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Колонка на главния редактор

Здравейте, уважаеми читателю,

С този брой се разделяме с 2020 г. и навлизаме в Новата 2021 г. с надеждата и оптимизма, че тя ще ни донесе обрат в много отношения. Изпращаме една календарна година, белязана с поредица социални, политически и икономически процеси, но всички доминирани от пандемията COVID-19. Навлизаме в годината с очакване за успешна ваксина и лекарство срещу COVID-19 и достигане на т. нар. „стаден“ имунитет, с което да се сложи край на тази пандемия. Дали това ще е последната криза или ни дебнат и други „неочаквани“ катаклизми от наводнения, миграции, земетресения, разпадаща се инфраструктура, икономическо неравенство, войни и климатични промени?

Европа е в най-дългия период на мир и просперитет от края на Римската империя, но вече е очевиден неуспехът ѝ да направи дълбоки системни промени след финансовия колапс от 2008 година и дали ще намери необходимия обединяващ модел за успешното справяне с COVID-19. Това би бил най-добрият сценарий, че след като бъде победен COVID-а ще сме в състояние да победим всяка следваща криза.

Изглежда азиатските държави реагираха на кризата по-адекватно и ефективно от Европа и САЩ. Дали 21 век не е азиатският век, както пита известния американски икономист Дейвид Голдман? Ако съдим с погледа на нашата собствена визия, то в сферата на научните публикации автори от Китай, Япония, Индия в почти всички области на науката, техниката и технологиите бележат огромен напредък не само в количествено, но и в качествено отношение.

Пандемията разкри слабите места на много неща от това, което преди се приемаше за даденост, особено когато стремежът за високо-ефективен бизнес игнорираше устойчивостта - основният принцип за работоспособността на всяка система.

Нека влезем в Новата година не само с надеждата за оцеляване, но и с оптимизма за един по-добър свят.

На всички Вас – **здраве и късмет!**

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Comparative analysis of modern methods for asynchronous motor control in automated electric drives

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***Abstract*— This paper presents a comparative analysis of modern methods for controlling a three-phase induction motor with a short-circuited cylindrical rotor. For this purpose, researches have been made on: frequency control according to the law U/f = const, loading with static moments depending on the speed of rotation of the rotor and vector control.**

***Keywords*— Matlab/Simulink, induction motor, frequency control, vector control.**

I. Introduction

It is known that one of the main consumers of electricity in the world are electric motors. About 70% of the total electricity consumed by them is in the industrial sector, and about 30% is the share of all other sectors. About 96% of the operating costs of an electric motor are due to the electricity consumed by it during operation, 2.5% are the costs of its purchase and 1.5% are the costs of its maintenance.

Nowadays, about 90% of the asynchronous motors used have a short-circuited rotor. Their advantages over other electromechanical converters of electricity are: simple construction, good possibility of overload, high operational reliability, low price and others. The disadvantages are mainly related to the complexity of their management. With asynchronous motors, direct control of torque and magnetic flux is impossible, as like DC motors.

As they are one of the main consumers of electricity in the world, more and more attention is focused on the creation and development of new management methods, characterized by high efficiency and lower electricity consumption [1, 2].

The methods for speed control of three-phase induction motors are:

1. Parametric - the speed regulation is mainly at the expense of changing the amplitude of the stator voltage at its constant frequency.

2. Frequencies - This control acts directly on the frequency and amplitude of the supply voltage. It is done through one of two laws:
I law - U / f = const
II law - U = const, f = var

3. Vector:
-Control on the vector of the main magnetic flux;
-Control of the rotor flux vector;
-Control of the stator flux vector;

4. By orientation of the magnetic field - when using spatial-vector modulation.

II. Research of a model of a three-phase induction motor

Figure 1 show a block diagram of a model of a three-phase asynchronous motor, realized by Simulink of MATLAB [2, 3, 4].

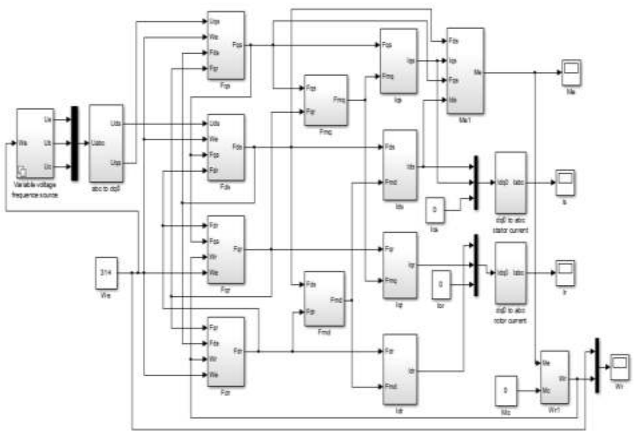

Fig. 1. Block diagram of a model of a three-phase asynchronous motor.

