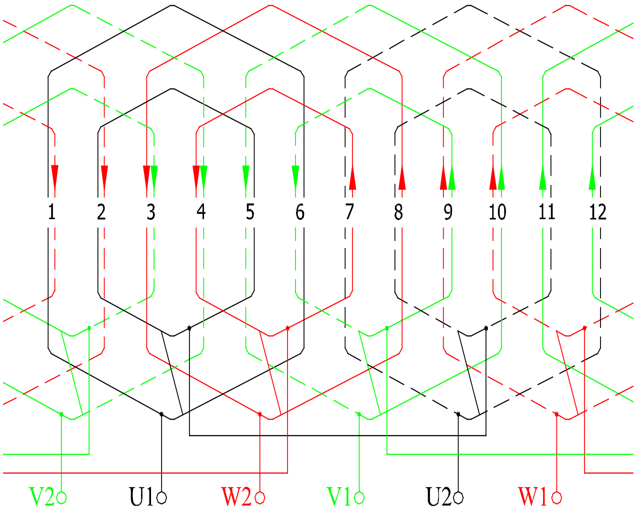

Fig. 2. The Average Short-pitch Sinusoidal Three-phase Winding, which $q = 2$

Optimizing the pulsating magnetomotive force, the tentative relative quantities of the number of section turns of the average short-pitch sinusoidal three-phase windings are evaluated as follows

$$\varphi^{2}_{p\,i} = \sin\left[(\pi - \beta)/2 - \beta(i-1)\right]. \tag{4}$$

Continuing the theoretical analyses, the average short-pitch sinusoidal three-phase winding is linked with the concentrated three-phase winding by recalculating the tentative relative quantities of the number of section turns that are derived from the expression (4) to the real ones:

$$N^{*2}_{p\,i} = \varphi^{2}_{p\,i} / C^{2}_{p}\,; \tag{5}$$

where C^{2}_{p} is the sum of the tentative relative quantities of the number of section turns that are derived from the expression (4):

$$C^{2}_{p} = \sum_{i=1}^{q} \varphi^{2}_{p\,i}\,. \tag{6}$$

Summing up the dimensional functions of the pulsating magnetomotive forces that have been optimized by all three phases in fixed time moments the dimensional functions of the rotational magnetomotive forces in certain moments of time. However, these functions are not closest to the sinusoidal repartition. This may be explained by that the dimensional repartition of the pulsating magnetomotive force is formed by q, while $Z/4p = \tau/2$ of the rotational magnetomotive force is formed by the active sides of sections. Since the quantity of the three-phase windings $Z/4p$ is half as great again as the number of sections q in the group of sections, thus, while optimizing the dimensional repartition of the rotational magnetomotive force it is possible to set it closer to sinusoid.

On purpose to optimize the dimensional function of the rotational magnetomotive force, for example, in a moment of time t = 0, the number of turns of sections in the groups of sections must be set according to the sinusoidal function of the dimensional coordinates the beginning of which should be the reference axis that should be coincident with the symmetry axis of the two adjacent groups of sections of the U phase. Considering this, the sinusoidal function values of the sections in their group of the position from the solid angles (that are expressed in electrical degrees) of the given reference axis are found; and they will conform the tentative relative quantities of the number of the turns of sections. By optimizing the rotational magnetomotive force these relative quantities of the maximum average pitch sinusoidal three-phase windings are evaluated as follows

$$\varphi^{1}_{s\,i} = \sin\left[\beta(q + 1 - i)\right]. \tag{7}$$

The maximum average pitch sinusoidal three-phase winding is also linked to the concentrated three-phase winding by recalculating the tentative relative quantities of the number of turns of sections that are derived from the expression (7) to the real ones:

$$N^{*1}_{s\,1} = \varphi^{1}_{s\,1} / 2C^{1}_{s}\,; \tag{8}$$

$$N^{*1}_{s\,i} = \varphi^{1}_{s\,i} / C^{1}_{s}\,; \tag{9}$$

where C^1_s is the sum of the tentative relative quantities of the number of turns of sections derived from the expression (7)

$$C_s^1 = \varphi_{s1}^1 / 2 + \sum_{i=2}^{q} \varphi_{si}^1 . \tag{10}$$

By optimizing the rotational magnetomotive force the tentative relative quantities of the number of turns of sections of the average short-pitch sinusoidal three-phase windings are evaluated as follows

