POLE-CHANGING MOTOR FOR LIFT INSTALLATION

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Abstract. The Numerous lift installation require two speeds of rotation for the work. One of them is necessary for lifting, and another for exact stop of a cabin at a level of a floor. Now in these installations two speed motors with two separate windings are used. In this paper the opportunity of creation of the highly effective two-speed motor with pole-changing winding for lifts and elevator installations is considered. The industrial test results of motors with such windings are shown. The advantages of motors with pole-changing windings over conventional motors with two separate windings are given.

Introduction

Two-speed induction motors (TSIM) with the big difference of speeds are widely used in numerous lift- and elevator installations and agricultural machines [1]. In most cases these mechanisms operate under intense working conditions and with a high switching rate (up to 200 cycles/h). As investigations have shown [2, 3], in electrical drives of this type a speed ratio of 1:4 is the most favourable, since with this ratio it is possible to reduce substantially electrical energy losses, and also the weight and size of the motors. Motors now in use usually have two separate windings on the stator for the two speeds. This involves a considerable deterioration in the effectiveness of the motor, and a reduction in its energy parameters; it also complicates manufacture and repair. As an example, a two speed lift motor of type 4AH250 S6/24 Y3 as its highest speed produces a nominal power of 12 kW, but a standard 4AH250S6Y3 motor of the same size produces 55 kW. As can be seen, there is considerable scope for increasing the effectiveness of the motor.

Improvement of such motors is possible by using of one pole-changing winding (PCW) instead of two separate, that allows to increase useful powers and improve power parameters of two speed motors from both pole and also to simplify technology of manufacturing and repairing.

However, at the present time, existing pole-changing windings have not found general applications because of the large number of output leads and switching contacts required, and also because the production technology is rather complex owing to the need to produce unequal pitch coils with unequal numbers of turns [4].

For pole switching, contactors with open poles are usually used, which, with a large number of switching operations, quickly fail and prevent the normal operation of the drive. Therefore, it is advisable to develop contactless switches based on semiconductor elements to ensure the normal functioning of such mechanisms in various operating modes [5, 18, 19]. At the same time, an urgent issue is the study of the operation of such engines in dynamic operating modes [6].

1 New method of design of pole-changing windings

In Tashkent State Technical University named after Islam Karimov (Uzbekistan) new method of the design pole-changing windings - Discretely Specified Spatial Function Method (DSSFM) is carried out [4, 7, 13, 14]. By means of this method it is possible to get the scheme for any pole ratio and number of stator slots.

For two-speed motors with the big difference of speeds PCW with schemes of switching “star - double star” and “star- double star with additional branches” are most effective. These base schemes are shown on Fig.1.a and 1.b. The windings on basis of these schemes have a minimum number of output leads (6 or 9) and additional contacts (2), and their manufacturing technology is identical to the technology used for the ordinary two-layer simplex lap windings with an equal pitch and number of turns in the coils [8, 15, 20].

When power is applied to terminals A, B, C of the windings (see Fig.1), the rotating magnetic field in the motor air gap is developed with higher pole pair number p_2.

If the power supply is applied to terminals D, E, F with the switch contacts K closed, the rotating magnetic field is developed with the lower number of pole pairs p_1, since the current direction is reversed in the coils connected between terminals D, E, F and switch K.

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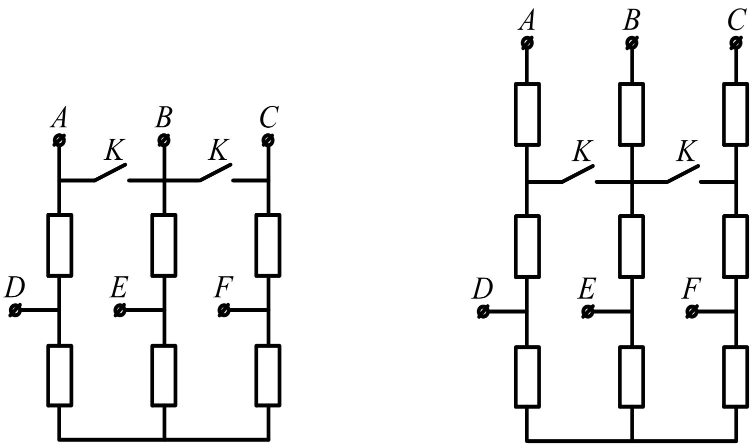


Fig.1. Scheme of switching for PCW: a) «star – double star»; b) «star - double star with additional branches».