The researches of the synthesized model were performed with the parameters of a real engine presented in Table 1.

TABLE I.

P_n	I_n	U_n	J	M	n	Rs
KW	A	V	$Kg.m^2$	N.m	min^{-1}	Ω
1.5	3.7	220	0.00278	10.16	1410	5.585

Rr	p	L_{ls}	L_{lr}	L_m	L_s	L_r	T_r
Ω		H	H	H	H	H	s
4.22	2	0.0156	0.0129	0.291	0.304	0.3066	0.0726

To simulate the induction motor it is necessary to calculate the parameters involved in the model.

```
Rr=4.22;          %rotor resistance
Rs=5.585;         %stator resistance
Lls=0.0156;       %stator inductance
Llr=0.0129;       %rotor inductance
Lm=0.291;         %magnetizing inductance
fb=50;            %base frequency
p=2;              %number of poles
J=0.00278;        %moment of inertia
Lr=Llr+Lm;
Tr=Lr/Rr;
Wb=2*pi*fb;       %base speed
Xls=Wb*Lls;       %stator impedance
Xlr=Wb*Llr;       %rotor impedance
Xm=Wb*Lm;         %magnetizing impedance
```

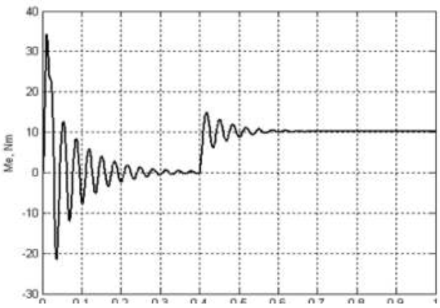

Fig. 2. Transient process of the electromagnetic moment.

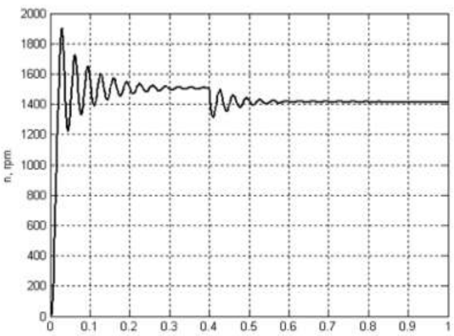

Fig. 3. Engine speed transient.

The peak value at the beginning of the simulation reflects the starting value of this quantity. After the completion of the transients, this value is set to a nominal value. The research found that the obtained values of torque and speed are as follows: M = 10.20 N.m, n = 1405 min^{-1}.

III. Research with the synthesized model of the induction motor in frequency control according to the law U / f = const

The voltages and their frequencies are set to 100% of their nominal values. After each new research, they are reduced by 10%. The results of the initial values are noted in tabular form and are presented in the form of graphs.

TABLE II.

%	100%	90%	80%	70%	60%
U, V	311	278	247	222	200
Is, A	5.38	5.49	5.59	5.51	5.51
ω, rad^{-1}	314	282.6	251.2	219.8	188.4
f, Hz	50	45	40	35	30
M, N.m	10.16	10.16	10.15	10.13	10.13
Mc, N.m	10.03	10.03	10.03	10.03	10.03
n, min^{-1}	1408	1350	1117	935	636

The graphical dependences of the torque, stator current and motor speed as a function of voltage and frequency are shown in the following figures:

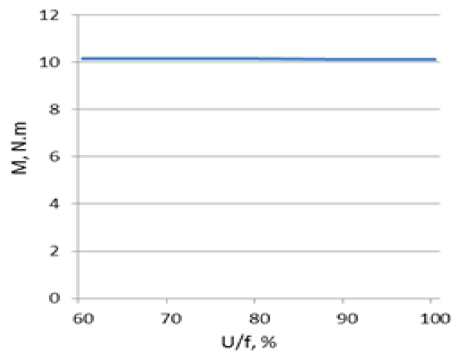

Fig. 4. Graphic dependence M=f(U/f).

