CSITA

INFORMATION TECHNOLOGIES

ISSN 2414-9055

UDC 681.313.451

https://doi.org/10.31721/2414-9055.2017.3.3.49

FORMING THE EQUIVALENT ROTOR CURRENT FOR POST REPAIR TEST OF ASYNCHRONOUS MOTOR

Maksymov M. M., PHD (Engineering), Assoc. Prof.,
Fillip Y. B., PHD (Engineering), Assoc. Prof.,
Poltavsky O. S., graduate student
Kryvyi Rih National University

Abstract. Modern economic conditions set special tasks to ensure the reliability and durability of the equipment to be used. It is particularly true for such a group of electrical products as induction motors used at almost every enterprise. At present, the accident rate of induction motors at enterprises is high; meanwhile, only up to 25% of the motor base is reequipped annually. One of the main reasons of such a condition is the low quality of repair and the lack of the devices to examine the repaired induction motors thoroughly taking into account the specific "accidental" technical parameters of a tested machine. Based on the fact that asynchronous motors frequently fail for any reasons (overloads, adverse environmental conditions, low quality of power supply etc.) was determined a need for conducting complex repair and maintenance. As a result, it makes possible to re-exploit the engine for a long time. The major weakness of electric motor during the repair works was identified. Consequently, several solutions are proposed for motor windings electromagnetic energy change that help to load the motor excluding the mechanical influence on the shaft. These circumstances are substantiated by the formulas of the frequency, voltage and torque change. Thus, there is an urgent need to create a new equipment type to test the repaired induction motors under load conditions without increasing the testing time period, whose results will allow to estimate the real condition of a motor, namely, to reveal hot spots, loading capacity, etc.

Keywords: induction motor, voltage forming, modulation, loading, torque, synchronous speed.

Current parameters forming in the circuits of asynchronous squirrel-cage motors. The way of pulsating current forming in stator and rotor circles of induction motor is considered for further evaluation of motor operability. This current has a wide range of variation.

Problem and its connection with scientific and practical tasks. Modern economic conditions pose particular tasks for reliability and durability of used equipment. Especially, it concerns such a group of electrotechnical products like asynchronous squirrel-cage motors (AM) virtually used at any industrial enterprise. Presently, the AM breakdown rate is considerable at the industrial enterprises, and motor park renewal makes up 20% annually. One of the main reasons of such a condition is lack of repair quality and absence of means, which would enable to make an advanced investigation of repaired AM condition, taking in account a specific character of technical parameters "randomness" of the tested machine.

These circumstances lead to the fact, that the repaired motor is oriented to the passport of a new machine. But using it at the same place, before being repaired without preliminary heat tests, results to a rapid failure of AM.

Research analysis and publications. Some works [1] consider the possibility of AM load by alternation of traction and braking modes without any action on the motor shaft. This method includes complicated approaches in making equivalent load parameters and identification of control parameters. Also another works [2,3] are known by proposing current load process forming by assignment of simple modulated signal to the input of thyristor regulator. The main disadvantage of these systems is limited range of control action variation to ensure the necessary level of current load of stator and rotor windings.

Problem definition. The main task of this article is to investigate a way of stator and rotor circuits load with pulsating current, which has a wide range of variation for further evaluation of motor operability

Statement of material and results.

ISSN 2414-9055

Economic load mode of AM can be obtained by forming voltage by law

$$U_n = U_0 \sin \omega t(k+m\cdot \sin \Omega t) \text{ .}$$

where k,m - experimental coefficients, Ωt - angular frequency of m coefficient change.

In general view the voltage can be represented as follows

$$U_n = U_1 \sin\omega t + U_2 \sin\omega t \cdot \sin\cdot t \text{ ,}$$

where: $U_1 = kU_0$ – voltage amplitude of commercial frequency, $U_2 = mU_0$ - voltage amplitude of combined frequency. For understanding the processes that take place in AM with voltage supply of represented form, it's necessary to obtain expressions that describe phase voltages separately.

