SIEM-1 (english)

Ministry of Education and Science of Ukraine
Dnipro University of Technology

DNIPRO UNIVERSITY of TECHNOLOGY 1899

Department of Electrical Engineering

Kolb A.A.

COLLECTION OF METHODICAL MATERIALS
for laboratory work on discipline " Special issues of electric machines "

for students studying specialty 141 “Electrical Power Engineering, Electrical Engineering and Electromechanics”

Dnipro
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Methodical instructions are intended for laboratory work in the discipline of "Special issues of electric machines" students majoring in 141 - Electrical Power Engineering, Electrical Engineering and Electromechanics.

LABORATORY TEST SIEM-1
DC TACHOGENERATOR STUDY

Aim of the training

Investigate the design, principle of operation and main characteristics of the DC tachogenerator.

Work program

1. Study of the design and principle of operation of the tachogenerator.
2. Experimental study of the tachogenerator.
3. Reporting.

The work procedure

Stage 1. Study of the design and principle of operation of the tachogenerator

To study the design and principle of operation of the DC tachogenerator presented at the stand. Determine the purpose of all structural elements and their interaction during the operation of the tachogenerator. Get acquainted with the laboratory equipment designed to study the DC tachogenerator. Put the rating data of the tachogenerator in table 1.

Table 1

Type and serial number	U_{er}	I_{er}	n_r	R_r
	V	A	rpm	Ohm

Stage 2. Experimental study of the tachogenerator

Connect the electrical circuit according to the diagram in Fig. 1.

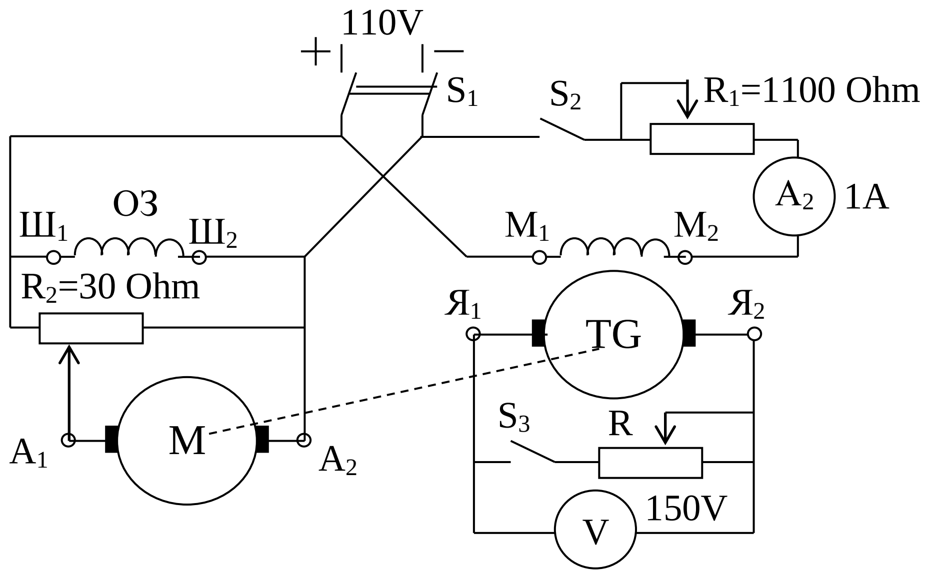

Fig. 1. Tachogenerator research scheme

After the supervisor has checked the correctness of the circuit assembly, connect the drive motor to the power source and take the idle characteristic and the output characteristic of the tachogenerator.

The no-load characteristic $U_0 = f\ (I_e)$ is the dependence of the tachogenerator voltage U_0 on the excitation current I_e in the absence of load (with the S3 switch off) and a constant shaft speed $n = n_r$ of the tachogenerator. This characteristic is measured with a smooth increase in the excitation current I_e from zero to its maximum value $I_e = 1.5 \cdot I_{er}$ (ascending branch of the characteristic), and then with its smooth decrease to zero (descending branch of the characteristic). In this case, it is advisable to measure the shaft rotation frequency n using a stroboscopic tachometer. Pay attention to the fact that when the excitation current decreases to zero (when the S2 switch is turned off), there is an insignificant voltage of the tachogenerator due to the residual magnetization of its magnetic system. Enter these idling characteristics in Table 2.