$$\varphi_{si}^2 = \sin\left[(q-i)\beta + \beta/2\right]. \tag{11}$$

In further research the average short-pitch sinusoidal three-phase winding is also linked to the concentrated three-phase winding by recalculating the tentative relative quantities of the number of turns of sections that are derived from the expression (11) to the real ones:

$$N_{si}^{*2} = \varphi_{si}^2 / C_s^2 ; \tag{12}$$

where C^2_s is the sum of the tentative relative quantities of the number of turns of sections that are derived from the expression (11):

$$C_s^2 = \sum_{i=1}^{q} \varphi_{si}^2 . \tag{13}$$

The real relative quantities of the number of turns of sections of the sinusoidal three-phase windings of all types that are linked to the concentrated three-phase windings are evaluated according to the expressions made (1) ÷ (13) and are given in Table 1.

Table 1. The real relative quantities of the number of turns of sections of the sinusoidal three-phase windings

q	β	i	N_{pi}^{*1}	N_{pi}^{*2}	N_{si}^{*1}	N_{si}^{*2}
2	30°	1	0,5359	0,5774	0,4641	0,7321
		2	0,4641	0,4226	0,5359	0,2679
3	20°	1	0,3696	0,3949	0,3054	0,5321
		2	0,3473	0,3473	0,4534	0,3473
		3	0,2831	0,2578	0,2412	0,1206
4	15°	1	0,2826	0,2989	0,2280	0,4142
		2	0,2729	0,2785	0,3724	0,3178
		3	0,2447	0,2391	0,2633	0,1998
		4	0,1998	0,1835	0,1363	0,0682
5	12°	1	0,2288	0,2401	0,1821	0,3383
		2	0,2238	0,2296	0,3124	0,2798
		3	0,2091	0,2091	0,2471	0,2091
		4	0,1851	0,1794	0,1710	0,1292
		5	0,1531	0,1419	0,0874	0,0437
6	10°	1	0,1923	0,2005	0,1515	0,2856
		2	0,1894	0,1944	0,2681	0,2465
		3	0,1807	0,1824	0,2249	0,2000
		4	0,1666	0,1649	0,1750	0,1473
		5	0,1473	0,1423	0,1197	0,0902
		6	0,1236	0,1155	0,0608	0,0304

The Research of the Magnetic Circuit Slot Priming while Setting the Sinusoidal Three-phase Windings in Them

Since the numbers of turns of sections in groups of sections in the sinusoidal three-phase windings are always different, thus in general in the slots, in which the windings are set, the numbers of effective conductors will be not equal. Consequently, the magnetic circuit slots will also be primed unequally. Their priming in sequence will periodically change from the permissible to a certain minimum quantity.

The sections of the biggest pitch of the groups of sections of the sinusoidal three-phase windings that are marked in the first number always consist of most of the turns, and the number of turns of sections is declining when coming up to the symmetry axes of these groups. The sinusoidal three-phase windings in any case may be reeled only as two-ply windings and their sections of the winding phases that have more turns are set into adequate magnetic circuit slots together with other sections of the winding phases that have less turns (Fig. 1 and Fig. 2).

In the sinusoidal three-phase windings of the maximum average pitch the active sides of sections of the same phases take up $6p$ of the magnetic circuit slots (all sections of the winding which pitch is equal to the pole pitch), and the active sides of sections of different phases are set into remaining slots ($Z - 6p$, where Z is the number of the magnetic circuit slots, p is the number of the pole pairs) (Fig. 1). If, for example, the active sides of the maximum pitch (first) sections of adjacent groups of sections of the winding of any phase are set into the first slot, then the second slot will be taken up by the active sides of the same group of sections of the second section and of the other group of sections of the q section and etc. Thus, the order of the setting into adequate slots of the active sides of sections according to their numbers in a group will depend only on the number of sections (q) forming a group. In Table 2 the repartition of the active sides of sections of the maximum average pitch sinusoidal three-phase windings according to their numbers in a group into the magnetic circuit slots depending on the q quantity.

Table 2. The setting of the active sides (according their numbers in a group) of sections of the maximum average pitch sinusoidal three-phase windings into the magnetic circuit slots depending on the quantity of q

q	Slot No.						
	1	2	3	4	5	6	…
2	1	2	1	2	1	2	…
	1	2	1	2	1	2	
3	1	2	3	1	2	3	…
	1	3	2	1	3	2	
4	1	2	3	4	1	2	…
	1	4	3	2	1	4	
5	1	2	3	4	5	1	…
	1	5	4	3	2	1	
6	1	2	3	4	5	6	…
	1	6	5	4	3	2	

It is seen from the table 2 that the slot priming in the groups that have two slots each when q is equal to two or three will be different as well as the slot priming in the groups that have three slots each when q is equal to four or five, and the slot priming in the groups that have four slots each when q is equal to six.

