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THE ADJUSTABLE ELECTRIC DRIVE FOR PRINTING PRESSES

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The essence of the original pulse-width voltage for the asynchronous electric drive is stated. It does not include certain higher harmonious compo-nents of the small order. Results of the harmonious analysis of this voltage which feeds windings of the engine had been investigated. Construction of individual model in the environment of MatLab–Simulink for this research that had been established and of the transients in the considered electric drive had been concluded. The model has no basic errors which are inherent in some regular Simulink blocks. Electromagnetic transitive processes in the engine and electro mechanic processes, established in the engine under the different loadings and final values of speed of the mechanism had been investigated. Results of the research confirm adequacy of realization of necessary processes of the electric drive. Advantages of offered pulse-width pressure for the windings of the asynchronous engine feeding have been shown. Research results will specify essential decrease in heating volume losses while start-up and braking processes.

Keywords: *printing presses, the adjustable parametrical asynchronous electric drive.*

Task. To evaluate the offered width-impulse voltage from the point of view of its use, for powering the asynchronous electric drive stator windings. To develop a model in Simulink environment for the study of the electric drive modes with asynchronous electric motors which are fed up by the mentioned above PWM voltage. To show the possibility of organizing start-up energy-saving mode and braking for the certain group of printing equipment.

Analysis of the recent researches and publications. Currently, due to the relatively simple power circuit of semiconductor converters of small weight and dimensional parameters, as well as the low cost of all regulated electric drive, parametric method of controlling an induction motor, implemented by it is in great demand. A lot of scientific and technical publications confirm conduction of the numerous developments in the field of theoretical studies as well as in the field of it industrial applications. In the industrial sector these converters are called the soft starter devices (soft starter) [1]. A significant disadvantage of this method is the presence in the voltage feeding the winding of the stator, the whole set of the higher harmonic components which substantially worsen the work of the asynchronous electric modes (e.g., torque, speed, power loss in the engine). In more detailed way the negative side of the phase voltage control method had been considered, for example, in [2, 3]

Purpose of the article is to acquaint with PWM voltage, in which high harmonic components of small order are absent, thus causing the significant effect when feeding windings of the induction motor influencing on its electromagnetic torque and speed. To show in Simulink environment the construction of the original model of induction motor with PWM control. To give the study results which will confirm the efficacy of the proposed PWM voltage as the control action while managing asynchronous short-circuit engine, also for providing the energy saving modes.

In these cases occurs the need in organization of the energy saving electric drive control, especially the start-up modes as the main processes in electric consumption.

Actual research material. A certain group of printing equipment that performs technological processes is equipped with the electromechanical system with the induction engine working in a start-stop mode, characterized by a large number of launches per hour. Examples of such machines are mechanisms of cover case feeders making machine, feeder in automatic mode of Guillotines and cutting machine, knife cutting machine of Schneider Company, which is activated every time by the motor pump drive, receiving and palletizing unit of printing presses, the mechanism of the knife-grinding machine carriage and so on. In these cases, there is the need to organize energy-efficient motor control, in particular start-up mode as the basic processes of power consumption.

Direct launch of the asynchrony electric drive is accompanied by the significant engine start current, causing it intensive heat and creating shock moments, which negatively influence on the state of the kinematic transmission, thus increasing backlash and gaps, causing low-quality products and additional adjustment works. The main methods of obtaining high-quality launch, regulating and braking properties of the controlled AC drive are the frequency and the parametric control methods. Frequency control method provides a high-quality regulation, various functional properties of induction drive. However, this is accompanied by the rather complicated control systems using smart semiconductor converters.

There are some restrictions for the parametric control method usage on the range of adjustment characteristics receiving, extension of which increases the overall power of the electric engine and, as a rule, to the capacity underutilization. But in the organization of dynamic processes (for example, start-up or braking) it is an alternative for the frequency control. Converters implementing parametric method are the semiconductor voltage regulators and carry out the phase method of the output voltage change.

