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SELECTION OF ROTOR WINDING IN COLLECTOR-FREE ELECTRICAL MACHINE--ETC(U)
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FOREIGN TECHNOLOGY DIVISION

SELECTION OF ROTOR WINDING IN COLLECTOR-FREE ELECTRICAL MACHINE AMPLIFIERS (BEMU) AND FREQUENCY TRANSFORMERS

by

A. I. Skorospeshkin, K. A. Khor'kov, Ye. K. Dergouzov

EDITED TRANSLATION

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Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

SELECTION OF ROTOR WINDING IN COLLECTOR-FREE ELECTRICAL MACHINE AMPLIFIERS (BEMU) AND FREQUENCY TRANSFORMERS

A. I. Skorospeshkin, K. A. Khor'kov, Ye. K. Dergobuzov

The BEMU [Collector-free Electrical Machine Amplifier] and frequency transformers that we developed are two-cascade and integrated. The first cascade is essentially a synchronous machine. But the size of the air gap in them is adopted as in asynchronous machines. It can be expected, therefore, that without the use of stabilizing resources, the external characteristics of the synchronous cascade will have a steeply dipping nature. Experiment confirms this.

The existing methods for stabilizing voltage by using feedback are more suitable for transformers and amplifiers of direct current and fixed frequency. In transformers and amplifiers with controllable frequency, the use of feedback results in an additional load of the controllable semiconductor collector (UPK) that with large limits of frequency regulation can surpass the rated output (with base frequency) several times. In other words, the presence of feedback through the UPK results in a decrease in the rated loading of the machine.

This forces us to search for new methods of stabilizing the voltage.

We have suggested a method for improving the rigidity of the external characteristics of the synchronous cascade of the machine by reducing the effect of the demagnetizing action of the armature reaction with the help of a special design of the rotor winding called "zigzag."

The essence of this winding design is that each phase of the winding is divided into parts that are shifted in space in relation to each other at a certain angle α (fig. 1).

As a result of this connection, a shift is created between the main flux and the flux of the armature reaction. As a result, the demagnetizing effect of the armature reaction is diminished. The resulting electromotive force (e.m.f.) of the machine is also reduced, but insignificantly, in any case, to a lesser degree than the demagnetizing effect of the armature reaction is reduced.

Logic predicts that phase division into two equal parts will be the best. [Illegible] the following calculated formula:

$$X_p = 2mf \frac{\mu_0 D l K_w W_p^2}{K_\delta K_\mu p \delta}, \qquad (1)$$

m--number of winding phases,

f--e.m.f. frequency,

μ_0--magnetic permeability of air,

K_w--winding coefficient,

W_p--number of winding loops,

$K\delta$--coefficient of air gap,

$K\mu$--saturation coefficient,

p--number of pole pairs,

δ--size of air gap.

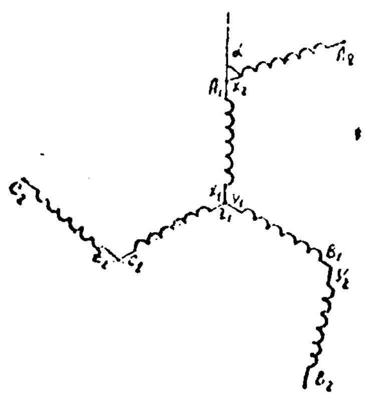

Figure 1.