Using the trigonometric identities and making the following transformations, we obtain the following expressions for each phase voltage of AM

$$U_A = U_1 sin\omega i + \frac{U_2}{2} cos(\omega - \Omega)t - \\ - \frac{U_2}{2} cos(\omega + \Omega)t$$

2

3 **F**

$$U_B = U_1 sin\left(\omega t - \tfrac{2\pi}{3}\right) U_2 sin\Omega i \cdot sin\left(\omega t - \tfrac{2\pi}{3}\right) = \\ + U_2 sin\Omega i \cdot sin\omega i \cdot cos\tfrac{2\pi}{3} - \\ U_2 sin\Omega i \cdot cos\tfrac{2\pi}{3}\omega t \cdot sin\tfrac{2\pi}{3} = \\ = U_1 sin\left(\omega t - \tfrac{2\pi}{3}\right) + \frac{U_2}{2} cos(\omega - \Omega)t \times \\ \times cos\tfrac{2\pi}{3} - \frac{U_2}{2} cos(\omega - \Omega)t \cdot cos\tfrac{2\pi}{3} - \\ - \frac{U_2}{2} sin(\omega + \Omega)t \cdot sin\tfrac{2\pi}{3} = \\ = U_1 sin(\omega i - \tfrac{2\pi}{3}) + \\ + \frac{U_2}{2} cos\left[(\omega - \Omega)t + \tfrac{2\pi}{3}\right] - \\ - \frac{U_2}{2} cos\left[(\omega + \Omega)t + \tfrac{2\pi}{3}\right]$$

$$U_c = U_1 sin\left(\omega i + \frac{2\pi}{3}\right) + U_2 sin\Omega i \times \\ \times sin\left(\omega i + \frac{2\pi}{3}\right) = U_1 sin\left(\omega i + \frac{2\pi}{3}\right) + \\ U_2 sin\Omega i \cdot sin\omega i \cdot cos\frac{2\pi}{3} + \\ + U_2 sin\Omega i \cdot cos\omega o \cdot sin\frac{2\pi}{3} = \\ U_1 sin\left(\omega i + \frac{2\pi}{3}\right)$$

Finally, the system is as follows

Expressions (2) show that there are three voltage systems, which rotate in different directions with different frequencies. Vector diagram (Fig. 1) provides a visual representation of the abovementioned operations.

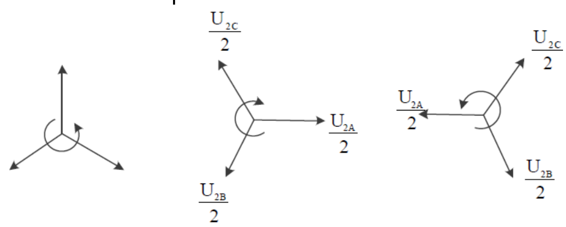


Figure 1. Vector diagram of voltage systems generated under load

In addition, to simplify calculations and statements inserts, operations are made with the

ISSN 2414-9055

hypothesis, that the rotor current system is not movable relative to voltage system of commercial frequency.

On the base of the above-mentioned hypothesis, we can conclude that in rotor circuit there are two current systems induced, which rotate in opposite directions with the same frequency Ωt. Consequently, the total rotor current vector is determined by two components system with amplitude $U_2/2$; Ψ - initial angle between the vectors and I_{p1} I_{p2}

For the convenience of further calculations, we assume that·$\Psi=\pi/2$. Let us calculate the total rotor current with angular frequency Ωt changing from 0 to 2π.

We calculate this according to the relation

$$Ip = \sqrt{\left(I_{p0}\sin\Omega t\right) + \left(I_{p0}\sin(\psi - \Omega t)\right)^2} -$$
$$\sqrt{2I_{p0}\sin\Omega t \cdot I_{p0}\sin(\psi - \Omega t)\cos\varphi}$$

where $\varphi = \psi + \Omega t$ - the angle between the vectors I_{P1} and I_{P2} taking in consideration defined Ωt.

white $\Omega t=\pi/6$

The result is

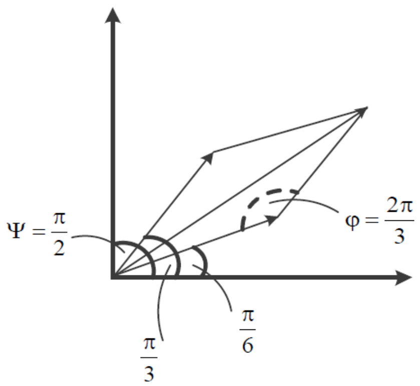


Figure 2. Vector diagram of the total rotor current

We calculate this according to the relation

The table (1) of calculation results of values of the total rotor current, rotating relative to the rotor with the most convenient calculation parameters Ωt can be presented below:

