DYNAMIC INDEXES OF DOUBLE-WAY FEED MACHINE AT DIFFERENT FREQUENCY SUPPLY

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The features of a double-way feed machine performance in the operation of periodic reverse at different frequency supply are considered. A comparative valuation of the system's transient indexes and an electric machine parameters and the load for asynchronous and synchronous operating regimes has been carried out.

The double-way feed machine (DFM) oriented oscillating electric drives' synthesis, the choice of a rational control structure and its options providing maximal operating speed and the pre-set coordinate accuracy are not possible without the estimation of transient processes taking place within the system. Even in the mode of sustained oscillations the actuating motor performs a peculiar periodic reverse operation which is equivalent of a quasi-stationary process. At the start, perturbation actions control, stop and reclose there appear additional transients in the electrical machine, which, together with periodic steady-state values, form complex magneto-electric and electromechanical couplings.

One of the most efficient instruments to investigate the transients in electrical machines at the periodic motion is the use of numerical differentiation, the availabilities of interesting to us results expanding essentially when considering both linear and nonlinear mathematical models of actuating motors. The numerical methods of computation allow attaining the minimum of hypothesis and getting the maximal adequacy to real processes taking place in electromechanical energy converters [1].

For the DFM oscillatory operation conditions the numerical differentiation is reasonable to be carried out according to differential system of equations recorded for flux linkage within the intrinsic frame of reference supplemented with algebraic equations for line currents, and the calculation data are to be considered in terms of the corresponding graphic charts determining the dependence of the electrical machine features, loading and feed elements effect on the oscillating system's dynamic characteristics.

At different frequency supply the regulating functions for the stator and rotor motor windings can be written as

$$U_{\alpha s}(t) = U_m \cdot \alpha_1 \sin(\omega_1 t + \alpha); \quad U_{\beta s}(t) = U_m \cdot \alpha_2 \sin(\omega_2 t + \beta);$$

$$U_{dr}(t) = U_m \cdot \alpha_3 \sin(\omega_1 t + \alpha); \quad U_{qr}(t) = U_m \cdot \alpha_4 \sin(\omega_2 t + \beta),$$

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where α_i – are the coefficients of signals; α, β, ω_1, ω_2 – starting phases and voltage frequencies across the motor windings; $i = 1, 2, 3, 4$. If only the inertial load component is considered, then at different frequency feed the transient current characteristics $I = f(t)$ (1) of the moments $M_{эм} = f(t)$ (2), speeds $\omega = f(t)$ (3), and also the motors' moving elements' joint coordinate $\chi = f(t)$ (4) at starting into the DFM mode ($\alpha_1 = \alpha_2 = 1$; $\alpha_3 = \alpha_4 \neq 0$) or into the mode of an asynchronous motor (AM) ($\alpha_1 = \alpha_2 = 1$; $\alpha_3 = \alpha_4 = 0$) will have a quality format represented in the picture 1.

As it is seen, the starting sequence is attended by the surge currents (I_s) and torques (M_t) emergence, that is actually typical of all synchronous and asynchronous unidirectional motion machines. However, for the DFM oscillatory operation conditions the transient is primarily of oscillation nature, the quality of which depends on the actuating motor type. In the current curves the amplitude modulation with the motor oscillation frequency $\Omega = \omega_1 - \omega_2$, and in the moment-speed curves – vibrations and surging, are observed.