Analogously, the derived expression for the inductive resistance of the winding when it is connected on the "zigzag" plan looks like:

$$X_{pz} = 2mf \frac{\mu_0 D l K_{wz}}{K_\delta K_\mu p \delta} \cdot [(W_1 + W_2 \cos\alpha)^2 + (W_2 \sin\alpha)^2]. \qquad (2)$$

On the condition that the number of winding loops of the "zigzag" $W_z = W_1 + W_2$ equals the number of loops of the normal winding W_p, we obtain

$$\frac{X_{pz}}{X_p} = \frac{K_{wz}[(W_1 + W_2 \cos\alpha)^2 + (W_2 \sin\alpha)^2]}{K_w (W_1 + W_2)^2} =$$
$$= \frac{K_{wz}}{K_w}\left[1 + \frac{2W_1W_2}{(W_1 + W_2)^2}\left(\cos\alpha - 1\right)\right]. \qquad (3)$$

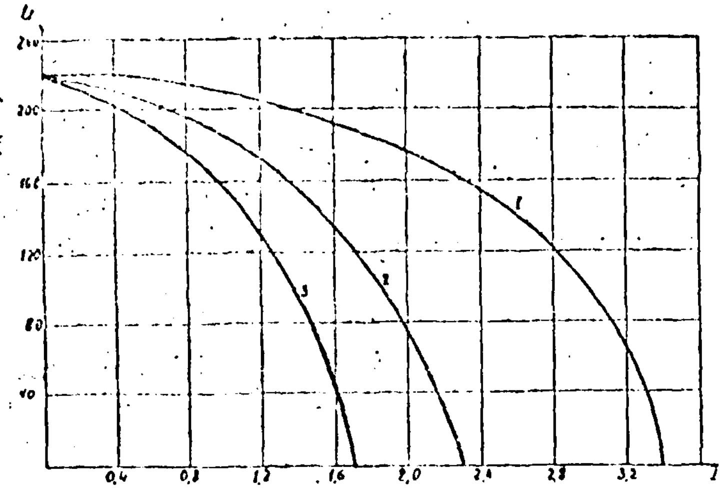

Figure 2. External Characteristics of Cascade with $f_y=0$.

The optimal ratio of the number of loops W_1 and W_2, and the optimal value of angle α are obtained after the partial derivatives of expression (3) are equated to zero,which are equal to:

$$W_1 = W_2 \quad \text{and} \quad \alpha = \frac{\pi}{2}. \qquad (4)$$

The presented experiments completely confirm this conclusion. A model was created for the study in overall dimensions of AOK 42-4. The armature winding was placed on the rotor. The following types of windings were studied:

1) standard loop winding with number of loops W_p.

2) "zigzag" winding with $W_1+W_2=W_p$ with $W_2=\frac{1}{2}W_1$.

A study was made of the effect of angle α on the rigidity of external characteristics, with frequency of the control field $f_y=0$.

The testing results are presented in figure 2 in the form of the relationship $U=f(I)$. It is apparent from the figure that with $\alpha=90°$ (curve 1), the external characteristics are more rigid than with $\alpha=60°$ (curve 2) and $\alpha=0$ (curve 3).

The developed plan of "zigzag" winding with $\alpha=90°$ is presented in figure 3.

Thus, the connection of winding by "zigzag" significantly increases the rigidity of the external characteristics of the machine.

