# Investigation of the methods of starting and braking in the "Frequency converter asynchronous motor" system

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**Abstract.** Various start-up methods depending on the power of the asynchronous motors, the nature of the load: direct, autotransformer start-up, star-to-Triangle sharpening of the spark plugs, launches using reactor, thyristor modifiers are taxied. The start-up current generates oscillation in the supply network, lowering the electrical energy quality, which negatively affects the electrical consumers being supplied from that network, especially at launch moment sensing values, frequent start-ups and reverses. The asynchronous motor with a short-circuited rotor has proven itself well as a driving link of various mechanisms due to its simple design, high reliability, and ease of maintenance. One of the disadvantages of BP is the high consumption of reactive power, especially at the moments of reducing the mechanical load on the shaft, which is typical for many actuators under the conditions of the technological process.

## 1 Introduction

Other disadvantages of BP include high starting current, significant electrodynamic forces acting on the active parts of the electric motor, mechanical shocks in the mechanisms due to significant fluctuations in the starting electromagnetic torque, which lead to a decrease in the service life of both the engine itself and the drive mechanism. Inrush currents cause voltage fluctuations in the supply network, reduce the quality of electrical energy, which negatively affects all electrical receivers powered by this network, this is especially noticeable with significant starting moments, frequent starts and reversals. The required value of the starting torque of the short-circuited rotor is determined by the moment of starting the actuator. In the vast majority of cases, the actuators do not have a high value of the moment of starting. An electric drive based on an if – short-circuited rotor with the use of a frequency-controlled short-circuited rotor provides a high level of energy saving. According to their structure and the resulting energy saving effect, if – short-circuited rotor systems can differ significantly depending on which control principle is embedded in their control systems [1, 2].

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## 2 Materials and methods

It becomes possible to limit the starting currents of BP to a level of 2-3 of the nominal by using soft-start devices (SCP). In the case of a high starting torque of the actuator, a high starting torque is required. In this case, in order to avoid overestimating the rated power of the BP and limit the peak current in the supply network, it is possible to use forced start devices. Depending on the power of the electric motor, the nature of the load, there are various ways to start an short-circuited rotor with a short-circuited rotor: direct start, autotransformer start, start by switching windings from a star to a triangle, reactor start, start using a thyristor voltage converter, start using a frequency converter, capacitor start. Let's consider the features of each launch method. So, the simplest way to start the short-circuited rotor is a direct start, when the stator winding is connected directly to the mains, to the rated voltage of the stator winding.

However, the direct start of the short-circuited rotor has a significant drawback, which manifests itself in the occurrence of a current surge in the network powering the electric motor. It is known that in serial engines, during direct start, a current exceeding the nominal value by 4-7 times occurs, while the power factor cosφ remains small (0.2 – 0.4), and the active power consumed exceeds the rated power of the electric motor by 1.5 – 2 times. A large inrush current can cause a significant voltage drop, as a result of which other electric motors powered by this network may stop [3, 4].

It must be remembered that limiting the current by the reactor causes a sharp (squared) decrease in the moment of BP. Therefore, the reactor start-up method can be used in cases where, with the required current limitation, the necessary excess of the starting torque of the short-circuited rotor over the moment of straining of the mechanism is observed. Starting through the reactor is recommended for electric drives of mechanisms in which the starting mode is carried out at idle, for example, adjustable pitch screws, wing thrusters. In practice, as a rule, during reactor start-up. In the Department of Automation and Control of the Navoi Mining and Technological University, a study was conducted on the methods of starting and braking in the system “Frequency converter - asynchronous motor” in the Somove program. The layout of the stand is shown in (Figure 1).

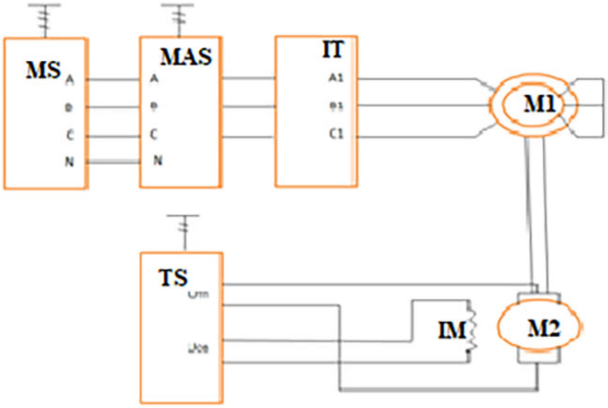

**Fig. 1.** The scheme of the stand for removing the characteristics of the frequency converter – asynchronous motor (if- short-circuited rotor) system. MS – magnetic starter; PM – power meter; FC – frequency converter; M1, M2 – electric motors; TC – thyristor converter; EW – excitation winding. Linear start consists in accelerating the electric drive to a set speed, with an increase in the frequency of the voltage on the stator, depending on the time set in the if settings [5, 6, 7].