Table 2

Ascending branch	I_e, A								
	U_0, V								
Descending branch	I_e, A								
	U_0, V								

The output characteristic $U=f\ (n)$ is the dependence of the voltage U on the rotational speed of the shaft n of the tachogenerator at constant values of the excitation current I_e and the load resistance R in the armature circuit. This characteristic is determined with $I_e = I_{er}$, the S_3 switch is on, three values of the load resistance R and the change in the speed of rotation of the shaft n of the tachogenerator within (0.1 ... 1.25) nr by regulating the supply voltage of the drive motor using the rheostat R_2. Pay attention to some non-linearity of the output characteristics of the tachogenerator and the presence of a dead zone. Enter the output characteristic data $U = f\ (n)$ in table 3.

According to Tables 2 and 3, construct graphs of idling characteristics and output characteristics of the tachogenerator and analyze these characteristics. Determine the transmission coefficient of the tachogenerator at three values of the load resistance and its dead zone Δn.

Table 3

$R=\infty$		$R=R_r$		R=2 kOhm	
n	U	n	U	n	U
rpm	V	rpm	V	rpm	V

<u>Stage 3. The report execution</u>

The report on this laboratory work should contain:

1. The name and purpose of the work.
2. Scheme of experimental studies (Fig. 1).
3. Tables 1, 2 and 3 with experimental data.
4. Graphs of the main characteristics of the tachogenerator and their analysis.

Methodical guideline

<u>To stages 1 and 2</u>

A tachogenerator is used to convert the speed (frequency) of rotation of mechanical elements into electrical voltage. The principle of operation of a DC tachogenerator does not differ from a DC generator. The highest conversion accuracy occurs when the voltage is linearly dependent on the rotational speed, i.e. with a linear output characteristic of the tachogenerator (graph 1 in Fig. 2), the slope of which is determined by the transmission coefficient K of the tachogenerator.

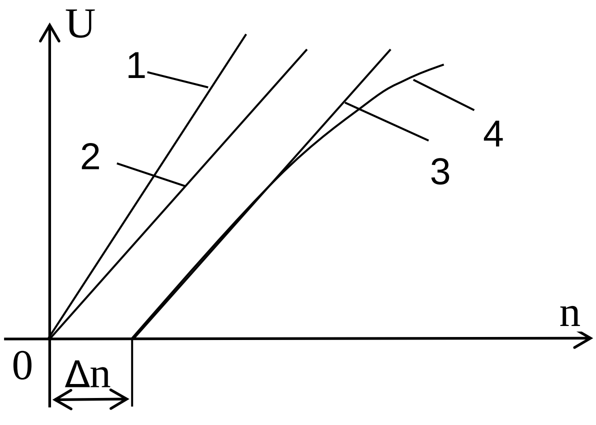

Fig. 2. Tachogenerator output characteristics

The voltage of the loaded tachogenerator decreases by the amount of voltage drop across the resistance of its armature circuit (graph 2 in Fig. 2), which leads to a slight decrease in the transmission coefficient K.

The output voltage of the tachogenerator is removed from the armature winding through a sliding brush contact, the resistance of which changes with a change in current in such a way that the voltage drop across it ΔU_b remains almost unchanged. Therefore, a dead zone Δn appears on the output characteristic of the tachogenerator (graph 3 in Fig. 2). To reduce this zone, copper-graphite and silver-graphite brushes are used.

With a low load resistance R, the current in the armature winding creates a transverse magnetizing force, which, due to the saturation of the material of the pole pieces, leads to a decrease in the main magnetic flux and, consequently, to a decrease in the output voltage of the tachogenerator. Due to this effect of the load, called the demagnetizing action of the armature reaction, the output characteristic of the tachogenerator deviates from the linear law (graph 4 in Fig. 2).