$$I_p = \sqrt{\left(\frac{\sqrt{3}}{2} I_{p0}\right)^2 + \left(\frac{1}{2} I_{p0}\right)^2} +$$
$$\sqrt{2 + \frac{\sqrt{3}}{2}\frac{1}{2} I_{p0} I_{p0}\frac{1}{2}} =$$
$$\sqrt{\frac{3}{4} I_{p0}^2 + \frac{1}{4} I_{p0}^2 + \frac{\sqrt{3}}{4} I_{p0}^2} =$$
$$= I_{p0}\sqrt{1 + \frac{\sqrt{3}}{4}} = 1{,}2\, I_{p0}$$

velocities $(\omega-\Omega)t$ and $(\omega+\Omega)t$ respectively; I_{p0} - amplitude of rotor current, induced by voltage

For exp : if $\Omega t = \pi/6$,

figure2), then $\psi - \Omega t = \pi/3$, white $\varphi = 2\pi/3$

we assume that □=□/2. Let us calculate the total rotor current with angular frequency Ωt changing from 0 to 2π.

system with amplitude $U_2/2$; Ψ - initial angle For the convenience of further calculations,

:

ISSN 2414-9055

Table 1

Ωt, rad	Ψ-Ωt, rad	sin		Ip1	Ip2	Ip	Other values Ωt, when current value is similar
		Ωt	Ψ-Ωt				
0	π/2	1	0	Ip0	0	Ip0	π, 3π/2, π/2
π/6	π/3	1/2	$\sqrt{3}/2$	$1/2 I_{p0}$	$\sqrt{3}/2\ I_{p0}$	$1{,}2 I_{p0}$	7π/6, 4π/3, π/3
π/4	π/4	$\sqrt{2}/2$	$\sqrt{2}/2$	$\sqrt{2}/2\ I_{p0}$	$\sqrt{2}/2\ I_{p0}$	$1{,}41 I_{p0}$	5π/4
π/3	π/6	$\sqrt{3}/2$	1/2	$\sqrt{3}/2\ I_{p0}$	$1{,}2 I_{p0}$	$1{,}2 I_{p0}$	
π/2	0	1	0	I_{p0}	0	I_{p0}	
3π/4	- π/4	$\sqrt{2}/2$	$-\sqrt{2}/2$	$\sqrt{2}/2\ I_{p0}$	$-\sqrt{2}/2\ I_{p0}$	0	7π/4
2π/3	-π/6	$\sqrt{3}/2$	-1/2	$\sqrt{3}/2\ I_{p0}$	$-1/2 I_{p0}$	$0{,}75 I_{p0}$	5π/6, 11π/6, 5π/3

In accordance with the mentioned rotor current vector, while Ωt changing in the calculations we build a diagram of changes of the interval [0; 2π], which takes the form of Figure 3.

a

b

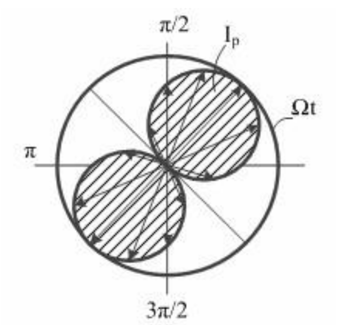


Figure 3. Load current forming diagrams

As it can be seen from the diagram (Fig. 3, a), the rotating amplitude of the rotor current vector has the form of eight, and "eight" fixed relative to the rotor, therefore, those coils (rods), which assume the maximum value of pulsating current, will be overloaded in reference to the others, and the coils (rods), which are located in the plane which is perpendicular to them, are not loaded by current I_p at all, and that could be proved by fig. 3(b), which shows that the winding B1-B4 is the most loaded, and winding B5-B13 is the least loaded.

Thus, there is a clear problem of uneven distribution of pulsating current. To solve this problem is possible, if the uniform "eight" rotation relative to the rotor is provided. For this, it's necessary to comply with the condition ω / Ω ≠ n, where n - integer.

According to [15], the economic loading mode of induction motors with pulsating current can be achieved while forming the power supply voltage by the law

$$U_n = U_0 \sin \omega t (k + m \cdot \sin \Omega t)$$

where: k, m are experiment coefficients, Ωt is the circuit change rate of the coefficient m.