The graphs show that with the proportional reduction of the voltage and the frequency of the supply voltage, the motor speed decreases and the torque remains constant.

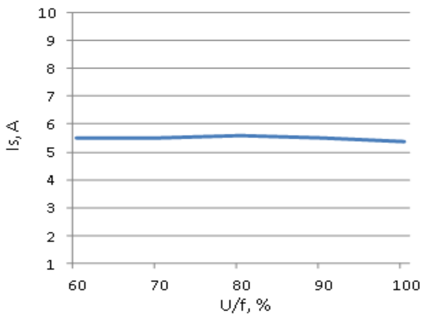

Fig. 5. Graphic dependence I_s=f(U/f).

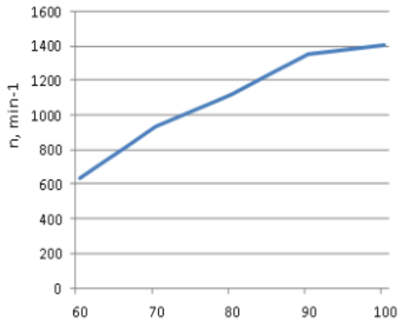

Fig. 6. Graphic dependence n=f(U/f).

IV. Research of the mechanical characteristics of the synthesized model of an induction motor.

The difference from the previous frequency research here is that a variable load is set and for each voltage and frequency ratio the mechanical control characteristics are removed.

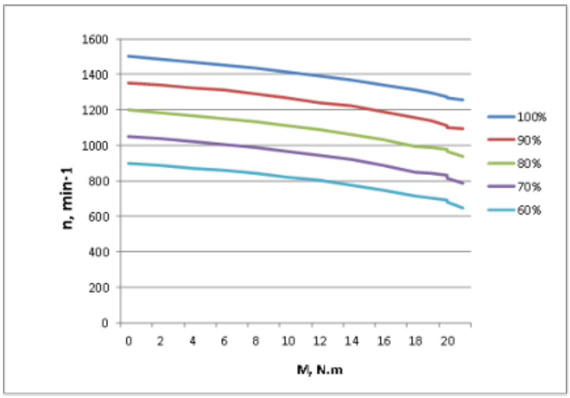

Fig. 7. Graphic dependence n = f(M) at different percentages of U/f=const.

V. Experimental research of motor type AO-901-4 at frequency control with capacity 1.5kW; frequency converter "Altivar" -ATV-12U15M2 of the company "Telemecanique" powered by 220V single-phase voltage.

Fig. 8. Photo of the realized scheme.

The characteristics of the research were removed (current consumption, voltage, speed) at different frequencies (12Hz, 25Hz, 50Hz and 60Hz) at idle and under load.

The idle values are shown in Table 3.

TABLE III

Ms[N.m]	0	0	0	0
f[Hz]	12	25	50	60
I [A]	0.29	0.48	0.50	0.33
U [V]	164	168	172	176
n [min^{-1}]	374	759	1 410	1 806

Table 4 shows the values of the characteristics of the revolutions as a function of Ms at network frequencies 12Hz, 25Hz, 50Hz and 60Hz.

TABLE IV

f[Hz]	12	25	50	60
0.0N.m	374	759	1 410	1 806
2.6N.m	384	772	1 524	1 826
5.0N.m	395	780	1 538	1 756
6.8N.m	396	784	1 548	1 736

Figure 9 presents the graphical dependences of the revolutions as a function of Ms at network frequencies 12Hz, 25Hz, 50Hz and 60Hz.

The motor current at the same load values and different values of the supply voltage frequency plays in very narrow limits.

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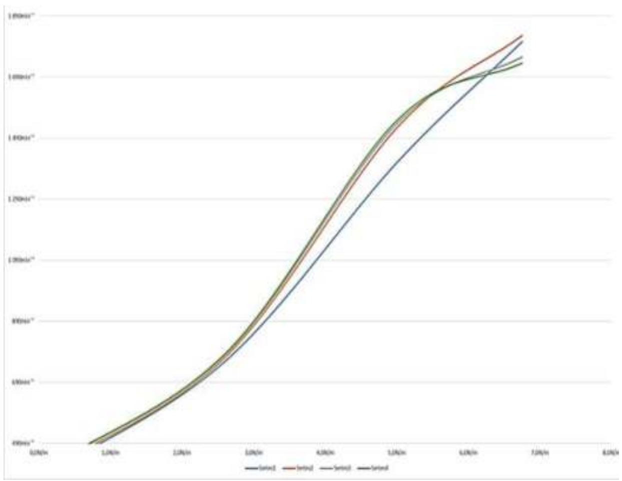

Fig. 9. Graphic dependence n= f(Ms).