# 3 Results

The DC motor is connected to the thyristor converter module (TC). The armature winding is connected to the outputs of the armature converter of the TC module, the excitation winding is connected to the outputs of an unregulated voltage source = 220V of the TC module. The asynchronous electric motor is connected to an IF frequency converter, which, in turn, is powered by a voltage of 3X380 V from the power supply module. Current and voltage sensors from the power module are connected to the stator circuits of the asynchronous motor. The sensor outputs of the power module are connected to the inputs Linear start consists in accelerating the electric drive to a set speed, with an increase in the frequency of the voltage on the stator, depending on the time set in the if settings 1, Linear start consists in accelerating the electric drive to a set speed, with an increase in the frequency of the voltage on the stator, depending on the time set in the IF settings 2, and short-circuited rotor 3, respectively, of the input/output module. The stator windings of the asynchronous motor are connected to the outputs of the frequency converter. The frequency converter is connected via a power meter to a three-phase mains voltage. A short-circuited rotor motor connected to a thyristor converter (TC) acts as a loading machine: the armature winding is connected to the outputs of the regulated voltage ($U_{tc}$), and the excitation winding is connected to the outputs of the unregulated voltage of the Sov.Impulse voltage is one of the qualitative indicators of electricity, which is characterized by a sudden jump in the volt-ampere properties of the network. Investigation of the ways of starting in the if- short-circuited rotor system. The short-circuited rotor electric drive, made on the basis of an inverter-type frequency converter, has the ability to perform several ways of starting braking an electric motor:

- linear start of the electric motor with a set rate;
- start of the electric drive on the S-ramp;
- starting the engine on the U-ramp.

To study the linear start of the electric drive, it is necessary: Select menu 1 “IF menu”, select submenu 1.7 “Applied functions" in it, select a group of parameters” “Setpoint” in it, configure the following parameters: $r_{pt}$ - type of acceleration and deceleration curves AT - acceleration time;-set the maximum engine speed with the TC potentiometer of the if module; set the acceleration time at the level of 5 seconds; perform a transient start-up process with the if direction switch (SA2). The electric motor will accelerate at a set pace to a set speed. The overclocking process is controlled using an oscilloscope software. Similarly, to carry out studies of other types of the acceleration curve of the electric drive, to change the shape of the acceleration curve in menu 1 “IF Menu”, select submenu 1.7 “Applied functions”, select a group of parameters “Setpoint” in it, configure the following parameters: $r_{pt}$ - type of acceleration and braking curves (S and U, respectively). Each of the modes is explored with two different constant acceleration times.Investigation of braking methods in the IF-BP system. Ramp braking is implemented in a similar way to ramp start, in addition, the frequency converter provides several methods of braking: run-out braking; dynamic braking. In run-out braking mode, when the braking command is received, the inverter turns off and the engine stops running. To set the braking mode of the electric motor on the run-out, select menu 1 “IF menu”, select submenu 1.7 “Application functions” in it, select the group of parameters “Stop configuration” in it, configure the following parameters: Stt is the braking method (nSt is the run-out). Perform a transient braking process with the if direction switch ($SA_2$).The braking process is controlled using an oscilloscope software. Currently, short-circuited asynchronous electric motors are mainly used on existing mining equipment and transport systems, the starting currents of which are 4-7 times higher than the nominal ones These currents create additional voltage losses in the line, as a result, the operating mode of other motors changes. In addition, starting powerful asynchronous motors with a short-circuited rotor can make the operation of the load node unstable. Starting under low voltage due to a decrease in the torque of the engine increases the acceleration time of the working machine, which leads to overheating of the windings [8, 9, 10].

As you know, the power of electric motors of mining transport systems (MTS) is different. The voltage of the electric motors is determined taking into account the stability of the load node to which the electric motor is connected [11, 12, 13, 14, 15]. The stability of the load node is determined using the critical voltage (1):

$$U_{kp} = U_n \sqrt{\frac{M_d}{M_k}} \tag{1}$$

where $M_d$ is the permissible value of the engine torque, below which there is a danger of exiting stable operation and stopping the working machine; $M_k$ is the maximum torque of the motor at rated voltage.

