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Experimental studies of soft start synchronous motors of longitudinal-transversal excitation

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ABSTRACT: The article presents the results of an experimental study of the process of soft start of a synchronous motor of longitudinal-transverse excitation. The negative aspects of direct starting of synchronous motors are listed. To reduce the negative impact of the direct start process, the task of the need to reduce or limit the starting currents of the motor is inserted. Reducing or limiting starting currents will enable the smooth start of a synchronous motor. An experimental study was carried out in an operating synchronous motor with longitudinal-transverse excitation. The results of the experiment are given in the form of an oscillogram displaying the processes of soft start of the engine. The oscillograms show the patterns of changes in the voltage of the stator winding, the currents in the stator and rotor windings, and the engine start time. A comparative analysis of the starting modes of a uniaxial and biaxial synchronous motor is made.

KEY WORDS: Synchronous motor, soft start, longitudinal-transverse excitation, experiment oscillograms, stator voltage, stator current, rotor current, start-up time.

I.INTRODUCTION

Currently, synchronous motors are started in various ways. The choice of method for starting the engine depends on the mode of operation and the magnitude of the moment of resistance acting on the shaft.
Synchronous motors (SM) are a complex energy and material-intensive electrical device. The start of a synchronous motor leads to significant energy costs and is accompanied by a 5-7-fold inrush current, which creates a shock electromagnetic moment transmitted through the motor shaft to the driven mechanism. During 15 to 20% of the motor acceleration time, this torque contains forced and free components in the form of a sign-variable torque with an amplitude of up to 4 rated motor torques. The resulting large alternating electrodynamic forces in the stator winding lead to a deterioration in the insulation of the sections and bending of the end parts of the winding due to the displacement of the conductors relative to each other. Also, the alternating moment causes burnout of the intercoil connections, burning of the output ends, breakage of shafts, couplings, gearboxes and other malfunctions. The rhythm of production is disrupted and the output of finished products is reduced, enterprises incur high costs for the repair of failed equipment [1-4].

The flow of increased currents through the elements of the power supply circuit also adversely affects, leading to large voltage losses, which negatively affects the stability of other consumers. Considering that high-power high-voltage SMs are mainly used in large-scale industries, then, as a result of the start-up, a voltage drop can be observed among consumers participating in the technological process [2].
Due to the significant volumes of active materials in SM, the heating time constant of these motors reaches several hours. In the case of a restart after a short period of time, during which the active materials and the SM insulation do not have time to cool down to the established ambient temperature, then at high starting currents, these elements will overheat and premature failure of expensive electrical complexes. Therefore, according to the heating conditions, such SMs are limited to starting from a "hot" state, as a rule, once or twice a day [2, 5].

Multiple excess of the starting current of the electric motor from the passport nominal values leads to a lack of power in the power system. Therefore, the calculation of start-up transients is of great importance when designing a power system.

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Our earlier experimental study also confirms the above provisions [6, 7]. Based on the above, in order to reduce the negative impact of the SM starting process, it is necessary to reduce or limit the starting currents of the motors. Reducing or limiting starting currents will make it possible to implement a soft start of the SM.

II. SIGNIFICANCE OF THE SYSTEM

In this article, based on the results of experimental studies, a comparative analysis of the soft start process of a conventional SM and SM with longitudinal-transverse excitation (SM d-q) is given. The study of literature survey is presented in section III, Methodology is explained in section IV, section V covers the experimental results of the study, and section VI discusses conclusion.