VI. Research of the model of a three-phase asynchronous motor by vector control, realized in Simulink of MATLAB

When designing a vector control system, new units such as a pulse generator, a three-phase inverter unit and a vector control unit have been added to the three-phase induction motor model.

One of the most important advantages of vector control systems for asynchronous three-phase motors is the separate control of torque (speed) and magnetic flux. This is done by two separate PI regulators, which compensate for the difference between the actual and set values of magnetic flux and speed [5, 6, 7].

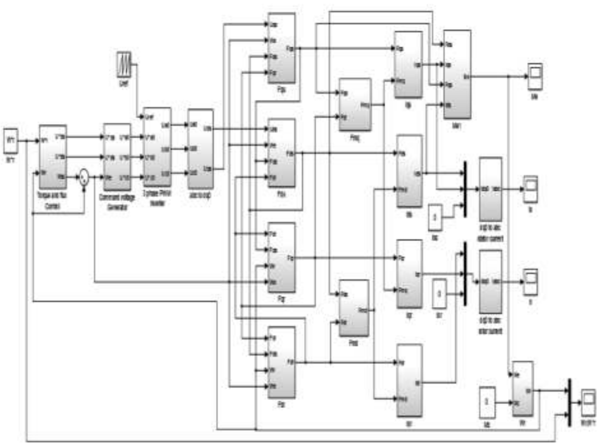

Fig. 10. Scheme of vector control of an induction motor.

The purpose of this research is to establish the dynamics of management of the designed system, as well as the times for the transients. To achieve this, the motor model is loaded with different static torques and a different rotor speed is set. As a result, stator current, voltage and set and actual rotor speed are tested.

At the beginning of the research, an angular velocity $\omega_r = 147{,}7\mathrm{rad}^{-1}$ is set, which after the fourth second changes to $\omega_r = 30\mathrm{rad}^{-1}$. A static moment (load) Ms=0,1N.m is set , which after the second second changes to Ms = 10 N.m. The results for voltage and current are presented in Figure 11.

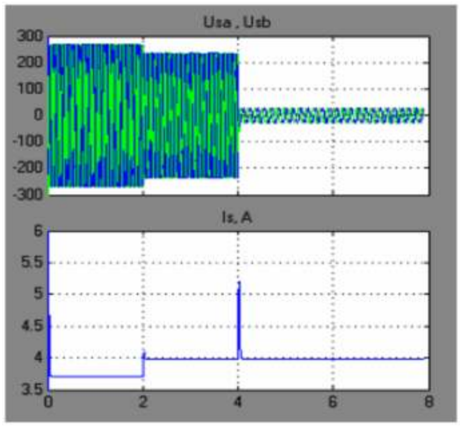

Fig.11. Graph of phase voltage and current.

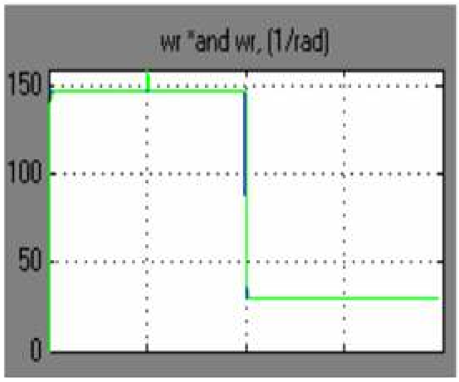

Fig.12. Graphical dependence of the set and actual rotor speed at different loads.

The induction motor settles much faster and the transients run more smoothly due to the vector control system.

The results obtained from the research show that at a small static moment the input voltages have a larger amplitude, and at an increase in the load the amplitude is smaller.

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Conclusions

1. In a comparative analysis of the results obtained from Fig.5 and Fig.11 it is found that in the frequency control of the induction motor model the stator current consumed is about 5.5A, and in the vector control is about 4A.

2. The use of vector control in the control of induction motors leads not only to increase the quality of control, but also to save a significant amount of electricity, which is of great importance in modern economic conditions.

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