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The Problems of Direct Start-Up of Asynchronous Engine of Large Power Fan Settings for TPS

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ABSTRACT:The article presents the results of studies to improve the starting modes of high-voltage induction engines (AE) of high power chimney fans of boiler plants for thermal power plants. Carrying out research of transient processes of AE on mathematical model, it is offered to carry out smooth start of the engine by means of the thyristor regulator of tension developed by authors.

KEY WORDS: start-up, start-up duration, starting current, low voltage, electric drive, asynchronous engine, direct start-up, transient, mechanical characteristics, electromagnetic moment, thyristor.

I.INTRODUCTION

In boiler units of thermal power plants (TPPs), where organic fuel (gas, coal or fuel oil) is used to heat water and steam, asynchronous motors (AE) are used as a drive of fan units for suction from the boiler and discharge into the atmosphere through a chimney of carbon monoxide (AE)) with a squirrel-cage rotor, the power and voltage of which reach up to 4 ÷ 5 MW and 6-10 kV, respectively. In practice, the operation of large electric drives mainly use synchronous engine (SE), the control capabilities of which are limited due to their design features [1].

Due to the fact that this AE fan unit must provide relatively frequent starts, stops and changes in rotational speed, use two-speed AM. Despite this, the process of automatically starting large AEs using the method of switching the stator winding from a star to a triangle is accompanied with great difficulties.

So, for example, when using high-power high-voltage direct-drive motors with direct connection of the stator winding to the star (phase voltage decreased by $\sqrt{3}$ times), due to the delay in time of the starting process with a high stator current exceeding the rated current by $(4 \div 7)/\sqrt{3}$ times, the stator windings of the motor units often become worthless, because of which the windings of the stators of the motors are repaired.

The aim of this work is to investigate the starting process of high-voltage high-voltage AEs with a squirrel-cage rotor, as well as the development of modern means for the smooth start-up of AEs with minimum starting currents, shortening the time of the forced shutdown of the installation due to damage and replacement of the AEs, as well as reducing the cost of its repair. When choosing possible methods for starting large-capacity asynchronous motors, the following basic requirements were taken into account:

a)the engine must develop at start-up a sufficiently large starting torque, more than the static moment of resistance on the shaft, so that the rotor of the engine can accelerate and reach the necessary speed of rotation;

b)the value of the starting current should be limited to such a value that at that there was no damage to the stator windings of the motor and a violation of the normal operating mode of the network;

c)scheme of starting a high-voltage high-voltage motor should be the simplest, to ensure high reliability of the electric drive and low cost of starting devices [1-3].

The analysis of the works of other authors of publications whose studies are devoted to solving problems of this nature showed the following results. When starting a high-power AE of a centrifugal submersible pump used for oil production [4], significant starting currents arise that negatively affect the windings of the AE stator, destroy it, and create a significant voltage drop. Direct start without restrictions on the stator current and torque leads to shock mode,

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which can lead to disruption of the normal operation of the installation. The use of a soft starter based on an electric drive with a thyristor voltage regulator and an induction motor (thyristor voltage converter TVC-AE) allows you to avoid the above adverse factors during operation. However, to use the TVC-AE system for the high-voltage drive under consideration, a large-capacity device is not possible due to the lack of corresponding capacities.

II. SIGNIFICANCE OF THE SYSTEM

Other possible ways of applying the starting characteristics of the drive under consideration are the implementation of a rotor winding, or two cell windings, or with a deep groove, or with a phase rotor. However, these proposals are associated with structural changes in the rotor of the motor unit, which was advisable to carry out when designing the electric drive of the ventilation unit, since large-scale motor units with such a rotor design are not produced by the industry.

In the study of the process of starting the AE, generally accepted assumptions are made about an idealized electric machine.

The authors of this article propose microprocessor control of a high-voltage high-voltage motor with AE, the design of which is supplemented by some elements [5]. The design of a powerful high-voltage TVR (Trystor Voltage Regulator) for powering an asynchronous drive of a fan unit with microprocessor control allows for a smooth start of AE at a low voltage, where the starting current in the stator winding does not exceed unacceptably large values (1,0 ÷ 1,5)·$I_н$

To ensure a satisfactory course of transient processes occurring in the start-up and control modes of the rotor speed of the AE rotor, continuous control of the values of the reference quantities is necessary. For these purposes, a feedback (r.p.) on the rotor speed has been introduced in the circuit. This allows you to accelerate the blood pressure according to a predetermined schedule and give the necessary rate of acceleration of the electric drive and allows you to get a rigid static characteristic in steady state and increase the stability of the electric drive when operating at low speeds. If installing speed sensors on the motor shaft is problematic, in this case the rotor speed should be estimated using indirect methods based on the measurement of stator currents and voltages [3].