Test questions

1. Name the main structural elements of the tachogenerator and their purpose.
2. Explain the principle of the DC tachogenerator.
3. How to explain the nonlinearity of the idling characteristic of the tachogenerator?
4. What is the output characteristic of the tachogenerator and in what order is this characteristic determined?
5. What does the tachogenerator transfer coefficient depend on and under the influence of what factors can this coefficient change?
6. What is the reason for the appearance of the dead zone on the output characteristic of the tachogenerator and how can this zone be reduced?
7. How can you explain the nonlinearity of the output characteristics of the tachogenerator?

LABORATORY TEST SIEM-2

INVESTIGATION OF THE ELECTRIC MECHANICAL AMPLIFIER OF THE TRANSVERSE FIELD

Aim of the training

Investigate the design, principle of operation and the main characteristics of the electric machine transverse field amplifier (EMA)

Work program

1. Study of the design and principle of operation of the EMA.
2. Experimental study of EMA.
3. Reporting.

The work procedure

Stage 1. Study of the design and principle of operation of the EMA

To study the design and principle of operation of the EMA presented at the stand. Determine the purpose of all structural elements and their interaction during the operation of an electric machine amplifier. Get acquainted with the laboratory setup designed for the study of EMA. Write down the technical data of the EMA in Table 2.1, where:

U_r, P_r, I_r - rated values of voltage, power and current of the drive motor and EMA.

R_a, R_{add}, R_k, R_{c1}, R_{c2} - resistances of armature windings, additional poles, compensation winding, first and second control windings

Table 2.1

Type and factory EMA number	Motor				EMA							
	Winding scheme	U_r	P_r	I_r	U_r	P_r	I_H	Winding resistance				
								R_a	R_{add}	$R_к$	R_{y1}	R_{y2}
-	-	V	kW	A	V	kW	A	Ohm	Ohm	Ohm	Ohm	Ohm

Stage 2. Experimental study of EMA

Connect the electrical circuit according to the diagram in Fig.3.

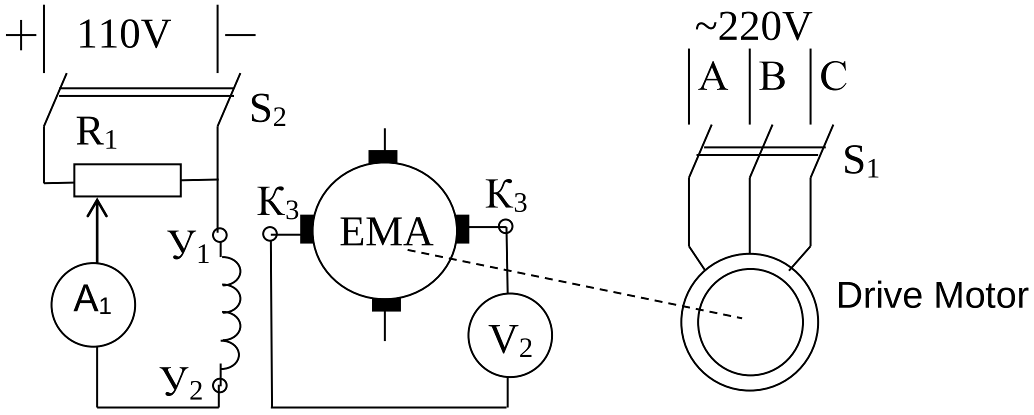

Fig.3. Scheme of the study of EMA with open transverse brushes

After checking by the teacher that the circuit is assembled correctly, connect the drive motor to the three-phase network using the S_1 switch and make sure that the direction of rotation of the rotor is correct (the correct direction of rotation is indicated by an arrow on the machine body). Apply voltage to the control winding of the EMA (turn on the switch S_2) and, by adjusting the current in this winding using the rheostat R_1, determine the dependence of the voltage on the open transverse brushes (readings of the voltmeter V_2) on the current in the control winding (from the readings of the milliammeter A_1). Record the measurement results in Table 5.