III. LITERATURE SURVEY

To select a device that performs a soft start of a motor with a starting current limitation, a number of works are considered, in particular, in [5, 8, 9], methods for limiting the starting current are considered. For this, a reactor connected between the network and the motor stator winding can be used. The starting current limitation is due to the voltage drop across the reactor connected to the stator circuit, which leads to a significant decrease in the asynchronous torque (due to the quadratic dependence of torque on voltage). Also, an autotransformer can be used as a device that limits the starting current of a synchronous motor. The autotransformer reduces the voltage on the motor in proportion to the transformation ratio, while the current consumed from the network decreases in proportion to the square of the transformation ratio. Thus, the use of a starting autotransformer makes it possible to significantly reduce the current consumed from the network with a much smaller decrease in the starting torque than in the case of a reactor start. A promising direction at present is starting at reduced voltage through a thyristor voltage regulator or through the so-called soft starters. Indeed, starting at reduced voltage allows you to limit the starting current. However, at reduced voltage, the drive motor develops less torque on the shaft, which leads to an increase in the duration of the start-up and practically does not lead to a decrease in energy consumption during start-up. The problem of reducing the developed torque at start-up is removed when using a frequency start that maintains a constant multiplicity of the maximum torque. The acceleration time of the SM depends on the nature of the change in the starting current. The larger the area of limitation of the starting current curve and the time axis, the faster the SM accelerates to the rated speed. But frequency starters are much more expensive than other devices.

IV. METHODOLOGY

An analysis of soft start methods shows that the starting current is proportional to the applied voltage, the decrease of which causes a corresponding decrease in the starting current. In this paper, we have chosen the second method to limit the inrush current. To limit the starting current, we will use an autotransformer.

When starting the engine through a step-down autotransformer, the engine is first connected to a reduced voltage. In this case, the starting current of the motor, measured at the output of the autotransformer, decreases by a factor of K_A, where K_A is the transformation ratio of the autotransformer. As for the current in the network supplying the motor, i.e., the current at the input of the autotransformer, it decreases by a factor of $(K_A)^2$ compared to the starting current when the motor is directly connected to the network. The fact is that in a step-down autotransformer, the primary current is less than the secondary one by K_A times, and therefore the decrease in starting current during an autotransformer start is $(K_A)^2$ times. After the initial acceleration of the motor rotor, the values of the autotransformer K_A will be gradually reduced. In this case, the voltage at the terminals of the stator winding increases slightly, but still remains less than the nominal value. At the end, we will apply full mains voltage to the engine.

Thus, the autotransformer start takes place in three stages: at the first stage, a low voltage voltage is applied to the motor, at the second stage, the voltage will gradually increase, and, finally, at the third stage, the rated voltage is applied to the motor. Acquisition of synchronism is achieved after the inclusion of direct current in the excitation winding.
A four-channel digital oscilloscope of the Tektronix MSO64 type was used to carry out measurements and oscillography of the results.

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V. EXPERIMENTAL RESULTS

Experimental studies were carried out in the operating engine located in the scientific laboratory of the Department of "Electrical Machines" of the Tashkent State Technical University, in order to determine the patterns of changes in voltage and currents during the soft start of the SD.
The object of research is an implicit-pole synchronous motor with longitudinal-transverse excitation with a power of 2.2 kW, voltage 220V, rotation speed 1500 rpm. This implicit pole SM d-q is based on an asynchronous motor with a phase rotor type MTO-12-4.

Figure 1 shows an oscillogram of a soft start of a non-salient pole d-q excitation LED, while the longitudinal excitation winding is short-circuited and the transverse excitation winding is open. In this case, the experimental motor can be considered as a conventional single axle motor. When the starting characteristic was taken, the electrical parameters of the motor had the following values: stator voltage U=220 V stator current I_s=3.5 A, rotor current I_r=1.5 A. It can be seen from the oscillogram that at start-up the maximum stator current is I_{ss}=5.3 A (current ratio 1.5), the maximum rotor current is I_{rs} = 7.3 A. (current ratio 4.9), the voltage from zero increases to the nominal value. The engine start time was 6.0 seconds.