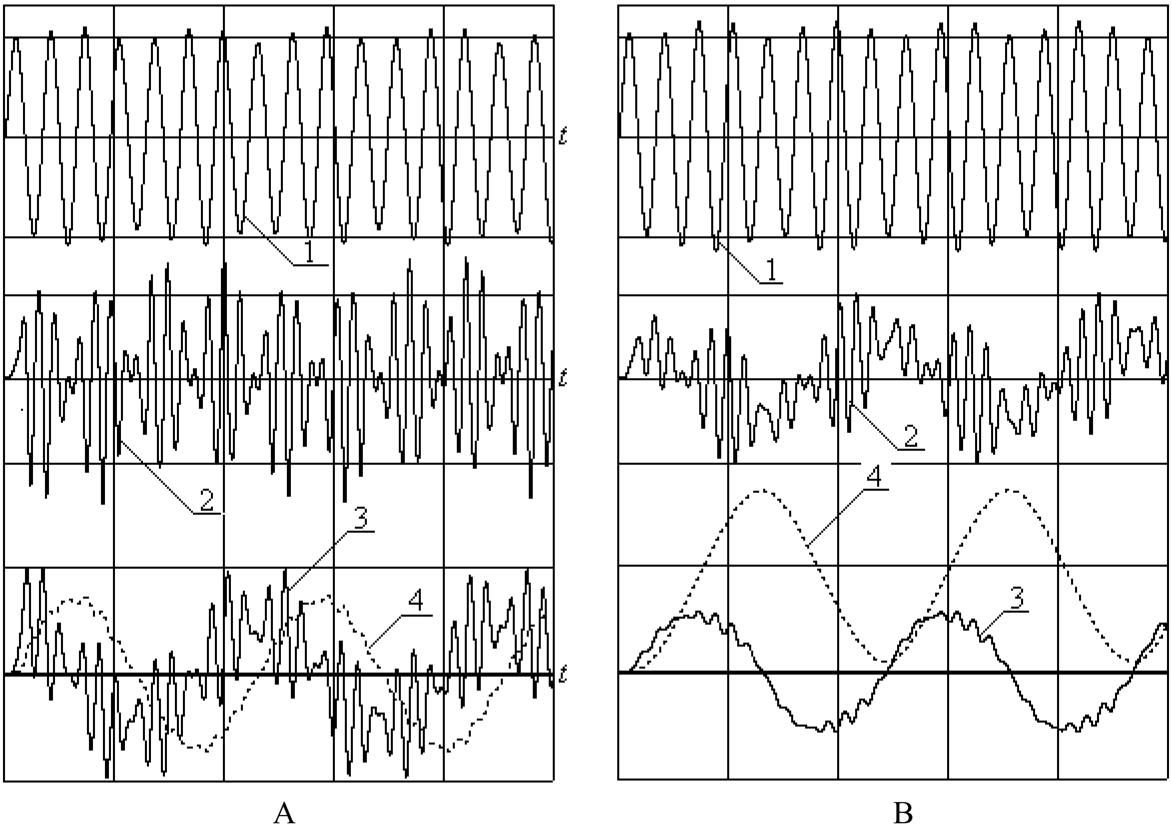


Figure 1. Time dependences of currents, torques, speed and coordinate in the DFM a) and AM; b) modes.

The fact that the motor moving element's steady-state coordinate value has a geometric displacement of the oscillation neutral point at the electrical machine operating in the mode of asynchronous motor ($\alpha_3 = \alpha_4 = 0$), while the displacement in the DFM mode is lacking, comes under notice. This fact is explained by the positional component presence in the oscillation electromagnetic DFM torque caused by the flux linkage resultant vector modulation on the move of the motor moving element [2].

It is evident that at research investigations the emphasis is made on the predetermined dynamic behavior oscillating system synthesis taking into account the parameters of the electrical machine used. As varied parameters it is recommended to choose relative values of the armature stator (R_s) and rotor (R_r) resistances, leakage inductance of stator $L_{\sigma s}$ and rotor $L_{\sigma r}$ coils and mutual inductance M.

As it is seen from the investigation the surge current I_s value behavior graphs are characterized by linear or almost linear dependences (nonlinearity doesn't exceed 10%) at stator and rotor leakage inductances change within the limits of 25%. At that the values of impact torques M_s can low for the AM mode by 30%, and for the DFM one – by 40%. Comparing the stator and rotor coils leakage inductance parameters effects on the electromechanical transients' characteristics, the identity of the last ones should be noticed once more, but still pointed at a greater efficiency of the $L_{\sigma r}$ influence from the position of the I_s and M_t values widest variation range achieving.