Table 5

Ascending branch of the characteristic	I_1, mA								
	U_2, V								
Descending branch of the characteristic	I_1, mA								
	U_2, V								

Connect the electrical circuit according to the diagram in Fig. 4 and determine the dependence of the output voltage of the EMA (voltmeter readings V_3) and the current in the circuit of closed transverse brushes (readings of the ammeter A_2) on the current in the control winding in idle mode (with the switch S_3 open). Put the measurement results in Table 6.

According to tables 5 and 6, plot the voltage dependences on the transverse brushes U_2 and on the longitudinal brushes U_3 on the current in the control winding I_1, i.e. graphs $U_2 = f(I_1)$ and $U_3 = f(I_1)$ in the idle mode of the EMA (when the S_3 switch is off). Determine the voltage gain values at one and two EMA amplification stages ($K_{1U} = U_2/U_1$ and $K_{2U} = U_3/U_1$), recalculating the current I_1 into the voltage U_1 of the control winding using the data on the resistance of this winding ($U_1 = I_1 R_y$).

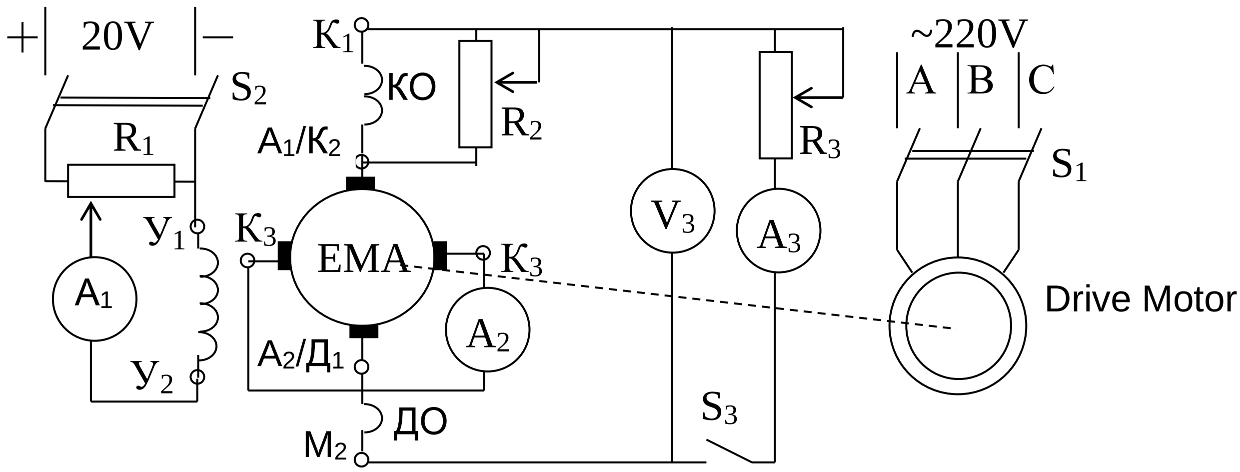

Fig.4. Scheme of the study of EMA with closed transverse brushes

Table 6

Ascending branch of the characteristic	I_1, mA								
	I_2, A								
	U_3, V								
Descending branch of the characteristic	I_1, mA								
	I_2, A								
	U_3, V								

Load the EMA to the rated load R_3 in accordance with the diagram in Fig. 4 (turn on the switch S_3) and read the dependences of the output voltage U_3 on the load current I_3 (external characteristics of the EMA) at different degrees of compensation of the demagnetizing effect of the load current. The degree of compensation is changed by adjusting the resistance of the rheostat R_2, which shunts the compensation winding of the KO. Compensation is considered normal if, when the load rheostat R_3 is turned on, the output voltage U_3 does not change. In case of undercompensation, the inclusion of the load rheostat R_3 leads to a decrease in U_3 as the load current increases, and in case of overcompensation, to an increase in U_3. Put the data of external characteristics $U_3=f(I_3)$ of EMA in Table 7.

Based on the data in Table 7, construct graphs of external characteristics and determine the power gain of the EMA at a rated load $K_P=P_r/P_1$, where P_r is the rated power of the EMA, $P_1=(I_1)2Ry$ is the power of the input signal of the EMA.