In order to understand the processes occurring in induction motors in case of pulsating loading from the perspective of mechanical loading it is necessary to determine the analytical expression of the developing induction motor torque.

It is known, that while inducing the threephase system of currents changing according to the form of the applied voltage, the induction vectors created by the currents have a similar direction and form. The created magnetic flux is the vector density of the magnetic induction and is determined by the expression

$$\Phi = \int_s BdS$$

In accordance to the above mentioned it is fair to say that while changing the power supply voltage under the law

$U=U_1 \sin\omega t+U_2 \sin\omega t \sin t$ the flux induced is determined by:

$$\Phi=\Phi_1 \cos \omega t+\Phi_2 \cos \omega t \sin\Omega t$$

where Φ_1 is the rotating magnetic flux from the system of currents induced by the power-frequency voltage (the basic flux), Φ_2 is the rotating flux of the system of currents induced by the pulsating voltage ($U_2\sin\omega t$). Thus, it is clear that two fluxes are induced – the basic flux Φ_1 rotating with the constant speed and the flux Φ_2, the flux pulsating with the frequency Ωt.

As a result of crossing the rotor circuit by the magnetic flux Φ, EMF E_2 is induced and, consequently, the current occurs. The analytical expression of the current can be as follows:

$I_r = E_2/Z$, where Z is the full resistance of the rotor circuit. While $E_2 = C\dfrac{d\Phi}{dt}$, where C is the proportionality coefficient.

Thus, in order to find the rotor current form it is necessary to take the flux derivative with respect to time accepting the equation C=1 for computational convenience is necessary to take the flux derivative with respect to time accepting the equation C=1 for computational convenience.
proportionality coefficient.

Thus, in order to find the rotor current form it is necessary to take the flux derivative with respect to time accepting the equation C=1 for computational convenience.

$$\frac{d\Phi}{dt} = (\Phi_1 \cdot \cos\omega t + \Phi_2 \cdot \cos\omega t \cdot \sin\Omega t)` =$$
$$(\Phi_1 \cdot \cos\omega t)` + (\Phi_2 \cdot \cos\omega t \cdot \sin\Omega t)` =$$
$$= \Phi_1` \cos\omega t + \Phi_1 \cdot \cos`\omega t +$$
$$+ \Phi_2 \cdot \cos`\omega t \cdot \sin\Omega t + \Phi_2 \cdot \cos\omega t \cdot \sin\Omega t +$$
$$+ \Phi_2 \cdot \cos\omega t \cdot \sin`\Omega t = -\omega\Phi_1 \sin\omega t -$$
$$- \omega\Phi_2 \sin\omega t \cdot \sin\Omega t + \Omega\Phi_2 \cdot \cos\omega t \cdot \cdot \cos\Omega t =$$
$$= -\omega\Phi_1 \sin\omega t \left[\frac{\omega\Phi_2}{2}(\cos(\omega-\Omega)t - \cos(\omega+\Omega)t - \right.$$
$$\left. - \frac{\omega\Phi_2}{2}(\cos(\omega-\Omega)t + \cos(\omega+\Omega)t \right] =$$
$$= -\omega\Phi_1 \sin\omega t - \frac{\Omega\Phi_2}{2}(\cos(\omega-\Omega)t +$$
$$+ \frac{\Omega\Phi_2}{2}(\cos(\omega+\Omega)t = -\omega\Phi_1 \sin\omega t +$$
$$+ \frac{\Phi_2}{2}(\omega+\Omega)\cos(\omega+\Omega)t =$$
$$= \omega\Phi_1 \sin\omega t + \frac{\Phi_2}{2}[(\omega+\Omega)\cos(\omega+\Omega)t -$$
$$-(\omega-\Omega)\cos(\omega-\Omega)t] =$$
$$= \Phi_1^* \sin\omega t + \Phi_2^* \cos(\omega+\Omega)t + \Phi_3^* \cos(\omega-\Omega)t$$

Where,

$$\Phi_1^* = -\omega\Phi_1;\ \Phi_2^* = (\omega+\Omega)\frac{\Phi_2}{2}$$
$$\Phi_3^* = -(\omega-\Omega)\frac{\Phi_2}{2}.$$

