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PRACTICAL RECOMMENDATIONS ON LIMITATION OF UNSTABLE MODES OF LIFT THYRISTOR ELECTRIC DRIVES

ПРАКТИЧЕСКИЕ РЕКОМЕНДАЦИИ ПО ОГРАНИЧЕНИЮ НЕУСТОЙЧИВЫХ РЕЖИМОВ ЛИФТОВЫХ ТИРИСТОРНЫХ ЭЛЕКТРОПРИВОДОВ

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Abstract. *The paper considers the problem of transition of an open-loop electromechanical thyristor lift system to an unstable mode characterized by fluctuations in the output coordinates and approaching the emergency mode in its manifestations. The types of unstable modes, their nature and factors of occurrence are described. Methods and technical means are presented that allow limiting self-oscillations or completely preventing them.*

Key words: *passenger lift, thyristor electric drive, auto oscillations, unstable modes, thyristor voltage converter, induction motor*

Анатація. *У роботі розглянута проблема переходу розімкнутої електромеханічної тиристорної ліфтової системи в нестійкий режим, що характеризується коливаннями вихідних координат і за своїми проявами наближається до аварійного. Описуються види нестійких режимів, їх характер і фактори виникнення. Приводяться методи і технічні засоби, які дозволяють обмежувати автоколивання, або повністю їх запобігати.*

Ключові слова: *пасажирський ліфт, тиристорний електропривод, автоколивання, нестійкі режими, тиристорний перетворювач напруги, асинхронний двигун*

Introduction.

In a number of operating modes, determined by the coincidence of parameters, in open-circuit asynchronous electric drives (ED) based on thyristor voltage converters (TVC), unstable modes occur, which are characterized by oscillations of output coordinates, by their manifestations approaching to emergency modes [1]. Fluctuations disturb the normal operation of the mechanism, complicate the calculation and adjustment of closed-loop systems, deteriorate the quality of coordinate control and energy performance. This mode is accompanied by large shock loads, noise and vibrations, and it should be classified as close to emergency

[2].

Main text.

Practical research of operating modes of the lift mechanism with two-speed asynchronous motor (AM) ACC 92-6/24 at power supply from TVC, also revealed the possibility of occurrence of such modes. At start-up of an empty car of the lift according to the triangular diagram formed in the open-circuit system of the ED with the TVC at supply from the source with reduced voltage U = 0,85U_n, the transition to the mode of undamped harmonic oscillations of output parameters was fixed (fig. 1.).

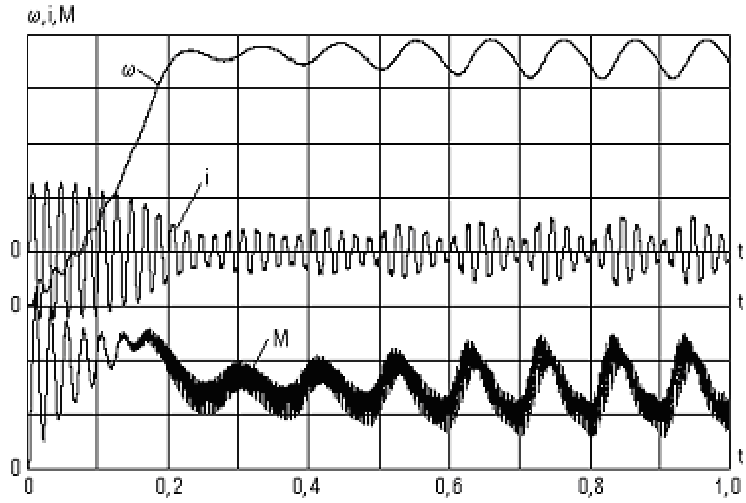

Figure 1. Oscillogram of start-up and small oscillation mode

The speed of AM and the hoisting mechanism at such auto oscillations can vary within the first quadrant or can exceed the synchronous one, and the oscillation area can cover the first and second quadrants [3]. Physically, such auto oscillations are associated with energy exchange between electromagnetic circuits and inertial flywheel masses of the lifting mechanism, and their presence is determined by the internal features of the thyristor converter [4]. The nature and quantitative indicators of such oscillatory process are quite diverse. Unstable modes of operation arise most often in the working sections of artificial characteristics of the ED, in dynamic modes at loads much less than nominal and at small moments of inertia of the lifting mechanism (no load) [5].

The behavior of the open-circuit thyristor drive system in the start-up mode when approaching the synchronous speed and in the overshoot region is indicative. If the parameters of the lifting mechanism, motor and start-up conditions create preconditions for speed overshooting, the current phase increases when approaching the sub synchronous speed, and the converter output voltage increases due to the action of the internal feedback of the TVC [6]. At speeds above synchronous speed, when the current phase becomes greater than 90 el. deg, the process is accompanied by almost complete opening of the valves, regardless of the set switching angle. Due to electromagnetic inertia, the motor continues to remain in the motor mode at speeds above synchronous speed, which contributes to the amplification of the overshooting process. As a result, overshoot always develops in the TVC as at nominal voltage, even if an artificial mechanical characteristic with a voltage lower than the nominal voltage is set. An open-circuit thyristor drive system can enter the oscillation mode with speed overshoot up to 40% and dips up to $0.5\omega_0$. The oscillation period includes the process of sharp braking by one or several torque pulses to some minimum speed and subsequent acceleration [7]. This process is far from harmonic in character and its investigation is possible only by mathematical modelling or experimentally. To study the nature of oscillations of thyristor electric drives, the obligatory conditions for mathematical description are to take into account nonlinearities of AM parameters and elastic oscillation processes of the lifting mechanism elements [8]. What methods and technical means can limit oscillations or completely prevent their occurrence?