Table 7

Normal compensation			Undercompensation			Overcompensation		
I_3	U_3	I_2	I_3	U_3	I_2	I_3	U_3	I_2
A	V	A	A	V	A	A	V	A

Stage 3. The report execution

The report on this laboratory work should contain:

1. Name and purpose of the work.
2. Schemes of experimental studies (Fig. 3 and 4).
3. Tables 4, 5, 6 and 7 with experimental data.
4. Graphs of characteristics and calculations of EMA gain factors for voltage and power.

Methodical guideline

To stage 1 and 2

The electric machine amplifier (EMA) is designed to amplify the power of electrical signals for the purpose of their further use both in open and closed automatic control systems - in the current and voltage feedback circuits of these systems. The armature of the EMA of the transverse field differs from the armature of a conventional DC machine only in the presence of two pairs of brushes: transverse q-q (clamps K3-K3) and longitudinal d-d (clamps R1-R2). This difference provides a high voltage and power gain, since the amplification is carried out in two stages: the control winding - q-q transverse brushes, short-circuited (first stage), and q-q transverse brushes - longitudinal brushes d-d (second stage). The use of longitudinal brushes leads to the demagnetizing effect of the load current, which requires compensation for this effect using the compensation winding KO. With full compensation, the output voltage of the EMA depends only on the control signal and does not depend on the load current. Usually, the EMA is tuned using the adjusting rheostat R2 for a slight undercompensation.

Test questions

1. Name the main structural elements of the transverse field EMA and their purpose.

2. Explain the principle of operation of the transverse field EMA.

3. How to explain the non-linear nature of the dependence of the voltage on the transverse and longitudinal brushes on the current in the control winding in the idle mode of the transverse field EMA?

4. What is the external characteristic of the EMA and how is this characteristic determined?

5. What determines the gain of the EMA in terms of voltage and power?

6. Why are there multiple control windings in the EMA?

7. What is the purpose of the compensation winding of the EMA of the transverse field?

8. How can one explain the differences in the external characteristics of the transverse field EMA at different degrees of compensation?

9. In what order is the transverse field EMA compensation adjusted?

10. Name the scope of the transverse field EMA

LABORATORY TEST SIEM-3
STUDY OF A UNIVERSAL COLLECTOR MOTOR

Aim of the training

To study the design, principle of operation and explore the universal collector motor

Work program

1. The study of the design and principle of operation of the collector motor.

2. Experimental study of a collector motor when it is powered from a DC network.

3. Experimental study of a collector motor when it is powered from an AC network.

4. The report execution.

The work procedure

<u>Stage 1. Studying the design and principle of operation of the collector motor</u>

To study the design and principle of operation of the universal collector motor presented at the stand. Determine the purpose of all structural elements and their interaction during motor operation. Familiarize yourself with the laboratory installation designed to study the motor. Record in table 8 the technical data of the motor.

Table 8

Type and factory motor number	P_r	n_r	DC		AC	
			U_r	I_r	U_r	I_r
-	W	rpm	V	A	V	A

Stage 2. Experimental study of a collector motor when it is powered from a DC network

Connect the electrical circuit according to the diagram in Fig. 5.