At the same time PCW should have structure close to structures of usual windings with width of phase zone 60º grad and 120º grad. (2m-zone and m-zone windings), i.e. corner between the coils, belonging different phases and laying in the next slots should be equal 60ºgrad (π/3 rad.) or 120º grad (2π/3 rad.). The deviation from these values will be defined as a difference between corners of shift of usual and new windings:

$$|\Delta\varphi| = |\varphi_{usual} - \varphi_{new}|.$$

2 Design of new pole-changing winding

Development of the pole-changing winding is carried out by simultaneous consideration of the discretely specified spatial functions (DSSF, function of formalized logic) of two ordinary windings [4, 9, 21].

As an example, let us consider process of construction PCW on ratio of poles 1:4 in number of slots 24 using of new method. From two pole side we take usual two-layer *2m*-zone a winding with number of slot on a pole and a phase *q*=4, and from eight poles - *m*-zone winding with *q*=2. On Fig.2 and 3 are shown DSSF (current distributions) of the down layers of 2- and 8-pole windings.

Number of stator slot																								Pole
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
d	d	d	d	f̲	f̲	f̲	f̲	e	e	e	e	d̲	d̲	d̲	d̲	f	f	f	f	e̲	e̲	e̲	e̲	p_1=1
0	0	0	0	+60°	+60°	+60°	+60°	+120°	+120°	+120°	+120°	+180°	+180°	+180°	+180°	+240°	+240°	+240°	+240°	+300°	+300°	+300°	+300°	Corner of shift
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	|Δφ|

Fig.2. DSSF of down layer of 2-pole winding

Number of stator slot																								Pole
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
a	a	b	b	c	c	a	a	b	b	c	c	a	a	b	b	c	c	a	a	b	b	c	c	p_2=4
0	0	+120°	+120°	+240°	+240°	0	0	+120°	+120°	+240°	+240°	0	0	+120°	+120°	+240°	+240°	0	0	+120°	+120°	+240°	+240°	Corner of shift
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	|Δφ|

Fig.3. DSSF of down layer of 8-pole winding

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Slots
d	d	d	d	f̲	f̲	f̲	f̲	e	e	e	e	d̲	d̲	d̲	d̲	f	f	f	f	e̲	e̲	e̲	e̲	p_1=1
a	a	b	b	c	c	a	a	b	b	c	c	a	a	b	b	c	c	a	a	b	b	c	c	p_2=4

Fig.4. Combine of DSSF of down layers of 2- and 8-pole windings

Apparently from this DSSF corners of shift in these windings do not differ from ideal *2m*-zone and *m*-zone windings, i.e. in all slots $|\Delta\varphi| = 0$.

Let's combine these down layers of current distribution of 2- and 8-pole windings (Fig.4).

For receiving conformity DSSF of a winding to the scheme « a star - a double star » (Fig.1.a) it is necessary to make some transformations in DSSF of small pole. If it is necessary to increase the attitude of effective numbers of coils in phases is used the scheme of switching «a star - a double star with additional branches» (Fig.1.b) and a some of coils is switching in additional branches.

Transformation of phases or synthesizing of a winding with number of poles p_1 should be carried out so that each phase of one pole at the accepted base schemes adjoined only to one phase of the second pole.

On Fig.5 synthesizing a 2-pole winding is presented, here in the third line is written down DSSF of one layer of the synthesized winding, i.e. DSSF of pole-changing winding, concerning to smaller pole p_1=1. It is received as though by "modulation" DSSF of an initial winding by means of DSSF a typical winding. In a basis of this process the principle of “approximation” of current distribution and pictures of magneto-motive forces (MMF) of PCW from pole $2p_1$ to current distribution and picture of MMF of a typical winding [4, 7], i.e. receiving $\Delta\varphi_{min}$ is used. The “approximation” consists in determining the state sign of the conductor DSSF of each slot of the synthesized winding, depending on the conductor state DSSF of the standard winding in the same slot, and on the mutual orientation of the phase current vectors in the three - phase system.