The different slot priming of the maximum average pitch sinusoidal three-phase windings in their groups may be determined from the real relative quantities of the number of turns of sections, that is from the data of the 1st table and by virtue of the 2nd table as well. Thus, the tentative slot priming, when the pulsating magnetomotive forces of the maximum average pitch sinusoidal three-phase windings are optimized, is determined in the following way:

$$\begin{cases} k_{p1}^{'1} = 2\,N_{p1}^{*1}\ ; \\ k_{p2}^{'1} = N_{p2}^{*1} + N_{pq}^{*1}\ ; \\ k_{p3}^{'1} = N_{p3}^{*1} + N_{p(q-1)}^{*1}\,; \\ -------------. \end{cases} \tag{14}$$

The tentative slot priming, when the rotational magnetomotive force of the maximum average pitch sinusoidal three-phase windings is optimized, is determined in the following way:

$$\begin{cases} k_{s1}^{'1} = 2\,N_{s1}^{*1}\ ; \\ k_{s2}^{'1} = N_{s2}^{*1} + N_{sq}^{*1}\ ; \\ k_{s3}^{'1} = N_{s3}^{*1} + N_{s(q-1)}^{*1}\,; \\ -------------. \end{cases} \tag{15}$$

The real slot primings k^1_{pi} or k^1_{si} that are linked to their permissible priming which is equal to one are determined by dividing all the tentative slot primings $k'^{1}_{p\,i}$ or $k'^{1}_{s\,i}$ by the maximum tentative slot priming. On the grounds of the expressions (14) Table 3 of the tentative and real slot priming of the maximum average pitch sinusoidal three-phase windings, which pulsating magnetomotive forces are optimized, is drawn.

Table 3. The tentative and real slot priming of the maximum average pitch sinusoidal three-phase windings, which pulsating magnetomotive forces are optimized

q	k_p^1	Slot No.						
		1	2	3	4	5	6	…
2	$k_{p\,i}^{'1}$	1,07	0,93	1,07	0,93	1,07	0,93	…
	$k_{p\,i}^{1}$	**1,0**	**0,87**	**1,0**	**0,87**	**1,0**	**0,87**	…
3	$k_{p\,i}^{'1}$	0,74	0,63	0,63	0,74	0,63	0,63	…
	$k_{p\,i}^{1}$	**1,0**	**0,85**	**0,85**	**1,0**	**0,85**	**0,85**	…
4	$k_{p\,i}^{'1}$	0,57	0,47	0,49	0,47	0,57	0,47	…
	$k_{p\,i}^{1}$	**1,0**	**0,84**	**0,87**	**0,84**	**1,0**	**0,84**	…
5	$k_{p\,i}^{'1}$	0,46	0,38	0,39	0,39	0,38	0,46	…
	$k_{p\,i}^{1}$	**1,0**	**0,82**	**0,86**	**0,86**	**0,82**	**1,0**	…
6	$k_{p\,i}^{'1}$	0,38	0,31	0,33	0,33	0,33	0,31	…
	$k_{p\,i}^{1}$	**1,0**	**0,81**	**0,85**	**0,87**	**0,85**	**0,81**	…

Table 4 of the tentative and real slot priming of the maximum average pitch sinusoidal three-phase windings, which rotational magnetomotive forces are optimized, is made.

Table 4. The tentative and real slot priming of the maximum average pitch sinusoidal three-phase windings, which rotational magnetomotive forces are optimized

q	k_s^1	Slot No.						
		1	2	3	4	5	6	…
2	$k_{s\,i}^{'1}$	0,93	1,07	0,93	1,07	0,93	1,07	…
	$k_{s\,i}^{1}$	**0,87**	**1,0**	**0,87**	**1,0**	**0,87**	**1,0**	…
3	$k_{s\,i}^{'1}$	0,61	0,69	0,69	0,61	0,69	0,69	…
	$k_{s\,i}^{1}$	**0,88**	**1,0**	**1,0**	**0,88**	**1,0**	**1,0**	…
4	$k_{s\,i}^{'1}$	0,46	0,51	0,53	0,51	0,46	0,51	…
	$k_{s\,i}^{1}$	**0,87**	**0,97**	**1,0**	**0,97**	**0,87**	**0,97**	…
5	$k_{s\,i}^{'1}$	0,36	0,40	0,42	0,42	0,40	0,36	…
	$k_{s\,i}^{1}$	**0,87**	**0,96**	**1,0**	**1,0**	**0,96**	**0,87**	…
6	$k_{s\,i}^{'1}$	0,30	0,33	0,34	0,35	0,34	0,33	…
	$k_{s\,i}^{1}$	**0,87**	**0,94**	**0,98**	**1,0**	**0,98**	**0,94**	…