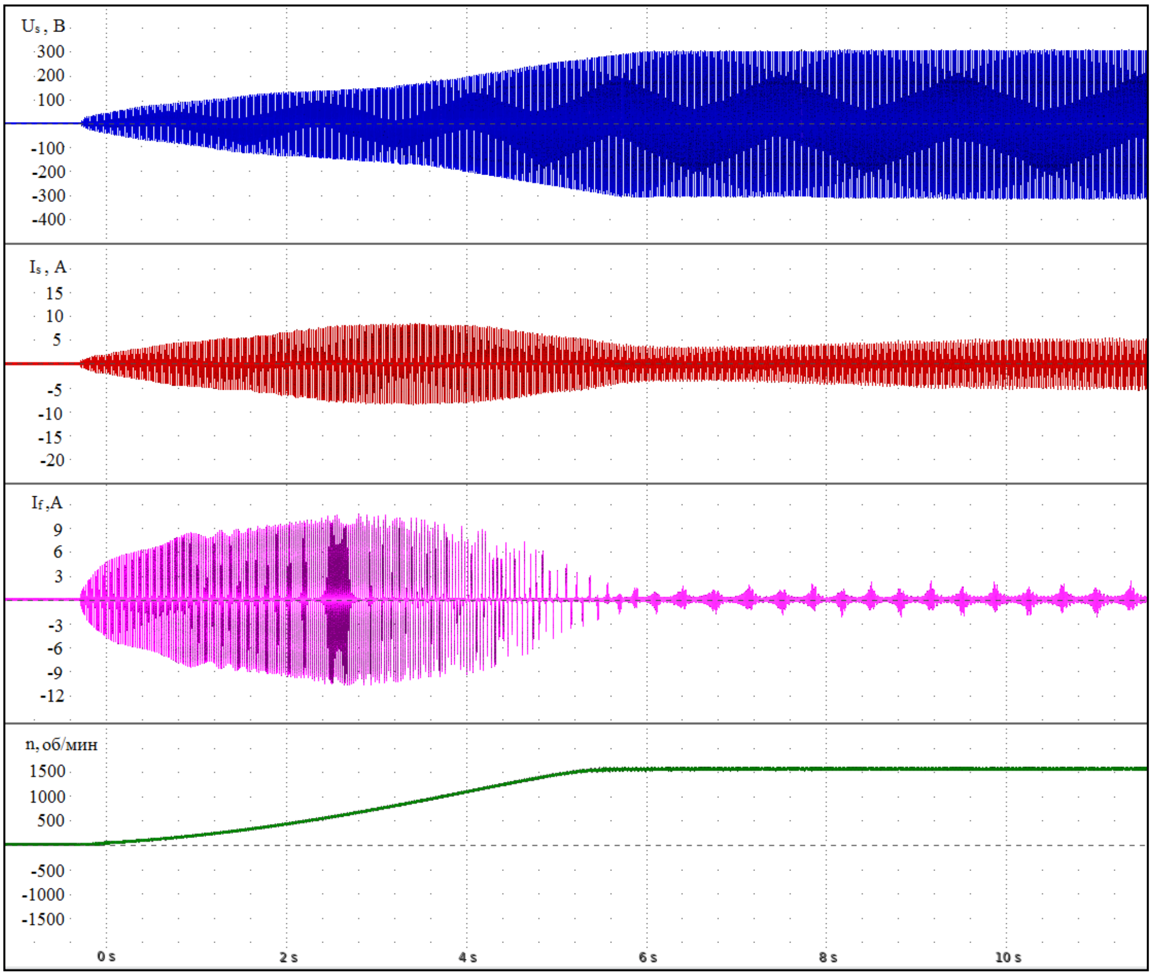

Fig 1: Autotransformer start-up of non-salient-pole SM d-q excitation,
d - longitudinal winding short-circuited, q - transverse winding open.

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Figure 2 shows an oscillogram of a soft start of a non-salient-pole d-q excitation LED, while the longitudinal excitation winding and the transverse excitation winding are short-circuited. In this case, the experimental motor will operate as a biaxial excitation motor. When taking the starting characteristic, the electrical parameters of the motor had the following values: voltage U=220 V stator current I_s=3.1 A, rotor current I_r=1.0 A. Analysis of the oscillogram gives the following results, that at start-up the maximum stator current is I_{ss}=4.0 A (current ratio 1.29), maximum rotor current I_{rs} = 4.3 A. (current ratio 4.3), the voltage from zero increases to the nominal value. The engine start time was 5.1 seconds.