Controlled start with the certain increasing intensity of the control influence (which supplies the engine windings voltage) enables to create a power-saving mode of the stop-start nature. Implementation of the phase method of by the voltage regulators can be performed using different laws, and you can see it using the information analysis of the Internet resource [1]. However, control of the output voltage of the voltage regulator can be performed not only in such a simple manner, but, for example, using various types of the pulse width modulation. The task of each of these variants includes the reduction of the higher harmonic components in the motor windings voltage supply. It enables to form a symmetrical three-phase system for both phase and for line voltages. Other methods do not provide a symmetrical three-phase system.

Let's consider proposed by the author variant of the tension formation at the each half -period of the impulses, the centres of which are on the distance π/m, where m = 3, 6, 9, 12 ... the whole number of impulses, the centre of the first pulse is at the point π / 2m from the half-cycle beginning and the position of the fronts of each pulse varies in both directions from the impulse centre. The number of impulses on each half-period of the three-phase voltage system is chosen from the correlation n = 2•m•k±1, where k = 1, 2, 3, 4, ..., and n is a number of the chosen harmonic, which must be present in the modulated voltage. Voltage diagrams at a given width and impulse formation are shown on the Fig. 1. Here U of the circuit is the voltage of the supply circuit, α – regulation angle, T1 - distance to the centre of the first impulse, Ti - the dis-tance between the impulses. If in harmonics are allowed the voltage numbers 5, 7, 11, 13 and so on., the number of impulses per half-period will be m = 3, and if the value will be - 11, 13, 23, 25, so m = 6. The investigated method of the pulse-duration modulation of the AC voltage suppresses certain harmonics that improves the harmonic composition of the supply voltage and thus improves energy indexes. It gives an opportunity to form a symmetrical three-phase system as for the phase so for the line voltages. Other methods do not enable to get a symmetrical three-phase system.

The angle α may be changed using any law: linear, proportionate, rectangular, sinusoidal, and so on. As the harmonic composition of the feeding the asynchrony voltage drive determines mechanical characteristics shape, and therefore its regulation properties and energy indexes, let's evaluate the offered method with the help of the mathematical analysis.

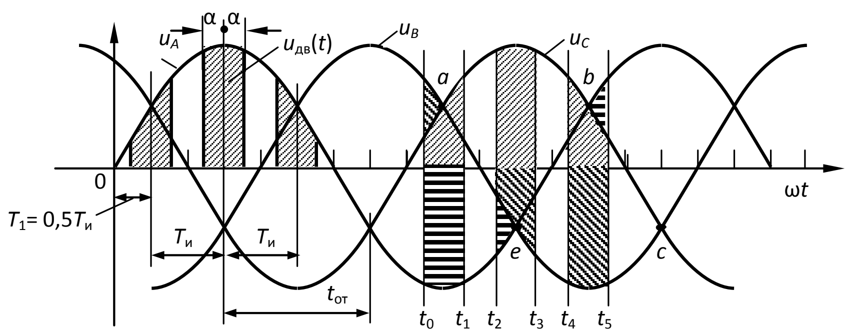

Fig. 1. Diagram of the simulated PDM voltage

Analyzed function (Fig. 1) is of a non-sinusoidal character; also it is uneven, periodic with the period 2π and is defined in this interval in the following manner:

$$f(\omega t) = \begin{bmatrix} 0; & \omega t \in \sum_{i=1}^{n} (A-\alpha);\ U\sum_{i=1}^{n} (A+\alpha;\ A-\alpha) \\ \sin\omega t; & \omega t \in \sum_{i=1}^{n} (A-\alpha;\ A+\alpha) \end{bmatrix}$$

where $A = \pi/(2m)\cdot n$, $n = m$, a n — is a number of uneven members of the natural numbers raw.

Because of its unevenness the investigated function while expansion in Fourier series will have coefficients a_0 and a_n equal to zero. Coefficients of the b_n type are functions reflecting the motor feeding voltage. They can be represented as follows:

$$U_k = \sum_{i=1}^{k} \int_{A-\alpha}^{A+\alpha} \sin \omega t \cdot \sin n \cdot \omega t =$$

$$= \sum_{i=1}^{k} \frac{1}{2} \left(\left. \frac{\sin(n-1) \cdot \omega t}{n-1} \right|_{A-\alpha}^{A+\alpha} - \left. \frac{\sin(n+1) \cdot \omega t}{n+1} \right|_{A-\alpha}^{A+\alpha} \right)$$

where k — is a number of harmonics meaning of which is being investigated.