All the magnetic circuit slots of the average short-pitch sinusoidal three-phase windings are taken up by the active sides of sections of different phases (Fig. 2). Suppose that the first slot will be taken up by the active sides of the first section of one phase winding and of the q section of the other phase winding, and that the second slot will be taken up by the active sides of the $(q - 1)$ section and of the second section of the same group of sections and of the same phase winding and etc., then the order of setting the active sides of sections according their numbers in a group into appropriate slots will depend only on the number q of sections forming their group. In Table 5 the repartition of the active sides of sections of the average short-pitch sinusoidal three-phase windings according to their numbers in a group into the magnetic circuit slots depending on the quantity q.

Table 5. The setting of the active sides of sections of the average short-pitch sinusoidal three-phase windings according to their numbers in a group into the magnetic circuit slots depending on the quantity q

q	Slot No.						
	1	2	3	4	5	6	…
2	1 2	2 1	1 2	2 1	1 2	2 1	…
3	1 3	2 2	3 1	1 3	2 2	3 1	… .
4	1 4	2 3	3 2	4 1	1 4	2 3	…
5	1 5	2 4	3 3	4 2	5 1	1 5	…
6	1 6	2 5	3 4	4 3	5 2	6 1	…

It is seen from the Table 5 that the slot priming in groups that have two slots each when q is equal to three or four and the slot priming in groups that have three slots each when q is equal to five or six will be different.

The different slot priming of the average short-pitch sinusoidal three-phase windings in their groups may be determined from the real relative quantities of the number of turns of sections, that is from the data of the 1st table and by virtue of the 5th table as well. Thus, the tentative slot priming, when the pulsating magnetomotive forces of the average short-pitch sinusoidal three-phase windings are optimized, is determined in the following way:

$$\begin{cases} k'^{2}_{p1} = N^{*2}_{p1} + N^{*2}_{pq}; \\ k'^{2}_{p2} = N^{*2}_{p2} + N^{*2}_{p(q-1)}; \\ ------------ \end{cases} \qquad (16)$$

The tentative slot priming, when the rotational magnetomotive force of the average short-pitch sinusoidal three-phase windings is optimized, is determined in the following way:

$$\begin{cases} k'^{2}_{s1} = N^{*2}_{s1} + N^{*2}_{sq}; \\ k'^{2}_{s2} = N^{*2}_{s2} + N^{*2}_{s(q-1)}; \\ ------------ \end{cases} \qquad (17)$$

The real slot primings k^2_{pi} or k^2_{si} that are linked to their permissible priming which is equal to one are determined by dividing all the tentative slot primings $k'^{2}_{p\,i}$ or $k'^{2}_{s\,i}$ by the appropriate maximum tentative slot priming. On the grounds of the expressions (16) the table 6 of the tentative and real slot priming of the average short-pitch sinusoidal three-phase windings, which pulsating magnetomotive forces are optimized, is drawn.

Table 6. The tentative and real slot priming of the average short-pitch sinusoidal three-phase windings, which pulsating magnetomotive forces are optimized

q	k_p^2	Slot No.						
		1	2	3	4	5	6	…
2	$k'^{2}_{p\,i}$	1,0	1,0	1,0	1,0	1,0	1,0	…
	$k^{2}_{p\,i}$	**1,0**	**1,0**	**1,0**	**1,0**	**1,0**	**1,0**	…
3	$k'^{2}_{p\,i}$	0,65	0,69	0,65	0,65	0,69	0,65	…
	$k^{2}_{p\,i}$	**0,94**	**1,0**	**0,94**	**0,94**	**1,0**	**0,94**	…
4	$k'^{2}_{p\,i}$	0,48	0,52	0,52	0,48	0,48	0,52	…
	$k^{2}_{p\,i}$	**0,93**	**1,0**	**1,0**	**0,93**	**0,93**	**1,0**	…
5	$k'^{2}_{p\,i}$	0,38	0,41	0,42	0,41	0,38	0,38	…
	$k^{2}_{p\,i}$	**0,91**	**0,98**	**1,0**	**0,98**	**0,91**	**0,91**	…
6	$k'^{2}_{p\,i}$	0,32	0,34	0,35	0,35	0,34	0,32	…
	$k^{2}_{p\,i}$	**0,91**	**0,97**	**1,0**	**1,0**	**0,97**	**0,91**	…

On the grounds of the expressions (17) Table 7 of the tentative and real slot priming of the average short-pitch sinusoidal three-phase windings, which rotational magnetomotive forces are optimized, is made.