A brand new look the transient characteristics acquire at mutual induction coefficient M changes. So, the impact torques values increase with the coefficient M increase. However, the AM and DFM modes M_t value increase is comparable. In its turn, the mutual flux increase affects the electromagnetic field empowerment on the secondary motor element, and it leads to the surge currents value decrease.

Another important index of electromechanical energy converters operating in special modes is the response time τ_r. At different frequency supply of the actuating motor it is hardly ever changes and the dependences $\tau_r = f(L_{\sigma s})$; $\tau_n = f(L_{\sigma r})$ bear almost linear character throughout the whole parameters variation range.

The armature stator and rotor resistances prove themselves quite opposite. Thus, with the R_s decrease the electromagnetic processes decay time increase is observed, that, in its turn, influences greatly on the period of electromechanical transients. This affirmation is related, in the first instance, to the DFM, for which a more obvious inductive reactance effect predominance is indicative at the R_s decrease.

As an illustration of the point, the transient quality indexes' quantitative assessment for the boundary and nominal values of the varied parameters is represented in Table 1.

The research testified that at comparable M_t values of the asynchronous motor and double-way feed machine, the last has a double excess of the steady-state torque amplitude value. The given affirmation is true for all the cases considered earlier and is typical when comparing the machines with a squirrel-cage induction and phase-wound rotor motor.

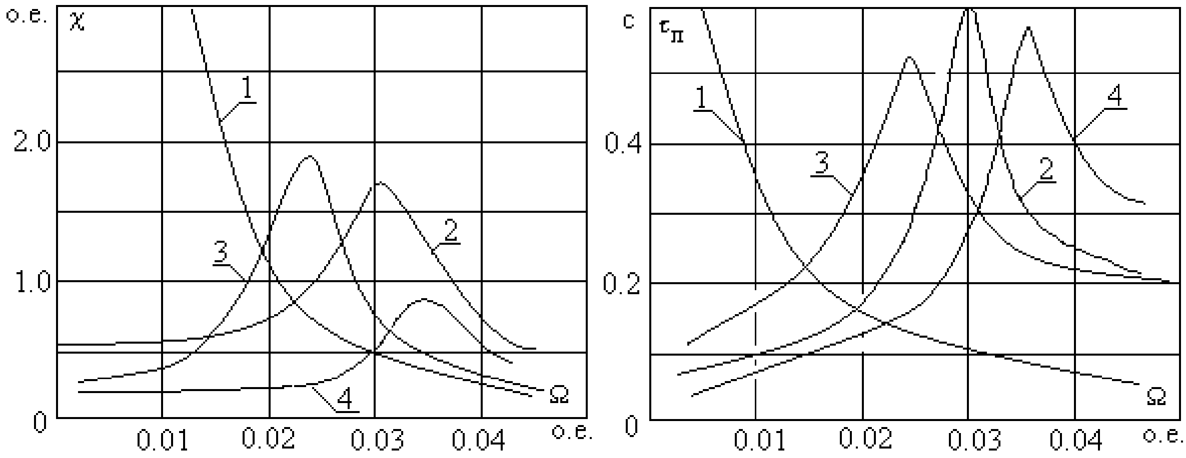
Table 1. The transient quality indexes' quantitative assessment for the boundary and nominal values of the varied parameters is represented

Transient quality indexes		R_s, o.e.			R_r, o.e.		
		0,03	0,06	0,09	0,047	0,094	1,141
AM	I_s, o.e.	2,2	2,0	1,83	2,27	2,0	1,86
	M_s, o.e.	0,23	0,6	0,5	0,5	0,48	0,646
	τ_n, c	0,1	0,1	0,1	0,1	0,1	0,1
DFM	I_s, o.e.	1,26	1,16	1,03	1,3	1,16	1,06
	M_t, o.e.	0,675	0,516	0,5	0,533	0,566	0,61
	τ_n, c	0,55	0,5	0,41	0,55	0,5	0,41