Specific numerical harmonic analysis of the investigated PWM voltage for m = 3, 6, 9, was performed using a software package such as Mathcad. On the Fig. 2 are shown the results of the performed harmonic analysis, which shows changes in values of the first and ten first higher harmonic components with the different number of impulses in the half cycle of the output voltage, namely for m = 3, 6 and 9 and in the table are summarized the notes thereto.

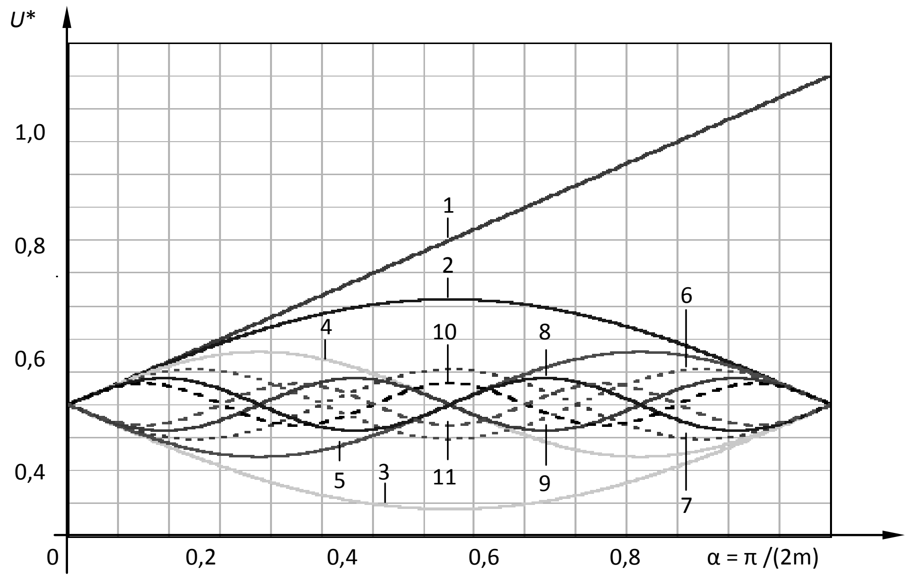

Fig. 2. Dependence of the harmonic components voltage amplitude from the control angle α

$U^* = U_i/U_{ном}$ – is a relative amplitude of the i harmonics;

m – number of voltage impulses on its half-period;

1 – first harmonics amplitude at any m

Table

Results of the harmonics analysis

Curve number	2	3	4	5	6	7	8	9	10	11
Impulses number	Higher harmonic component number									
$m = 3$	5	7	11	13	17	19	23	25	29	31
$m = 6$	11	13	25	23	35	37	49	47	59	61
$m = 9$	19	17	35	37	55	53	71	73	91	89

Analysis of the results leads to the conclusion that:

– The amplitude of the first harmonic component of the supply voltage (energy) as a function of the angle of the control voltage regulator is linear (dependence 1);
– Linearity of correlation 1 does not depend on the number of voltage impulses, of which it is formed by the proposed method, while the classical phase control leads to non-linear over-dependence;
– Changes in the amplitudes of the higher harmonic components are of oscillatory character;
– There are fixed control angles at which the amplitude of the different higher harmonic components is equal to zero, that should be used when speed control;
– Amplitude of higher harmonic components voltage is unchanged for the serial number of the sequence regardless of the number of voltage pulses.

Testing of the proposed electric drive PWM control was carried out on the mathematical model in the computing environment Mathlab (Simulink). The functioning of the electric drive system is described by differential equa-tions, which describe modes of induction motor theory of generalized machine [4, p. 18–24]. The scientific literature was confirmed that at non-sinusoidal and asymmetric voltage feeding the stator windings of the asynchronous motor is the most efficient modes of representation of its equations written in a fixed coordinate system α-β. The developed model is shown in Fig. 3.