Table 7. The tentative and real slot priming of the average short-pitch sinusoidal three-phase windings, which rotational magnetomotive forces are optimized

q	k_s^2	Slot No.						
		1	2	3	4	5	6	…
2	$k'^{2}_{s\,i}$	1,0	1,0	1,0	1,0	1,0	1,0	…
	$k^{2}_{s\,i}$	**1,0**	**1,0**	**1,0**	**1,0**	**1,0**	**1,0**	…
3	$k'^{2}_{s\,i}$	0,65	0,69	0,65	0,65	0,69	0,65	…
	$k^{2}_{s\,i}$	**0,94**	**1,0**	**0,94**	**0,94**	**1,0**	**0,94**	…
4	$k'^{2}_{s\,i}$	0,42	0,52	0,52	0,42	0,42	0,52	…
	$k^{2}_{s\,i}$	**0,93**	**1,0**	**1,0**	**0,93**	**0,93**	**1,0**	…
5	$k'^{2}_{s\,i}$	0,38	0,41	0,42	0,41	0,38	0,38	…
	$k^{2}_{s\,i}$	**0,91**	**0,98**	**1,0**	**0,98**	**0,91**	**0,91**	…
6	$k'^{2}_{s\,i}$	0,32	0,34	0,35	0,35	0,34	0,32	…
	$k^{2}_{s\,i}$	**0,91**	**0,97**	**1,0**	**1,0**	**0,97**	**0,91**	…

On the grounds of the real magnetic circuit slot primings it is possible to evaluate their average primings in point of the permissible one. The evaluation is made according to the following expressions:

$$k^{1}_{p\,vid} = \left(k^{1}_{p1} + k^{1}_{p2} + \ldots + k^{1}_{pq}\right)/q\ ; \qquad (18)$$

$$k^{2}_{p\,vid} = \left(k^{2}_{p1} + k^{2}_{p2} + \ldots + k^{2}_{pq}\right)/q\ ; \qquad (19)$$

$$k^{1}_{s\,vid} = \left(k^{1}_{s1} + k^{1}_{s2} + \ldots + k^{1}_{sq}\right)/q\ ; \qquad (20)$$

$$k^{2}_{s\,vid} = \left(k^{2}_{s1} + k^{2}_{s2} + \ldots + k^{2}_{sq}\right)/q\ . \qquad (21)$$

The results in Table 8 is calculated using (18)÷(21).

Table 8. The average magnetic circuit slot priming in point of the permissible priming while setting the sinusoidal three-phase windings

q	$k^{1}_{p\,vid}$	$k^{2}_{p\,vid}$	$k^{1}_{s\,vid}$	$k^{2}_{s\,vid}$
2	0,935	1,0	0,935	1,0
3	0,90	0,96	0,96	0,96
4	0,8875	0,965	0,9525	0,965
5	0,872	0,956	0,958	0,956
6	0,865	0,96	0,952	0,96

Conclusions

1. According to the structure of the electric schemes the sinusoidal three-phase windings can be of the maximum or short average pitch.
2. According to the repartition of the number of turns in the sections of groups of sections the sinusoidal three-phase windings can be with the optimized pulsating or rotational magnetomotive force.
3. The repartition of the number of turns of the sinusoidal three-phase windings of all four types in

sections is different when the number of sections in their group is the same.

4. While setting the sinusoidal three-phase windings of any type the magnetic circuit slots are primed differently, however the priming of some slots is equal to the permissible priming and priming of other slots is less than the permissible one, though this priming is close to it.

5. The minimal average magnetic circuit slot priming is obtained when the maximum average pitch sinusoidal three-phase windings with the optimized pulsating magnetomotive force are set into the slots.

6. While setting the average short-pitch sinusoidal three-phase windings of one or another type the average magnetic circuit slot priming is different when the number of sections in their group is the same.