We accept $M_d = \sqrt{1.25 M_k}$ with a margin of stability, then the critical voltage is in relative units (2):

$$u_{kp} = \frac{U_{kp}}{U_n} = \sqrt{1.25 b_n} \tag{2}$$

where $b_n$ is the multiplicity of the maximum torque at rated voltage Since the value of the critical voltage must be compared with the value of the voltage that is obtained when starting the most powerful engine, consider starting the engine on the crusher drive. Stability will be ensured if the condition is met (3)

$$u_p \succ u_{kp} \tag{3}$$

where up is the voltage in relative values at the terminals of the previously switched-on motors. When determining the voltage from the rated voltage of the power supply line, the coefficient of comparability of the starting engine is determined by the formula (4):

$$u_p = k_u - 2\Delta u(1 - p_n)/1 - \Delta u(k_i p_p - 1 - p_p) \tag{4}$$

The formula (3) allows you to determine the voltage depending on the calculated voltage losses and the coefficient of commensurability of the starting engine. In addition, the expression (4) can be used to determine the line voltage losses from the condition that the voltage at the start of the most powerful engine will not be less than the value necessary for starting. The calculated voltage losses Δu are determined by (5):

$$u = k_u - 0.8/1 + (0.8k_i - 1)p_p \tag{5}$$

Using the formula (4), it is possible to calculate voltage losses taking into account a decrease in the starting current, the voltage on the substation tires and the coefficient of commensurability of the starting engine [16, 17, 18, 19, 20]. Perform a transient braking process with the IF direction switch (SA2). The braking process is controlled using an oscilloscope software. Repeat the experiment for another DC level. The results of the experiment are shown in Table 1.

**Table 1**. The braking process is controlled using an oscilloscope software. Repeat the experiment for another DC level.

| **Calculated voltage losses $\Delta u$** | **Voltage at the motor terminals $u_1$** | | | |
|---|---|---|---|---|
| | **$u_1$ (by $P_p$ = 0,1)** | **$u_1$ (by $P_p$ = 0,4)** | **$u_1$ (by $P_p$= 0,6)** | **$u_1$ (by $P_p$ = 0,8)** |
| 0.02 | 0.96 | 0.9 | 0.87 | 0.85 |
| 0.04 | 0.92 | 0.82 | 0.77 | 0.75 |
| 0.06 | 0.89 | 0.75 | 0.69 | 0.66 |

| | | | | |
|---|---|---|---|---|
| 0.08 | 0.85 | 0.7 | 0.62 | 0.6 |
| 0.1 | 0.83 | 0.65 | 0.57 | 0.54 |
| 0.12 | 0.8 | 0.6 | 0.52 | 0.5 |
| 0.14 | 0.77 | 0.57 | 0.48 | 0.46 |
| 0.16 | 0.75 | 0.53 | 0.45 | 0.43 |
| 0.18 | 0.73 | 0.5 | 0.42 | 0.4 |
| 0.2 | 0.7 | 0.48 | 0.4 | 0.37 |

Dependence of the voltage at the motor terminals from the calculated voltage loss (Figure 2).

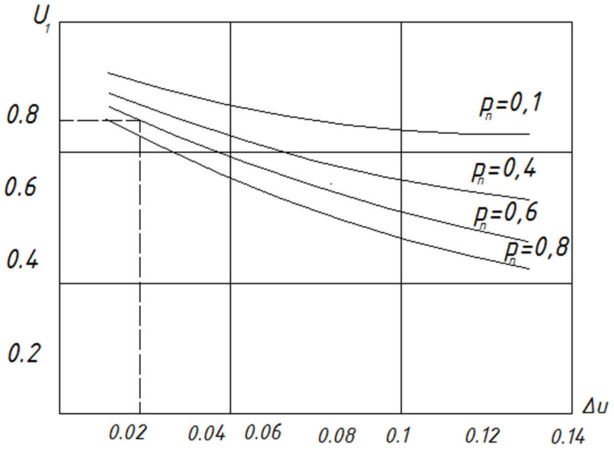

**Fig. 2.** Dependence of the voltage at the motor terminals from the calculated voltage loss.

## 4 Conclusion

In this work, the following starting methods were analyzed and modelled: direct start, start using a frequency converter, start using a capacitor in an auxiliary phase circuit, start via an autotransformer and start by switching from a star to a triangle. When starting the AD, the basic requirements should be met as far as possible: the start-up process should be carried out without complex starting devices, the starting torque should be large enough, and the starting currents should be as small as possible. Sometimes other requirements are added to these requirements, due to the characteristics of specific drives in which engines are used - this is the need for a smooth start and maximum starting torque. The resulting graph allows us to determine the voltage at the terminals of the mining complex engines having different power commensurability coefficients that ensure their stable operation.

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