It is universal. Due to it we can investigate the established and transient processes of the asynchrony motor during it launch, during the classic phase control and PWM control. The model is a set of subsystems that perform the respective functions of the investigated object. While work-out were used as the present for the Simulink environment logical blocks, and original, programmable on it base. Also the attention should be paid on the use of the regular block Asynchronous Machine, which are the manipulated inputs (A, B, C) and the reference input of the static moment of resistance acting on the shaft of the induction motor (T_m).

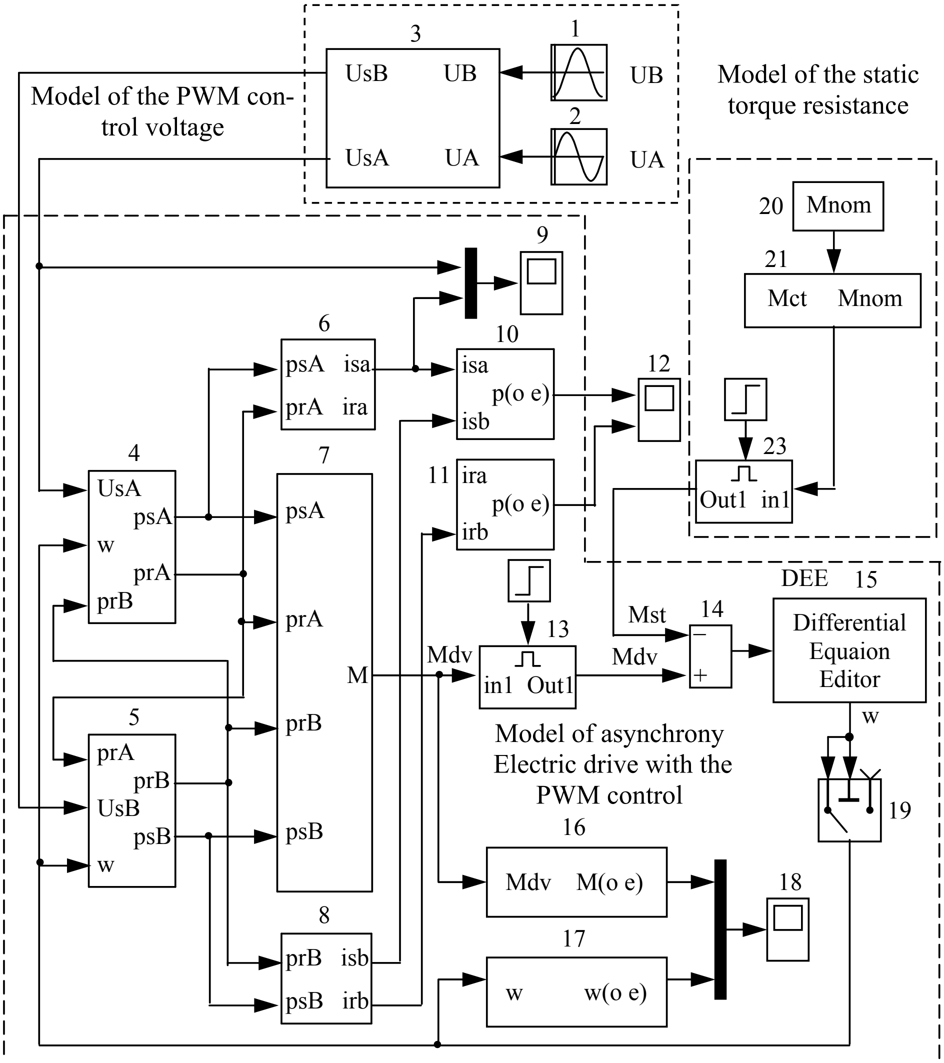

Fig. 3. Model of the asynchrony electric drive with the PWM voltage

In the windows of the task parameters of the block is not set the defini-tion of the nature of the time occurrence of the static resistance mechanism. It is known to be active or reactive. Programmed in block equation of motion is solved formally. In the procedure for solving equations Asynchronous Machine block is not provided analysis of the electromagnetic torque of the engine when it reaches the moment of static resistance, after which the actuator must be set in motion, which then is accompanied by the decision of the motion equations.