Microprocessor control was used to generate the necessary signal of the reference values and ensure automatic control of the processes of operation of the TVC-AE electric drive system (Fig. 1).

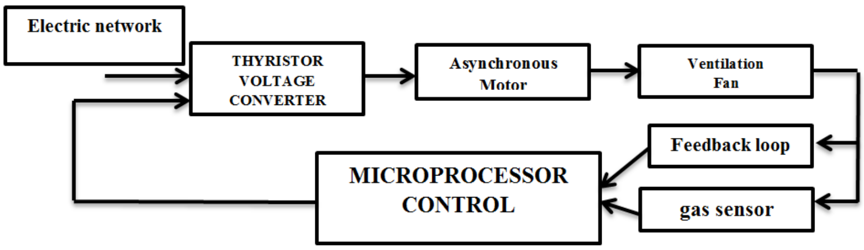

Fig.1. Schematic diagram of asynchronous electric drive

Performing experimental verification of equipment in a continuous process is difficult. Therefore, to conduct research on the experimental determination of the influence of individual elements of the electric drive on transients, a mathematical model of the TVC-AE system was developed.

III. LITERATURE SURVEY

In the study of transients of an asynchronous machine, we use systems of differential equations, including equations of electrical circuits and the mechanical motion of the rotor [2]. In this case, the voltage equations for the phase windings of the stator and rotor are written as follows

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$$\left.\begin{aligned} u_{As} &= -d\Psi_A / dt + i_{Ar} r_s \\ u_{Bs} &= -d\Psi_B / dt + i_{Br} r_s \\ u_{Cs} &= -d\Psi_C / dt + i_{Cr} r_s \\ u_{ar} &= -d\Psi_a / dt + i_{ar} r_r \\ u_{вr} &= -d\Psi_b / dt + i_{br} r_r \\ u_{cr} &= -d\Psi_c / dt + i_{cr} r_r \end{aligned}\right\}, \quad (1)$$

where Ψ_A, Ψ_B, Ψ_CиΨ_a, Ψ_b,Ψ_c - are the total flux linkages with phase windings *A*, *B*, *C* of the stator and *a*, *b*, *c* of the rotor; u_{As} , u_{Bs}, u_{Cs}иi_{As},i_{Bs},i_{Cs}- instantaneous values of phase voltages and currents of stator windings; u_{ar}, u_{br}, u_{cr}иi_{ar},i_{br},i_{cr}- instantaneous values of phase voltages and currents of the rotor windings; r_s and $r_к$ are the active resistances of the phase windings of the stator and rotor. For the mathematical model of the TVC-AE system, in (1) it is necessary to add an analytical expression of the electromagnetic moment of the blood pressure, the equation of equilibrium of the moments of the electric drive, control device and feedback of the drive.

When solving the system of equations (1) for an induction motor, the flux linkage with the corresponding windings is divided into separate components Ψ_k (where instead of the index *k* it is necessary to take the designation of the corresponding windings: *A*, *B*, *C* of the stator and *a*, *b*, *c* of the rotor): $L_k; M_k$ и i_k . For example, the flux linkage with the phase winding *α* is

$$\Psi_a = L_A i_{As} + M_{A,B} i_{Bs} + M_{A,C} i_{Cs} + M_{A,a} i_{ar} + M_{A,b} i_{br} + M_{A,c} i_{cr}\,, \quad (2)$$

where L_A is the inductance of the phase winding « *A*» of the stator, $M_{A,k}$ is the mutual inductance between it and other windings. Similarly, flux linkages are recorded for the five other phases of the stator and rotor phase windings.

Substituting equations (2) written for all six phases of the stator and rotor windings into the system of equations (1), we obtain a new system of equations with periodic coefficients that vary in harmonic law during rotation of the motor rotor. After substituting equations (1) into (2), the solution to the problem is the resulting flux linkages will be cumbersome with dozens of coefficients having a periodic nature of change.