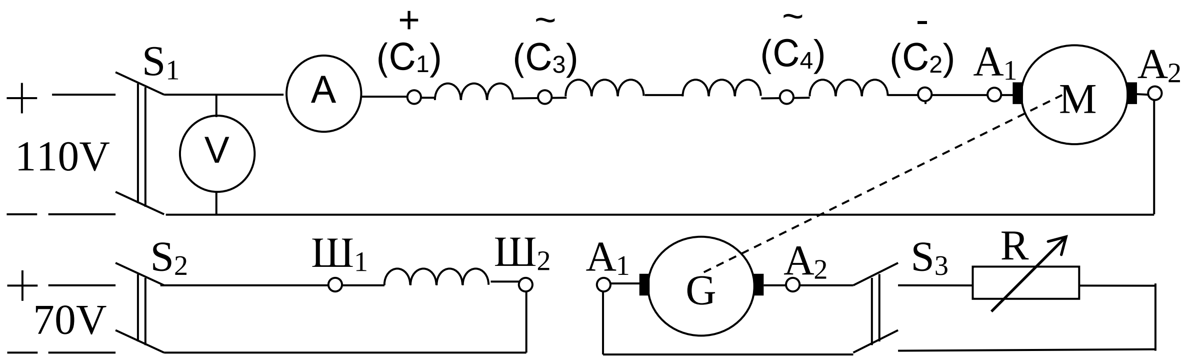

Fig.5. Scheme of research of universal commutator motor when powered by DC

After the teacher checks the correctness of the assembly of the circuit, carry out a trial inclusion of the collector motor under load. As a load of the motor, use a DC generator loaded on the resistor R (with the switches S_2 and S_3 on). When trying to run the motor, make sure that the motor is loaded according to its rating. Remove the speed characteristic of the motor n=f(I), reducing its load from the nominal value to the minimum possible value, at which the motor rotor speed will be equal to the maximum allowable value n_{max}=1.5 n_r. In this case, the rotor speed can be measured using a stroboscopic tachometer or a tachogenerator connected to the shaft of the motor under study. Put the results of measurements when taking the speed characteristics of the collector motor in Table 9.

Table 9

With direct current (natural characteristic)			With alternating current					
			natural characteristic			artificial characteristic (when shunting the armature)		
U	I	n	U	I	n	U	I	n
V	A	rpm	V	A	rpm	V	A	rpm

Stage 3. Experimental study of the commutator motor when powered by AC

Connect the electrical circuit according to the diagram in Fig. 6.

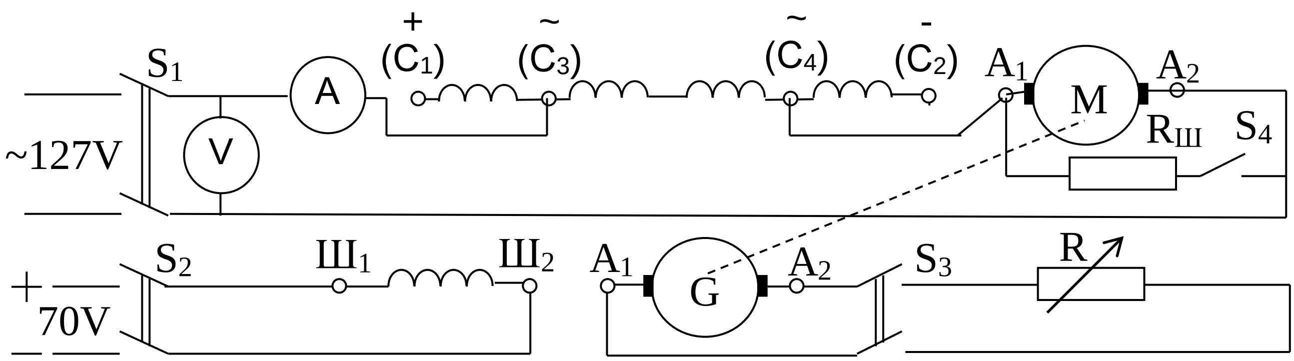

Fig.6. Scheme of research of universal commutator motor when powered by AC

After checking by the teacher that the circuit is assembled correctly, connect the collector motor to the AC mains under load. As a load of the motor, use a DC generator loaded on the resistor R (with the switches S_2 and S_3 on). Make sure the motor is loaded according to its rating. To remove the natural speed characteristic of the motor n=f(I) with the open switch P_4 is similar to the removal of the speed characteristic of the motor when powered from the DC network, reducing its load from the nominal value to the minimum possible value at which the motor rotor speed will be equal to the maximum allowable value n_{max} =1.5 n_r. Record the measurement results in Table 9

Shunt the armature of the studied motor with a resistor RSH (turn on the switch P4) and remove the artificial speed characteristic of the collector motor. Record the measurement results in Table 9.

Based on the data in Table 9, to build on a scale the graphs of the speed characteristics of the investigated universal collector motor when it is powered from a DC and AC network. Perform a comparative analysis of these characteristics.