It is known that the physical state of the actuator shown in Simulink models is not performed and it confirms the output estimation of the ωrn coordinate of this block (speed diagram). Prior to the above mentioned point speed it is negative, what is unrealistic for machines with the reluctance torque static resistance and should not be the case for machines with active torque static resistance according to the logics of the mechanisms motion. Because of this incorrectness in the developed simulation model of asynchronous machine the task was completed by the way of solving differential equations which describe the behavior of the engine based on the theory of generalized machine. Thus, the model represents a combination of both models: before the movement (the solving of electromagnetic processes in the engine) and after (solving of electromechanical processes in the electric drive).

In the model the realization of the technological equipment cycle by the electric drive is performed by addressing the control signal to carry out tasks in the subsystem Signal Builder (block 3). Thus the desired character of the angle change of the control voltage corresponding to the cycle is formed (see chart). For the voltage regulators the main interest is the initial part of the desired chart, i.e the increase of the supply voltage (electric launch). Fig. 4 shows variations of this voltage during start-up. The first correlation (line 1) is technically the most easily implemented, and it is a linear variation of the angle during the launch time $t_{пуск}$. The second correlation (line 2) creates the possibility of organizing the forced development of the electromagnetic engine torque $t_{форс2}$ due to the rapid increase in the supply voltage on the windings of the motor to a value equal to the time of the idling actuator for the quick start of its movement. The temporary and weight coordinate of the point B, from which begins a linear change in angle during the time period tпуск, is determined during the process of the model adjustment and its action is set at block 15 (Step). Similarly, we should act during the adjustment of the real electric drive with a voltage regulator. The third correlation (line 3) organizes the rapid development of the electromagnetic torque of the engine due to the supply of the rated voltage at the time of $t_{форс1}$ with the same purpose as in the previous case.

Temporary and weight coordinates of the point A are also determined when setting up of the model, or drive. The specific interest lays in the expo-nential dependence of the steering angle (line 4). Complicated control under the actuator launching corresponds to the dependence 5. The essence of it is that during the boost voltage electromagnetic torque reaches a value is equal to the static moment, and then it is given some time to «calm down», and then a ramp angle of the control voltage is created.

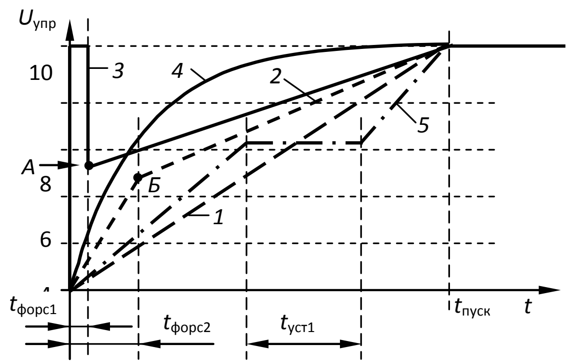

Fig. 4. Desired diagrams of the feeding voltage control angle changes

To make the model generalized the M-file was introduced, where are noted the input data used in the model. As an example, we shall investigate work of the electric drive mechanism, which demands a soft start with a mo-ment of idling to the required technological speed, impingement of the nominal load control, braking. The engine power, resulting in the movement mechanism is $P_{ном}$ = 2.2 kW. To review the nature of the drive is a priority study of power losses in the transition process, the behavior of the electromagnetic torque of the engine, its speed. Here are the results of calculation of the technological cycle of the drive with the traditional phase control and the management of the PWM voltage. Other conditions that characterize the electric drive and control laws for both cases are the same, and, namely, the time change of the supply of the motor winding voltage is $t_{упр\ пуск}$ = 5, changing the angle of the control voltage — linear from α_{max} to α_{min}, time idling M* xx = 0,2M* nom, total reduced moment of inertia of the actuator is $J_{\Sigma пр}$ = 1,2 $J_{дв}$.