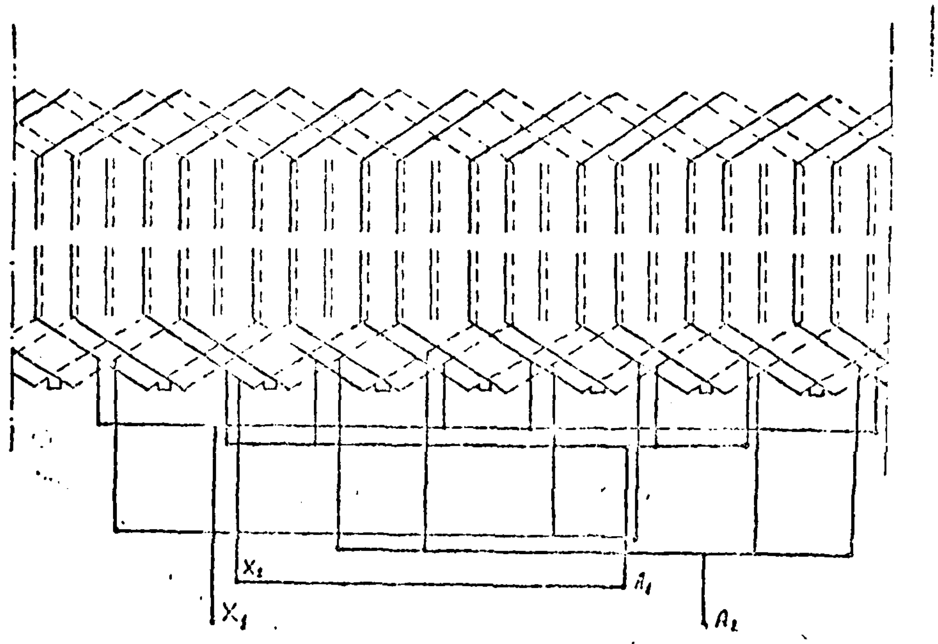

Figure 3. Developed Plan of "Zigzag" Winding with α=90° el.

However, the most indicative are the regulating characteristics (fig. 4) that were obtained with a fixed control field f_y=0 and e.m.f. frequency of the rotor f_p=100 Hz.

It is apparent from the curves that with small load currents, in order to obtain the same voltage at the outlet when the winding is connected on the "zigzag" plan, greater power of machine excitation is required (curve 1) than with normal winding. However, with currents close to the rated, the pattern is drastically altered. This indicates that the amplification coefficient of the cascade with a normal load will be considerably greater for "zigzag" winding since the control powers for both windings are classified as squares of currents.

For example, with power P=4 kW, the following amplification coefficients were obtained:

K_y=37 for normal winding,

K_y=54 for the "zigzag" plan.

It is especially important that these relationships that were

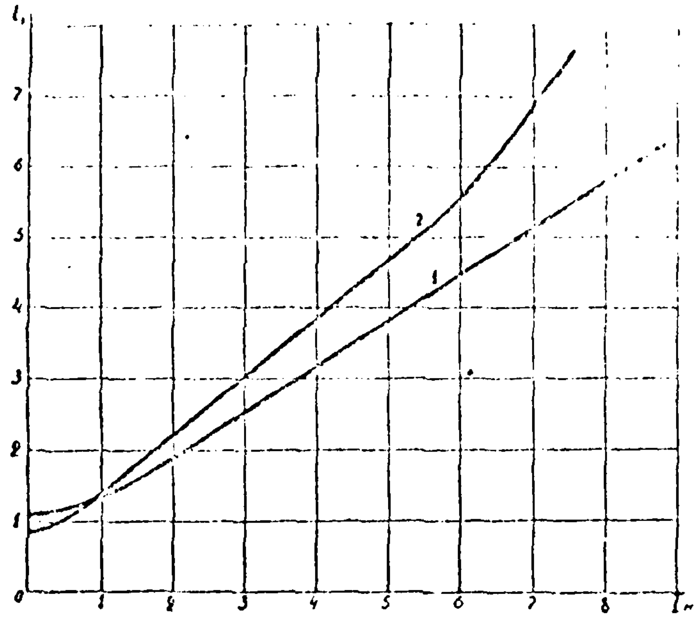

Figure 4. Regulating Characteristics of Cascade with $f_y=0$.

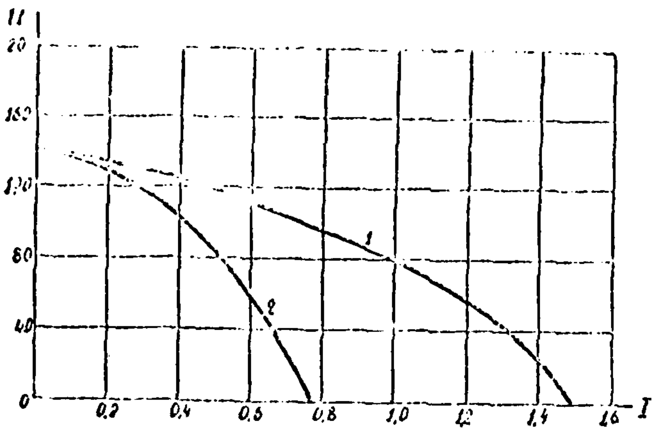

Figure 5. External and Regulating Characteristics of Cascade with $f_y=30$ Hz, $f_p=130$ Hz