7. When increasing the number sections in their groups the average priming of the magnetic circuit slots is obviously decreasing only when setting the maximum average pitch sinusoidal three-phase windings with the optimized pulsating magnetomotive force, while setting the windings of other types it changes remotely.

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J. Bukšnaitis. The Research of the Sinusoidal Three-phase Windings // Electronics and Electrical Engineering. – Kaunas: Technologija, 2006. – No. 6(70). – P. 23-28.

The distribution of the turns within section groups of the sinusoidal three-phase windings with maximal and reduced average span are analyzed. Pulsating or rotating magnetomotive forces of these windings are optimized. Analysis aspects for establishment of turn's number of all four types' spans were obtained. According to these aspects there were calculated turns` numbers in relative quantities of sections which compose the group from two to six sections. These relative quantities are related with concentrated three-phase winding. There were made tabulation in which sections according to their numbers in group are distributed in slots of magnetic circuit depending on section number in group. Considering the relative numbers of the sections` turns of sinusoidal three-phase windings and their distribution in slots according to section numbers in their groups, there were calculated tentative and proper, related with admissible, relative fillings of slots. These fillings of slots accord with relative admissible filling of slots or are a little bit less. With reference to these results average relative fillings of magnetic circuit slots of all now known sinusoidal three-phase windings were obtained. These fillings of magnetic circuit slots are related with admissible and depend on the sections` number in group. Ill. 2, bibl. 3 (in English; summaries in English Russian and Lithuanian).

Ю. Букшнайтис. Исследование синусных трехфазных обмоток // Электроника и электротехника. – Каунас: Технология, 2006. – № 6(70). – С. 23-28.

Рассматривается распределение витков в группах секций синусных трёхфазных обмоток с максимальным и уменьшенным средним шагом, в которых могут быть оптимизированы пульсирующие или вращающиеся магнитодвижущие силы. Приводятся аналитические выражения для определения относительных чисел витков секции всех четырёх типов этих обмоток. По этим выражениям рассчитаны относительные числа витков секций в их группах, которые составляют от двух до шести секций. Эти относительные числа витков секции связаны с сосредоточенной трёхфазной обмоткой. Составлены таблицы, в которых секции распределены на пазы магнитопровода по их номерам в группе (в зависимости от числа секций в группе. Исходя из относительных чисел витков секций синусных трёхфазных обмоток и распределения секций на пазы по их номерам в группе, определены прелиминарные и настоящие относительные заполнения пазов, которые в свою очередь связаны с допустимым заполнением. Полученные относительные заполнения пазов равны допустимому или немного уменьшены. На основе этих результатов получены средние относительные заполнения пазов магнитопровода зависимо от числа секций в группе всех сейчас известных синусных трёхфазных обмоток, которые также связаны с допустимым заполнением. Ил. 2, библ. 3 (на английском языке; рефераты на английском, русском и литовском яз.).

J. Bukšnaitis. Sinusinių trifazių apvijų tyrimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2006. – Nr. 6(70). – P. 23-28.

Nagrinėjamas maksimalaus ir sumažinto vidutinių žingsnių sinusinių trifazių apvijų, kurių gali būti optimizuojamos pulsuojamosios arba sukamosios magnetovaros, vijų paskirstymas sekcijoms jų grupėse. Gautos visų keturių šių apvijų tipų vijų skaičiui nustatyti sekcijose analizinės išraiškos. Šių išraiškų pagrindu apskaičiuoti sekcijų, sudarančių sekcijų grupę nuo dviejų iki šešių sekcijų, vijų skaičiai santykiniais dydžiais, kurie susiejami su sutelktąja trifaze apvija. Toliau sudarytos sekcijų paskirstymo pagal numerius jų grupėje į magnetolaidžio griovelius priklausomai nuo sekcijų skaičiaus, sudarančio jų grupę, lentelės. Žinant sinusinių trifazių apvijų santykinius sekcijų vijų skaičius, taip pat paskirstymą į griovelius pagal sekcijų numerius jų grupėje, apskaičiuoti preliminarūs ir tikrieji, susieti su leistinuoju, santykiniai griovelių užpildymai, kurie yra lygūs arba truputį mažesni už santykinį leistinąjį. Šių rezultatų pagrindu gauti visoms šiuo metu žinomoms sinusinėms trifazėms apvijoms priklausomai nuo sekcijų skaičiaus jų grupėje vidutiniai santykiniai magnetolaidžio griovelių užpildymai, kurie taip pat yra susieti su leistinuoju. Il. 2, bibl. 3 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).