Considering the above dependency $d\Phi$

$I_r = \dfrac{\frac{d\Phi}{dt}}{Z}$, we can write the expression to determine the rotor current form:

$$I_r = I_1 \sin\omega t + I_2 \cos(\omega+\Omega)t + I_3 \cos(\omega-\Omega)t$$

$Ir = \dfrac{\frac{d\Phi}{dt}}{Z}$, we can write the expression to determine the rotor current form:

$$I_r = I_1 \sin\omega t + I_2 \cos(\omega+\Omega)t + I_3 \cos(\omega-\Omega)t$$

If the flux and the rotor current expressions are evaluated, one can determine the developing induction motor torque using the equation

$$M = k\Phi \cdot I_r \cos\psi_2,$$

where Ψ_2 –is the angle between the vectors $\bar{I}_r$ and $\bar{E}_r$, k is the proportionality coefficient.

ISSN 2414-9055

As the parameters k and Ψ_2 are fixed, let us take $k \cdot cos\psi_2 = 1$ to avoid excessive complexity of calculations. In this case, the torque is etermined as follows:

$M=\Phi I_2 = (\Phi_1 \cdot cos\,\omega t + \Phi_2 \cdot cos\,\omega t \cdot sin\Omega t) =$
$(I_1 \cdot sin\,\omega t + I_2 \cdot cos(\omega+\Omega)t +$
$+ I_3\, cos(\omega-\Omega)t) =$
$= \Phi_1 \cdot I_1 \cdot cos\omega t\; sin\omega t +$
$+ \Phi_1 \cdot I_2 \cdot cos\omega t \cdot cos(\omega+\Omega)t +$
$\Phi_1 \cdot I_3 \cdot cos\omega t \cdot cos(\omega-\Omega)t +$
$+ \Phi_2 \cdot I_1 \cdot cos\omega t \cdot sin\omega t \cdot sin\;\omega t +$
$+ \Phi_2 \cdot I_2 \cdot cos\omega t \cdot sin\omega t\; cos(\omega+\Omega)t +$
$+ \Phi_2 \cdot I_3 \cdot cos\omega t \cdot sin\omega t\;\; cos(\omega-\Omega)t =$

$$M_{11}/2sin2\omega s + M_{12}/2cos2\Omega c +$$
$$M_{12}/2cos(2\omega+\Omega)t + M_{13}/2cos\Omega c +$$
$$M_{13}/2cos(2\omega-\Omega)t + M_{21}/2sin2\omega s \cdot sin\Omega i$$
$$M_{22}/2cos\omega c \cdot sin\Omega i +$$
$$M_{22}/2cos(2\omega+\Omega)t \cdot sin\Omega i +$$
$$M_{23}/2cos\Omega c \cdot sin\Omega i +$$
$$M_{23}/2 \cdot cos(2\omega-\Omega)t \cdot sin\Omega i +$$
$$M_{11}/2 \cdot sin \cdot 2\omega\omega + M_{12}/2 \cdot cos\Omega o +$$
$$M_{12}/2 \cdot cos(2+\Omega)t + M_{13}/2 \cdot cos\Omega o +$$
$$M_{13}/2 \cdot cos(2\omega-\Omega)t + M_{21}/4sin2(\omega+\Omega) +$$
$$M_{22}/4sin2\Omega t + M_{22}/4sin2\Omega$$
$$M_{23}/4 \cdot sin2(\Omega-\omega)t =$$
$$\frac{(M_{11}/2 - M_{22}/4 + M_{23}/4) \cdot sin\,2\omega t}{(M_{12}/2 - M_{13}/2) \cdot cos\,\Omega t}$$
$$\cdot \frac{(M_{22}/4 + M_{23}/4) \cdot sin\,2\Omega t}{(M_{12}/2 - M_{21}/4) \cdot cos(2\omega+\Omega)t} \cdot$$
$$\cdot \frac{(M_{13}/2 - M_{21}/4) \cdot cos(2\omega-\Omega)t}{(M_{22}/4\; sin\,2(\omega+\Omega)t} \cdot$$
$$\cdot \frac{1}{M_{23}/4) \cdot sin\,2(\Omega-\omega)t}$$

The obtained dependency indicates that the torque consists of seven components, the amplitudes of which depend on the parameters ω and Ω.

In order to make the essence of the mechanical loading simple let us consider the speed of the rotor rotation and that of the basic magnetic flux being equal, that is when ω=0.