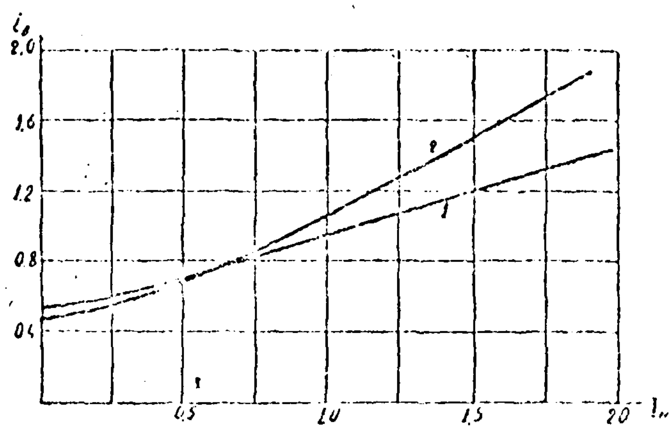

Figure 5 (continuation)

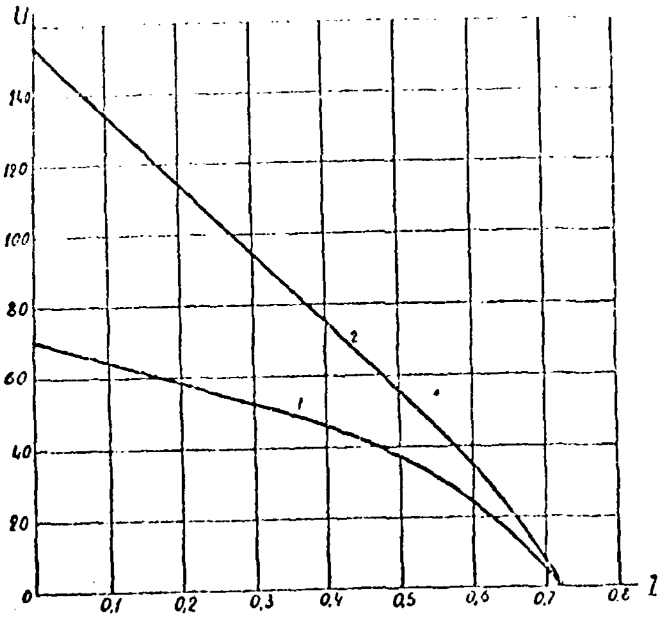

Figure 6. External Characteristics of Cascade with "Zigzag" Winding with Capacitance Load and f_y=30 Hz.
1. with C=0.
2. with C=15 μf.

obtained with a fixed control field remain correct even for the operation of the cascade with rotating field of the control winding.

Figure 5 presents the external and regulating characteristics of the cascade that were taken with frequency of the control field f_y = 30 Hz. This yields an e.m.f. frequency in the rotor winding of f_p = 130 Hz. It is apparent from the curves that during regulation of the frequency, the rigidity of the external characteristics for the "zigzag" plan (curve 1) is considerably greater.

It should also be noted that when working on the capacitance load, (for example, with attachment of the compensating capacitance to the cascade outlet), the winding that is connected on the "zigzag" plan acts in the same way as the normal winding. The external characteristics of the cascade in a capacitance load are given in figure 6.

Thus, the use in transformers and amplifiers of the integrated type of a winding connected on the "zigzag" plan instead of the normal winding, increases the rigidity of the external characteristics of the cascade and reduces the control power with rated load. This is especially important for machines with controllable frequency.

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