As it is possible to see from here, from big pole side PCW represents usual m-zone winding, from other side phase distribution of coils very close to distribution usual $2m$-zone winding. It means, that given PCW by the properties is close to the normal windings.

Number of stator slot																								Pole
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
a	a	b	b	c	c	a	a	b	b	c	c	a	a	b	b	c	c	a	a	b	b	c	c	p_2=4
a	a	a	a	$\underline{c}$	$\underline{c}$	$\underline{c}$	$\underline{c}$	b	b	b	b	$\underline{a}$	$\underline{a}$	$\underline{a}$	$\underline{a}$	c	c	c	c	$\underline{b}$	$\underline{b}$	$\underline{b}$	$\underline{b}$	p_1=1 typical
a	a	$\underline{b}$	$\underline{b}$	$\underline{c}$	$\underline{c}$	a	a	b	b	$\underline{c}$	$\underline{c}$	$\underline{a}$	$\underline{a}$	b	b	c	c	$\underline{a}$	$\underline{a}$	$\underline{b}$	$\underline{b}$	c	c	p_1=1 synthes.
0	0	-60°	-60°	0	0	+60°	+60°	0	0	-60°	-60°	0	0	+60°	+60°	0	0	-60°	-60°	0	0	+60°	+60°	$\lvert\Delta\varphi\rvert$

Fig.5. Synthesizing of a 2-pole winding

Definition of an optimum step of a winding is carried out on the basis of the analysis of harmonious structure of MMF, values of windingsfactors and factors of differential dispersion from both sides [10, 11].

3 Experimental Model and Results

For studying properties of a new winding in cooperation with specialists of firm “Schindler” (Switzerland) has been designed new two-speed lift motor with PCW [12, 13] on the basis of magnetic core existing lift motors 160MW - 4/16CR.

This magnet core has following dates: out diameter of stator $D_{out,stator} = 265mm$, internal diameter of stator $D_{int,stator} = 175mm$, length of stator core $L_{stator} = 150mm$, air gap $\delta = 1{,}4mm$, number of stator and rotor slots $Z_1 = 48$ and $Z_2 = 60$.

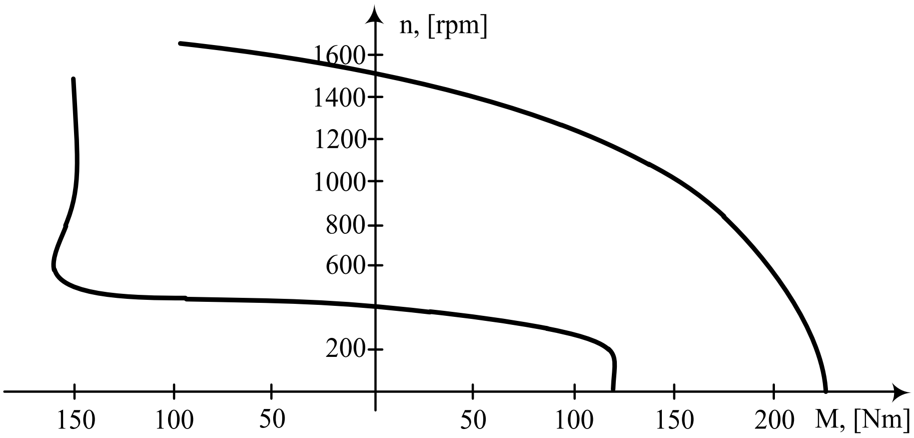


Fig. 6. The torque –speed curve of new motor 160MW4/16C.