On substituting ω=0 into the expression determining the torque, we obtain

$$M = (M_{12/2} + M_{13/2})\cos\Omega t + (M_{22/4} + M_{23/4}) \cdot$$
$$\cdot \sin 2\Omega t + (M_{12/2} + M_{21/4})\cos\Omega t +$$
$$+ (M_{13/2} + M_{21/4})\cos\Omega t + M_{22/4}\sin 2\Omega t +$$
$$+ M_{23/4}\sin 2\Omega t = (M_{12/2} + M_{13/2} + M_{12/2} -$$
$$- M_{21/4} + M_{13/2} + M_{21/4})\cos\Omega t +$$
$$+ (M_{22/4} + M_{23/4})\sin 2\Omega t =$$
$$(M_{12} + M_{13})\cos\Omega t + \left(\frac{M_{22} + M_{23}}{2}\right)\sin 2\Omega t$$

where the expressions $M_{12}=\Phi_1 I_2$; $M_{13}=\Phi_1 I_3$; $M_{22}=\Phi_2 I_2$; $M_{23}=\Phi_2 I_3$ indicate the interaction of the basic and the pulsating fluxes according to the pulsating rotor current.

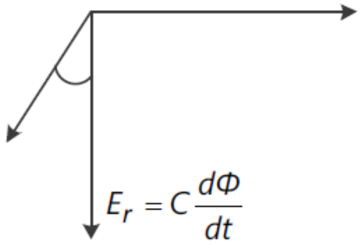
The correctness of the above calculations can be proven by obtaining the last expression in another way. Thus, if we initially accept the speeds of the rotor rotation and the basic flux as equal, the expression of the flux crossing the rotor circuit will be as follows

$$\Phi = \Phi_1 + \Phi_2 \sin\Omega t$$

Thus, the rotor current is determined as follows (C=1)

$$I_r = \frac{\frac{d\Phi}{dt}}{Z} = \frac{1}{Z}(\Phi_1 + \Phi_2 \sin\Omega t)` =$$
$$= \frac{1}{Z}(\Phi_1` + (\Phi_2 \sin\Omega t)`) = \frac{1}{Z}(\Phi_2 \sin`\Omega t + \Phi_2` \sin\Omega t) =$$
$$= \frac{1}{Z}\Phi_2 \sin`\Omega t = \frac{\Phi_2\Omega}{Z}\cos\Omega t = I_{2m}\cos\Omega t,$$

where: $I_{2m} = \frac{\Phi_2\Omega}{Z}$, which corresponds the equation $I_{2m} = I_2 + I_3$ if ω does not equals zero.



ISSN 2414-9055

Fig.4. Vector diagram of the developing torque calculation

The induction motor torque in this case is *(kcos* Ψ_2 *=1)*

$$M = \Phi I_r = (\Phi_1 + \Phi_2 \sin\Omega t) I_{2m} \cos\Omega t =$$
$$\Phi_1 I_{2m} + \cos\Omega t + \Phi_2 I_{2m} \sin\Omega t \cdot \cos\Omega t =$$
$$= M_1^* \cos\Omega t + \frac{M_2^*}{2} \sin\Omega t,$$

corresponding the equations $M_1^* = M_{12} + M_{23}$; $M_2^* = M_{22} + M_{23}$ while determining the torque by simplifying the expression for a general case.

The approximate form of the induction motor torque is shown in Fig. 5.

The approximate form of the induction motor torque is shown in Fig. 5.

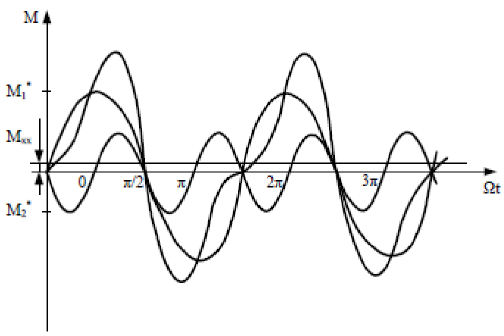


Fig. 5. Approximate form of induction motor torque during loading

Having analyzed the last expression, we can conclude that the interaction of the rotor current and the basic flux result in the alternating first harmonic torque, that is, the alternating capacity, while the interaction of the rotor current and the pulsating flux result in the alternating component of the basic frequency..