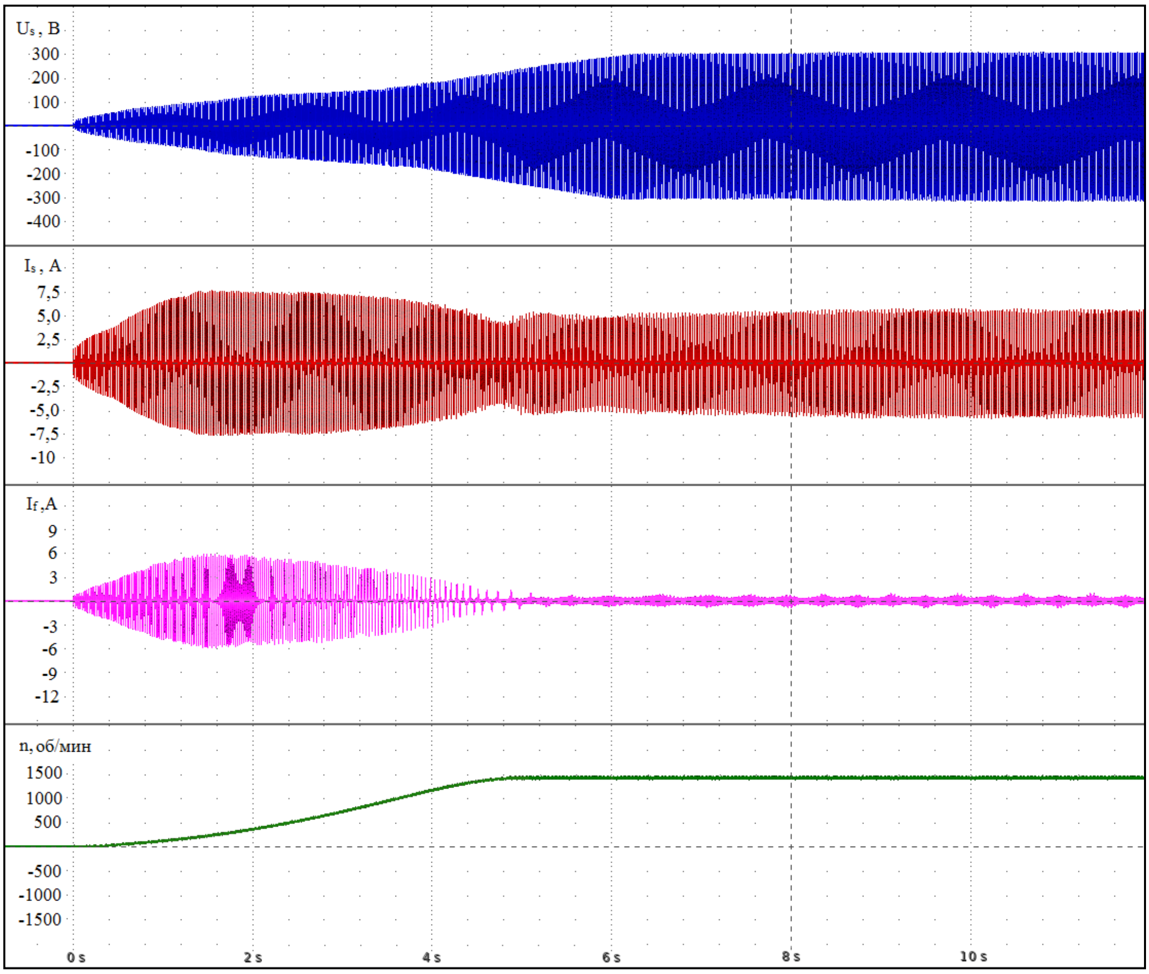

Fig 2: Autotransformer start-up of non-salient pole SM d-q excitation
d- longitudinal and q - transverse windings are short-circuited

After carrying out experiments for a single-axis and two-axis motor, a comparative analysis was made. The results were compared with the results of direct start [10] of this motor.