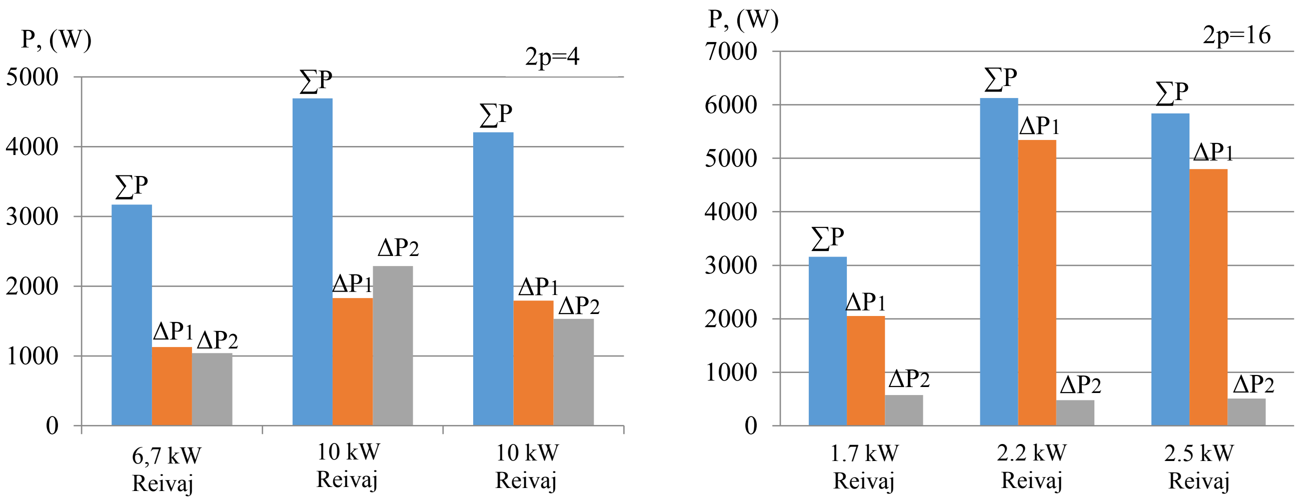
By results of calculation the sample model of the new asynchronous motor was made which the complete rate of industrial tests has passed in research laboratory firms «Schindler» according to the requirements of the world standard showed to lift motors.

The results of tests have shown [12], that the new two-speed motor on a ratio of speeds 1500rpm /375 rpm has useful powers 10/2.5 kW (instead of 6.7/1.7 kW in the existing motor with two separate windings), the value of currents and torques are in allowable limits. The torque – speed curve on the part of both speeds have a smooth kind (Fig.6).

Table 1.

Experimental data of lift motors

Typ of Motor	P_{nom} кW	U V	M_{nom} Nm	2p	M_{start}		I_{nom} A	I_{start}		cosφ	η %	S_{nom} %	J A/mm²	P_2 W	ΣP W	ΔP_1 W	ΔP_2 W
					Nm	%		A	%								
VCE 150-4/16 Reivaj	6.7	400	46.4	4	96	207	18.1	50.5	279	0.783	67.7	14.9	8.7	6649	3171	1129	1038
	1.7			16	73	157	13.4	15.6	134	0.561	30.5	27.2	13.9	1387	3156	2052	572
AM160-4/18 C	10	400	69.2	4	135	195	22.4	78.8	352	0.686	67.2	14.8	8.1	9616	4693	1830	2290
	2.2			18	110	159	25.4	31.6	125	0.484	24.1	19.6	22.4	1942	6128	5342	479
160MW 140-4/16 CR New	10	460	69.2	4	200	289	24.5	78.5	320	0.697	69.0	13.8	6.9	9376	4208	1792	1531
	2.5			16	104	150	22.8	28.3	124	0.444	27.7	17.6	12.9	2239	5842	4800	509



a) b)

Fig.7. Comparison of power parameters of lift motors: a) at 2p=4; b) at 2p=16

In the table 1 the experimental data of lift motors of firm "Reivaj" (Spain) VCE 150-4/16 and AM160-4/18C with ratio of powers 6.7/1.7 kW and 10/2.2 kW and new motor with PCW are shown, and in a Fig. 7 the diagrams of losses of these Motors with the indication of sizes of losses in stator and in a rotor in static mode of operations of two-speed motor are shown.

As it is possible to see from this comparison general losses in new motor on the part of high speed on 485 W less than in the motor AM160-4/18C. It means that the new motor will consume less electric power.

Besides the new motor is carried out on the magnetic core, which on 20 mm is shorter than in the motor AM160-4/18C, accordingly expenditure of copper and insulation materials will be less than in the motor AM160-4/18C.

Conclusion

Analyzing the above-stated data it is possible to assert that :

1. The new PCW with improved electromagnetic properties are received.
2. Using new PCW the new highly effective, compact, reliable and inexpensive TSIM is produced.
3. New TSIM has been successfully tested and corresponds to all industry requirements.

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