Stage 4. The report execution

The report for this lab should include:

1. Name and purpose of the work.
2. Schemes of experimental studies (Fig.5 and 6).
3. Tables 8 and 9 with experimental data.
4. Graphs of the speed characteristics of the universal collector motor in one coordinate system.

Methodical guideline

To stage 1,2 and 3

The universal commutator motor is an electric commutator motor of series excitation, which operates when powered from both a direct current network and a single-phase alternating current network. At the same time, the performance characteristics of the motor in both cases are approximately the same. Universal commutator motors are produced with power from 10 to 600 W at a nominal speed of 2500 to 20000 rpm.

The fundamentally universal commutator motor is practically no different from a series-excited DC motor. The only difference is that the magnetic circuit of the inductor is laminated similarly to the magnetic circuit of the armature, since when powered from the AC mains, the main magnetic flux changes with time. In addition, the excitation winding of the universal collector motor is divided into parts in such a way as to provide the possibility of:

- connecting the motor to a network of both direct current and alternating current, while maintaining approximately the same performance in both cases;
- use of parts of the excitation winding, connected on both sides of the armature, as chokes of LC filters, attenuating electromagnetic interference that

occurs due to switching in the collector and on the brushes and can enter the supply network (Fig. 7).

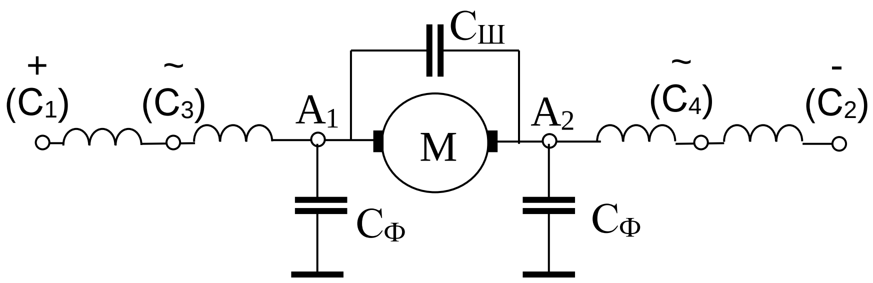

Fig.7. EMI mitigation circuit, created by a universal collector motor

The operation of a universal collector motor when powered from an alternating current network is based on the fact that the main flux (excitation flux) and the armature current of the motor change their sign at the same time, and therefore the sign of the electromagnetic torque and the direction of rotation of the rotor do not change. The motor is reversed by switching the terminals of the armature winding R_1 and R_2.

An important advantage of universal collector motors in relation to AC motors is the possibility of obtaining a rotor speed of more than 3000 rpm when powered from a mains with an industrial frequency of 50 Hz. At the same time, it should be taken into account that when powered from an alternating current network, losses in the magnetic circuit of the inductor are added and losses in the windings increase due to an increase in the current consumed from the network, under otherwise identical conditions..

Test questions

1. Name the differences in the design and principle of operation of a universal commutator motor and a similar series-excited DC motor.

2. For what purpose is the excitation winding of a universal collector motor divided into parts?

3. What are the reasons for the differences in the circuits for switching on a universal collector motor when it is powered from a DC and AC mains?

4. What are the differences in the energy performance of a universal collector motor when it is powered from a DC and AC mains?

5. What are the differences in the natural and artificial speed characteristics of a universal collector motor when it is powered from a DC and AC network?

6. What are the ways to control the rotor speed of the universal collector motor?

7. How can the direction of rotation of the rotor of a universal commutator motor be changed?

8. How can the effect of electromagnetic interference generated by a universal collector motor on the mains voltage be reduced?

9. What is the main advantage of a universal commutator motor from an AC motor when powered by AC?

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МАТЕРІАЛИ МЕТОДИЧНОГО ЗАБЕЗПЕЧЕННЯ
лабораторних робіт з дисциплін
“Спеціальні питання електричних машин”
для студентів спеціальності
141–Електроенергетика, електротехніка та електромеханіка
(на англ. мові)

Редакційно-видавничий комплекс