Allowing for the DFM air-gap irregularity the $\tau_n=f(L_{\sigma s}, L_{\sigma r})$ function's linearity distortion is observed. The more the design parameter deviation from its nominal value is, the more significantly the response time τ_n increases, and, in a range of cases, the oscillatory motion electric motor can loose its transient stability. The last manifests itself as the oscillation law breaking, and particularly, realization of rotation-vibration or stepwise operation, or the electric motor output shaft rotation with Ω creep speed. The own mutual inductance modulation doesn't influence significantly the other transient quality indexes (I_s, M_t), however, an error caused by engineering designs can reach in some cases 30%.

For a series of oscillation electric drives the oscillating system dynamics evaluation is of special value at the load parameters variation. In general, the complex load coefficient $Z_{mech}(\Omega)$ is frequency-dependent, it predetermining the general form of amplitude-frequency responses of the motors operating in the DFM and AM modes (Fig. 1) and, thus, the drive's transient indexes. Even moderate positional load implementation C_{mech}^{-1} leads to the AFR change and also surge current and moment values relative to the characteristics represented in the Fig. 1.

At $C_{mech}^{-1} \neq 0$ near the electromechanical resonance a sharp increase of both response time and impact torque amplitude is observed.



A B

Figure 2. Amplitude-frequency responses a) and response time b) for the AM (1,2) and DFM (3,4) modes at $C_{mech}^{-1} = 0$ (1, 3); $C_{mech}^{-1} \neq 0$ (2,4).

When analyzing the transient performance in below- or above-resonance areas, the positional load, as well as inertial one L_{mech}, doesn't have any significant influence on the behavior of the dependences $I_{surge} = f(C_{mech}^{-1}, L_{mech})$, $M_{surge} = f(C_{mech}^{-1}, L_{mech})$, $\tau_n = f(C_{mech}^{-1}, L_{mech})$. However, it should be noted that the rotating masses increase fairly affects the DFM moving element generalized speed format quality. At the L_{mech} increase the carrying high frequency fluctuations and the impacts in the speed performance curve are essentially smoothed, that is attained by means of the response time double increase.

A significant influence on the transient indexes of periodic motion machines is made by the damped load R_{mech}. Though its amount doesn't specify the electromechanical resonance condition, but influences the oscillating complex general factor of quality, actively affecting the oscillating electromagnetic torque sinusoidal components amplitude. The R_{mech} increase essentially decreases the response time and, in case of working in the asynchronous operation, regulates the oscillation neutral deviation, the oscillation amplitude decreasing and the impact torque increasing. The comparative quantitative assessment of the load parameters influence on the transient indexes of oscillation machines are represented in Table 2.

Table 2. The comparative quantitative assessment of the load parameters influence on the transient indexes of oscillation machines are represented

Transient quality indexes		L_{mech}, o.e.		C_{mech}^{-1}, o.e.		R_{mech}, o.e.	
		0,6	1,4	0,6	1,4	0,6	1,4
AM	I_s, o.e.	1,88	2,0	2,0	2,0	2,0	2,0
	M_t, o.e.	0,59	0,629	0,627	0,64	0,61	0,61
	τ_n, o.e.	0,14	0,2	0,25	0,52	0,14	0,12
DFM	I_s, o.e.	1,15	1,12	1,02	1,12	1,12	1,12
	M_t, o.e.	0,56	0,58	0,5	0,42	0,54	0,64
	τ_n, o.e.	0,28	0,56	0,25	0,12	0,7	0,3

The payroll results analysis testifies that, exclusive of the response time, the transient indexes of electrical machines when operating in the DFM mode are notably higher than asynchronous operating regimes ($\alpha_3 = \alpha_4 = 0$). However, this very index in a DFM can be considerably improved as well due to the positional load implementation.

References

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