The analysis of the experiments gave the following results: the multiplicity of the starting current of the stator winding during the smooth start of the motor of uniaxial excitation decreased by 2.64 times compared to the starting current of the direct start; the multiplicity of the starting current of the stator winding during the smooth start of the motor of biaxial excitation decreased by 3.05 times compared to the starting current of the direct start; the multiplicity of the starting current of the rotor winding during the smooth start of the uniaxial excitation motor was reduced by 2.5 times compared to the starting current of the direct start; the multiplicity of the starting current of the rotor winding during the smooth start of the motor of biaxial excitation decreased by 2.79 times compared to the starting current of the direct start; start-

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up time with soft start of a single-axis motor increased by 3.15 times compared to direct start; Starting time with soft start of biaxial motor increased by 3.98 times compared to direct start.

VI. CONCLUSION

The use of a soft start of a synchronous motor d-q leads to a decrease in the multiplicity of starting currents of the stator and rotor windings. Due to the reduction of starting currents, the shock electromagnetic moments are reduced, and the increase in the temperature of the windings during start-up is reduced.

REFERENCES

[1]. Abramovich B.N., Krugliy A.A. Excitation, control and switching of synchronous motors. - L.: Energoatomizdat: Leningrad. department, 1983. – 128 p.
[2]. Krivoruchko N.A. Advantages and disadvantages of asynchronous start of a synchronous motor using a reactor. Journal «BULLETIN OF SCIENCE» 2022 № 6 (51), pp. 221-224.
[3]. Calculation of U-Shaped Characteristics and Reactive Power of Synchronous Compensator with Longitudinal-Transverse Excitation. Pirmatov, N., Toirov, O., Bekishev, A., Zaynieva, O., Norkulov, U. AIP Conference Proceedings, 2022, 2552, 040020.
[4]. Calculation of winding factors and MMFs of rotor windings of synchronous machines with longitudinal-transversal excitation Akhmatov, M.G., Pirmatov, N.B. Elektrichestvo, 2003, (3), pp. 68–70.
[5]. Siromyatnikov I.A. Operating modes of asynchronous and synchronous motors. M.: Energoatomizdat, 1984. 240 p.
[6]. Pirmatov N.B., Giyasov S.M. Oscillogram of the starting mode of a synchronous motor with longitudinal-transverse excitation. VI All-Russian Scientific and Practical Conference "Energy and Energy Saving: Theory and Practice" December 2021, pg no:427-430.
[7]. Pirmatov N., Giyasov S., Duvlonov J., Berdiyorov U. Asynchronous start-up of a salient-pole synchronous motor with longitudinal-transverse excitation. Proceedings of the XXXI International Scientific and Practical Internet Conference "Trends and Prospects for the Development of Science and Education in the Context of Globalization": Sat. scientific works. – Pereyaslav-Khmelnitsky, 2017. – Vol. 31. – pp. 616-617.
[8]. Abramovich B.N., Ustinov D.A. Selection of the method of starting a synchronous motor used as a regulator consumer. Electronic scientific journal "Oil and Gas Business", 2012, № 6.
[9]. Nosov K.B. Means and methods of self-starting of electric motors / K.B. Nosov, N.M. Dvorak. - Kemerovo: Kemerovo book publishing house, 1985. – 128 p.
[10]. Pirmatov N.B, Giyasov S.M. Experimental studies of starting modes synchronous motor of longitudinal-transversal excitation // International Journal of Advanced Research in Science, Engineering and Technology Vol. 10, Issue 3, March 2023, pp. 20457-20461.

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