Conclusions and further investigation. The analysis allows to conclude that forming the power supply voltage in a certain way we can achieve both the current and the mechanical loading of the induction motor circuits, which can vary on a large scale. This method of loading an “accidental” motor can be applied to estimate the further efficiency of a motor. The development of loading devices for induction motors is valid for further investigation.

References:

1. Rodkin, D.I. (1992). *Sistemy dinamicheskogo nagruzheniya i diagnostiki elektrodvigateley pri posleremontnyh ispytaniyah [Systems of dynamic loading and diagnostics of electric motors in post-repair tests]*. Moscow: Nadra [in Russian]

2. Rodkin, D.I., & Maksymov, M.N., Alistratenko, Yu.V. (1991). Novoye pokoleniey system nagruzheniya i diagnostiki elektricheskih mashin [New generation systems of eclectic machines loading and diagnostics]. Proceedings from All-USSR scientific and practical seminar on ingeneering automation. (pp. 18-22). Kharkiv [in Russian]

3. Rodkin, D.I., & Maksymov, M.M., Kochkin, G.I. (1993). Published in AS SSSR №1815613 *Ustroistvo dlya upravleniya asinhronnym dvigatelem.[A divice to control an induction motor]* – №18 [in Russian]

4. Maksymov, M.M. (2013) Formuvannya parametrov pulsuyuchogo strumu v kolah korotkozamknenyh asinhronnyh dvyguniv [Formation of pulsating current parameters in squirrel-caged induction motors]. *Girnychiy visnyk DVNZ ‘KNU” – Mining Bulletin*

ISSN 2414-9055
of SIHE "Kryvyi Rih National University", Kryvyi Rih, 96, 176-178 [in Ukrainian]

5. Holdberg, O.D. (1968). *Kachestvo i nadezhnost asinhronnyh dvigateley [Quality and reliability of induction motors]*. Moscow: Energiya [in Russian]

5. Vol. 8), (114). Moscow: Informelektro [in Russian]

6. Soukup, C. G. **(**1988).*Determination of motor quality through routine electrical tests*. Ind. Appl. Soc. 35 The Annu. Petrol and Chemical Industry Conference, (pp. 187 – 195). Dallas [in English]

7. Stack, T.L. (1975) *The Repair and Maintenance of Rotating Electrical Machines*. Mining Technology, (Vol.57), № 662. (pp.460-470) [in English]

8. Sieradzka, M. (1972). *Badania esploatacygneg trwalosci silnicow indukaginich*. – Elektrotecknika. Buil. Inform., 1972, 26, № 2, (pp. 61-71) [in Polish]

9. Stavrou, A., & Sedding, H. G., Penman J. (2001) *Current monitoring for detecting inter-turn short circuits in induction motors.* IEEE Trans. Energy Convers., vol. 16, № 1, (pp. 32–37) [in English].

10. Zherve G.K. (1984). *Promyshelnnye ispytaniya elektricheskih mashin [Industrial tests of electrical machines]*. L.: Energoatomizdat [in Russian]

11. Klyueyv A.A. (1980). Avtomatizatsiya ispytaniy elektricheskih mashin sredney moshchnosti [Test automation of medium capacity electric machines]. *Elektrotehnicheskaya promyshlennost – Electrotechnical Industry, Series "Elektrotehnicheskiye mashiny" – Electrical machines.* (Vol. 8), (114). Moscow: Informelektro [in Russian]

12. Soukup, C. G. **(**1988).*Determination of motor quality through routine electrical tests*. Ind. Appl. Soc. 35 The Annu. Petrol and Chemical Industry Conference, (pp. 187 – 195). Dallas [in English]

13. Stack, T.L. (1975) *The Repair and Maintenance of Rotating Electrical Machines*. Mining Technology, (Vol.57), № 662. (pp.460-470) [in English]

14. Sieradzka, M. (1972). *Badania esploatacygneg trwalosci silnicow indukaginich*. – Elektrotecknika. Buil. Inform., 1972, 26, № 2, (pp. 61-71) [in Polish]

15. Stavrou, A., & Sedding, H. G., Penman J. (2001) *Current monitoring for detecting inter-turn short circuits in induction motors.* IEEE Trans. Energy Convers., vol. 16, № 1, (pp. 32–37) [in English].