To simplify the system of equations and get rid of periodic coefficients, it is necessary to go to the simplest model of a generalized electric machine. Then the number of equations and variables is significantly reduced, and the mathematical model becomes much simpler [2]. There are various options for constructing a mathematical model with a choice of coordinate system. The most suitable for this case are the voltage equations of the two-phase stator and rotor windings in orthogonal coordinates

$$\left.\begin{aligned} u_{\alpha s} &= -d\Psi_{\alpha s} / dt + i_{\alpha s} r_s \\ u_{\beta s} &= -d\Psi_{\beta s} / dt + i_{\beta s} r_s \\ u_{\alpha r} &= -d\Psi_{\alpha r} / dt + i_{\alpha r} r_r \\ u_{\beta r} &= -d\Psi_{\beta r} / dt + i_{\beta r} r_r \end{aligned}\right\}, \quad (3)$$

rotor motion (equations of equilibrium of electric drive moments)

$$d\omega_r / dt = [M_C(t) - M_{эм}(t)] / J \,, (4)$$

and electromagnetic moment

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$$M_{ЭM}(t) = pM(t)[i_{\beta s} i_{\alpha r} - i_{\alpha s} i_{\beta r}]. \quad (5)$$

The values in equation (4) are the dependence of the moment of resistance in time; it is determined in the process of calculating the equations of the mathematical model from the experimentally measured curve of the fan characteristic of the production mechanism by including specific values of the angular velocity of rotation of the rotor for a given moment in time.

IV. METHODOLOGY

The numerical values of experimentally measured values of the moment of resistance can be included in the mathematical model in the form of tables or graphs.

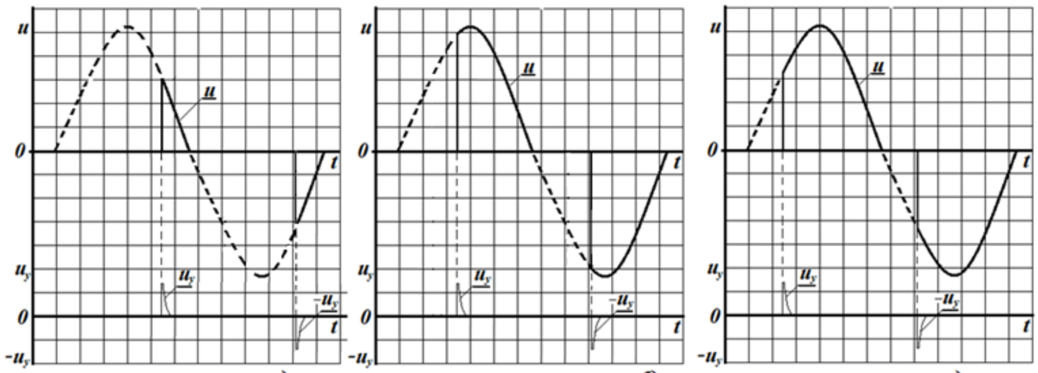

Fig.2. Graphs of voltage changes and at different control signals of U

The most convenient is the analytical representation in the form of M_C the following approximated function

$$M_C(\omega) = M_0 + (M_{CN} - M_0)\left(\frac{\omega}{\omega_N}\right)^q \quad (6)$$

where $M_C(\omega)$ is the moment of resistance at speed ω, M_0 is the idle moment of the mechanism, is the nominal moment of resistance at the nominal speed, is the exponent that determines the type of characteristic ($q = 1{,}65$ experimentally determined for this production mechanism).

A distinctive feature of the start-up method with the TVC-AE system from the direct start-up method of blood pressure is that the voltage of each phase of the stator winding passes through counter-parallel connected thyristors. In this case, the stator voltage form (solid bold lines of u in Fig. 2) changes depending on the state of the electric drive itself - thyristor control signals (solid thin lines of u_y and $-u_y$), which are formed and applied to the thyristor control electrodes. During the start-up of blood pressure, the half-period of the sinusoidal voltage changes its shape, the area between the voltage curve u and the abscissa axis increases [6]. At the same time, the average value of the stator winding voltage will smoothly change from its minimum value to the nominal value.

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Dataset Description

From equation (6) it can be seen that for small values of the rotor speed, i.e. at the initial stage of starting, the moment of resistance on the motor shaft is insignificant. The load on the motor shaft increases as the rotor speed increases according to a parabolic law.

Studies of the starting characteristics of the high-power high-voltage AE fan units of thermal power plants (TPP) using a mathematical model showed the following results.

If during direct start-up with rated voltage, the duration of the transient process is 65 ÷75 seconds, of which, within 50÷55 seconds, the current in the stator winding exceeds the nominal value 2.5 ÷ 7.0 times, because of which there is a frequent exit from building stator winding.

When feeding the stator winding of the blood pressure motor from the transformer substation using microprocessor control with feedback on the rotation frequency and with the set current in the stator winding not exceeding the value (1.5 ÷ 1.75) · In, the duration of the transient processes is about 105÷115 sec. It is calculated that the number of emergency situations with failure of the stator winding was reduced by 4÷5 times.

V.CONCLUSION AND FUTURE WORK

Using a thyristor voltage regulator and with microprocessor control, it is possible to maintain such a safe value of the AE stator current, at which the duration of the starting process is delayed, but the period without emergency operation associated with the failure of the AM stator windings is significantly reduced.

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