1). At smooth start-up by trapezoidal optimum diagrams for a given time, the oscillations of output coordinates, in all considered cases, do not pass into the characteristic mode of auto-oscillations. At the end of start-up, the tap changers are fully opened, and there can no longer be oscillations in principle [9]. In all cases this given time of acceleration according to trapezoidal diagrams is sufficient for absence of transition to unstable mode in the considered lift systems with the speed of cabin lifting 0.7 and 1 m/s. At the same time we considered the ascent (descent) with arbitrary loading of the cabin.

2) At essential change (reduction) of supply voltage (more than 15-20%), operation of the electric drive should not be allowed. In all investigated cases, at a significant decrease in supply voltage the transition of lift ED into the mode of ‘large’

oscillations was recorded.

3). Limitation of elastic oscillations of elements of the lift mechanism multi-mass system reduces the probability of thyristor electric drive transition to the auto oscillation mode [10].

4). When using closed-loop ED systems (limitation of inrush currents, speed control, power optimization through power factor stabilization, etc.), the development of oscillatory modes is completely limited due to the action of feedbacks [11].

5). The transition to a fundamentally different method of synchronization of valves - with the load current - makes it possible to completely avoid the occurrence of unstable modes of the open-circuit ED system. In the synchronization units of the pulse-phase control system based on this principle, the thyristor control signal is synchronised with the end of the AM stator current in the half-period preceding the control signal, and instead of the signal controlling the angle value a, the control of the dead-time pause duration g is used (Fig. 2) [12]. When the magnitude of the control voltage coincides with the ‘saw tooth’ voltage, a thyristor control current pulse I_u is formed in the output stage. The connection between the control angles of the two considered methods of synchronization - classical synchronization with mains voltage α and load current γ is carried out through the lag angle of the current termination δ with the help of expressions $\alpha = \delta + \gamma$ or $\gamma = \alpha - \delta$. Accordingly, in a system with synchronization with load current, the mode $\gamma = 0$ means equality $\alpha = \delta$ at any value of the load angle φ, and the case $\alpha < \delta$ is fundamentally absent, and a single short control pulse with a certain width is applied to the thyristors. The limits of the control range of the dead time angle γ do not dependent on the load angle φ and therefore at any value of the load angle $\gamma_{min} = 0$, and $\gamma_{max} = \alpha_{max} - \delta$. The range of variation of the dead band angle is smaller than that of the control angle and is $0 \leq \gamma \leq$ 60 el. deg. This method needs new circuitry solutions to be implemented, but provides the drive with many new positive properties.

The main ones, in this case, are: the value of the initial voltage of the tap changer is less dependent on the phase of the load current and has an inverse or negative character, in contrast to a system with synchronization with the mains voltage. In such a system, the internal phase current feedback acts as a stabilizing feedback. For example, during load pickup, the tap changer voltage increases as the current phase decreases, while during resetting, on the contrary, it decreases. In such systems oscillations cannot occur in principle, which is confirmed experimentally.

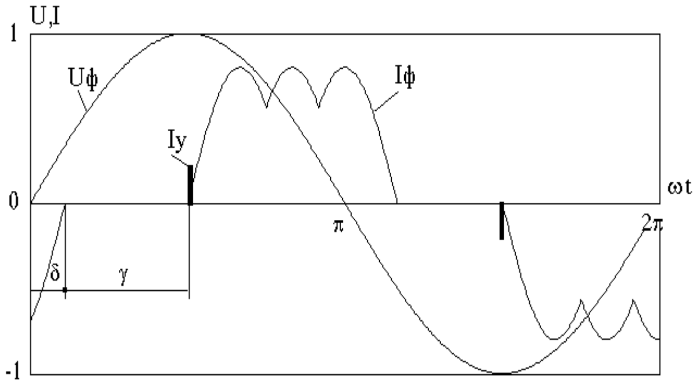

Figure 2. Time diagrams of currents, voltages and synchronous pulses when synchronized with the load current

Conclusions.

1. In a number of operating modes of passenger lifts, in open-circuit thyristor electric drives there are unstable modes, which are characterized by oscillations of output coordinates, by their manifestations approaching to emergency. Fluctuations disturb the normal operation of lifting mechanisms, complicate the calculation and adjustment of closed lift electric drives, deteriorate the quality of coordinates control and energy performance of lifts.

2. The type and the very presence of unstable operation modes completely depend on the parameters of induction motors, lifting mechanisms and initial electromagnetic conditions.

3. Practical recommendations for limiting and eliminating the occurrence of oscillations in lift thyristor electric drives are given, including an innovative method of synchronization of thyristor converter valves.

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