Fig. 5 shows diagrams of the total heating power losses Δp^*, of the electromagnetic torque M^* and the speed of the engine ω* during the phase control.

Fig. 6 shows diagrams of the total heating power losses Δp^*, of the electromagnetic torque M^* and the speed of the engine ω* during the PWM control.

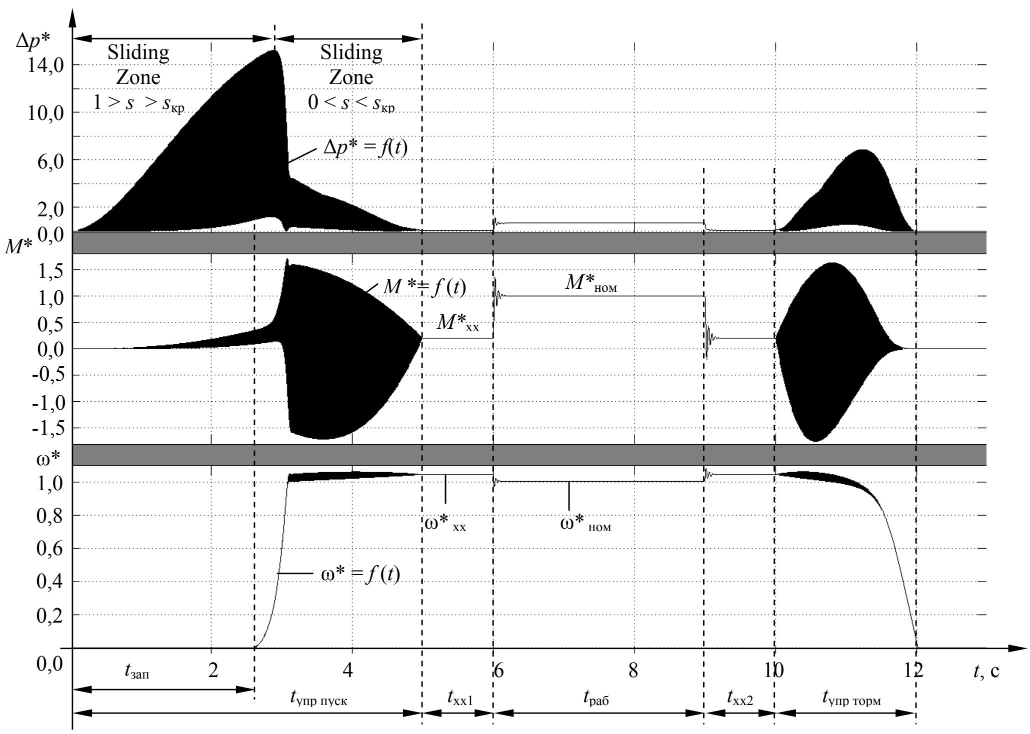

Fig. 4. Diagrams of the power losses $\Delta p^* = f(t)$, electromagnetic engine torque $M^* = f(t)$ And its angle speed $\omega^* = f(t)$ while the phase control (*soft starter*)

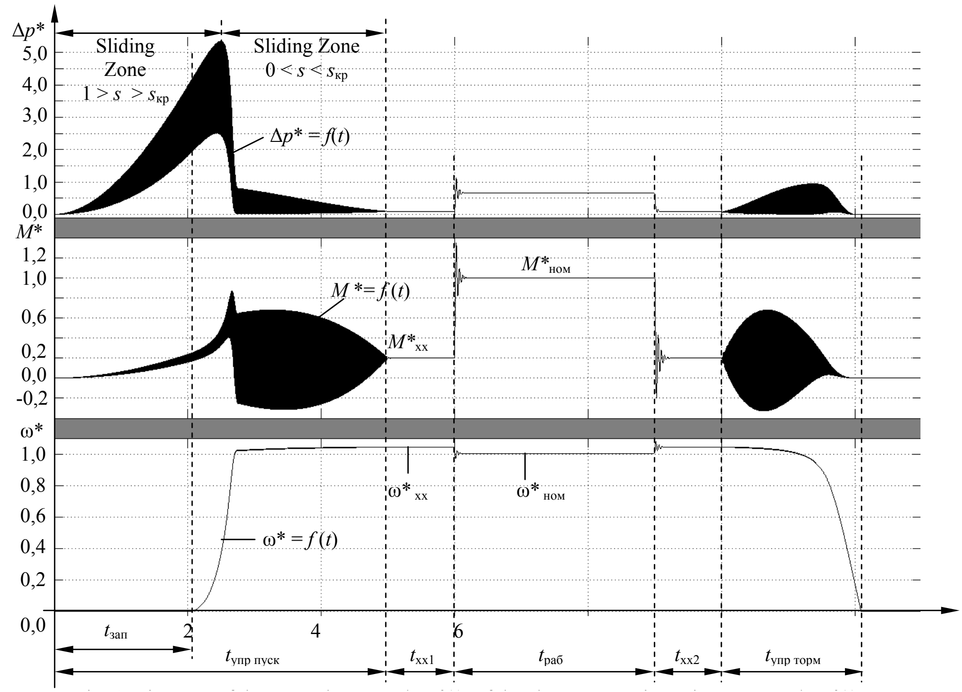

Fig. 4. Diagrams of the power losses $\Delta p^* = f(t)$, of the electromagnetic engine torque $M^* = f(t)$ and its angle speed $\omega^* = f(t)$ while PWM control

Conclusions. The developed model adequately reflects the electromagnetic and electromechanical processes in real-electric drive, it does not have these inaccuracies of Simulink blocks.

The results show a clear advantage of the use of PWM control, reflected in the fact that while start-up heat tracing power loss during the phase control $\Delta p^* = 15{,}78\Delta p$ are almost two times higher than the losses $\Delta p^* = 6{,}89\Delta p$ when PWM voltage. The electromagnetic torque developed by the engine during the rise (launch) and decrease (braking) of voltage while the control phase is of alternating character with the significant amplitudes, especially in the area of negative values. This leads to appreciable speed fluctuations in the sliding zone $0 < s < s_{кр}$ when the characteristic point of the electric drive moves along the stable part of the mechanical characteristics, ie. in the zone of high velocity, which is not observed while PWM control. These high torque and speed fluctuations negatively affect the work of the kinematic mechanism sections, eventually increasing the clearances and gaps in them.

It is advisable to apply the proposed pulse width modulated voltage to the volt-age regulators (soft starters) not only for the induction motor, but also for other electrical consumers, such as lighting.

Because of the universality of the asynchronous electric model it is recommended to use it as during the design of electromechanical systems, as well as during their operation.

For the study of electromechanical systems with elastic connections, which are often used in printing equipment, you must finalize the proposed model.

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РЕГУЛЬОВАНИЙ ЕЛЕКТРОПРИВОД ДЛЯ ПОЛІГРАФІЧНИХ МАШИН

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Викладено суть оригінальної широко-імпульсної напруги для асинхронного електроприводу. Вона не має у своєму складі деяких вищих гармонійних складових малого порядку. Дано результати гармонійного аналізу цієї напруги, що живить обмотку статора двигуна. Приведено побудову індивідуальної моделі в середовищі MatLab-Simulink для дослідження процесів, що встановилися і перехідних, в даному електроприводі. Модель не має принципових помилок, які властиві деяким штатним блокам Simulink. На моделі досліджуються електромагнітні перехідні процеси в двигуні і електромеханічні процеси, що встановилися, в електроприводі при разных навантаженнях і кінцевих значеннях швидкості ме-ханізму. Результати дослідження підтверджують адекватність реалізації необхідних процесів електроприводу. Показано перевагу пропонованої широко-імпульсної напруги для живлення обмоток асинхронного двигуна. Результати дослідження вказують на істотне зниження гріючих втрат потужності в процесах пуску і гальмування.

Ключові слова: *поліграфічні машини, регульований параметричний асинхронний електропривод.*

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