IOP Conference Series: Earth and Environmental Science

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To cite this article: A A Imanova *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **315** 032039

IOP Conf. Series: Earth and Environmental Science **315** (2019) 032039 doi:10.1088/1755-1315/315/3/032039

Energy saving electric drives of boilers fans of agricultural objects

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Abstract. The article reviles possibilities of a regulated electric drive for increasing the energy efficiency of agricultural mechanisms and pumps. The transition to regulated AC drive can significantly reduce operating costs, both reducing power consumption, and increasing reliability of electric motor, in whose windings currents close to nominal values are passed through sections of starting and braking modes. It has been established that agricultural regulated electric drive of blowing mechanisms consumes energy that is (50-70%) lower than with throttle control and (20-30%) lower than controlled directing devices. The shown effect can be significantly refined if one takes into account that reliability of system parameters in transition regulated AC electric drive increases. The agricultural electric drive, which operates at rated starting currents, according data in, has an increased resource approximately (30-40%).

1. Introduction

Increasing energy efficiency is relevant for all countries in the world. But this problem is especially important for Russia - the country of the coldest, longest in territory, burdened with a false tradition, that "we have a lot".

A large share of energy consumption is accounted for the agricultural electric drive. Suffice it to say that it consumes 65% of electricity produced, which, according to ABB experts, releases about 37 million tons of carbon dioxide annually. The main trend in world practice is transition from an unregulated agricultural electric drive to regulated one. If currently in technically developed countries regulated electric drive does not account for more than 10% of all cases, according to American experts, its share should be increased to 30 and even to 50% [1]. This is due to increased demands on quality of technological processes, rising costs and often depletion of energy sources, need save energy, including electrical energy. This task is much more effectively solved within framework of regulated electric drive [2].

Traction-blowing mechanisms of agricultural objects are designed to produce saturated steam or superheated steam, used universally for needs of industrial enterprises and for heat supply of heating and hot water supply systems [3].

The control of electric drives of traction-blowing mechanisms can be performed according to several schemes: with throttle control, regulation of directing devices and speed control of an electrical machine.

Currently, regulated electric drives based on variable-frequency asynchronous electric drives are being actively introduced in industry and housing and utilities. However, for today installed capacity of these systems remains high. The transition from an uncontrolled electric drive regulated drive allows, in some cases, considerable savings in electrical energy. Therefore, task of estimating efficiency energy consumption for purpose of justifying introduction regulated variable-current electric drive is actual.

2. Problem research statement

The achieve the stated goal is required the following tasks:

- analysis of technological facilities where introduction regulated AC electric drives is relevant for the purpose of estimating proportion regulated drives at sites of draft motors;
- choice of the most rational way controlling regulated electric drives of traction mechanisms;
- development of design scheme for energy consumption of traction mechanisms;
- comparison of energy objects consumption draft motors with unregulated electric drives.

3. Objects classification of introduction in variable- frequency drive

The transition to variable-frequency electric drive allows:

- to abandon the regulation of performance of pumps with valves and move to regulate the angular velocity of the pump unit. The efficiency of the installation can be upgraded to 10...40 % in depending on the depth of regulation;
- greatly facilitated the modes of supply, as it eliminates inrush current observed when direct launches asynchronous motors. This increases the service life of the motor;
- eliminate hydraulic shocks in pipelines observed in the direct missile motors. In steady-state mode when not needed throttling piping, water pressure is reduced and the service life of hydraulic equipment increased; the reliability of water supply increases;
- by eliminating the excess pressure is achieved by water savings). Thus, according to the [4] the use of controlled electric drives of the pumps of drinking water in residential buildings can save up to 10...30 % of water and up to 20...50 % of electricity [5].

4. Methods of control of traction-blowing mechanisms

You can achieve energy savings even in existing production models of electric drives, when choosing the rational method of control.

We should stop on the electric drive of pumps and fans [6]. First, it is the most massive electric drive with at least 30...40% of all energy consumed by all the drivers, to the drivers of these mechanisms [7]. Second, the transition is not requiring replacement of existing electric motors and pumping units, and the transition is reducing only by installing additional frequency converter [8].

So, we will specify accurately most effective options of application drives of traction-blowing mechanisms, it is necessary to have reliable source data for carrying out the corresponding energy calculations [9, 10]. Experimental characteristics of the object of study are the most accurate in terms of the current production. This purpose was experimentally determined energy characteristics of traction-blowing mechanisms and electric boilers [11]. Measured electrical quantities characterizing the consumption of electric energy from the network (voltages, currents and power) by changing the position of directing devices regulating air flow through traction-blowing mechanisms. Electric motor was connected to industrial network and, hence, its angular speed is not regulated [12].

During the measurement of electrical quantities voltages, currents and capacities that characterize mode consumption of electricity, the angular velocity rotation of the shaft traction-blowing mechanism did not change and corresponded to angular velocity of the induction motor, operating at the natural mechanical characteristic [13]. To adjust angle of blades guide vanes, which was fixed according testimony of factory instruments and were issued operator panel of boiler. For each of boilers was filmed two series of energy characteristics:

- based on power consumption of electric drive from the network, when changing relative size of the hole created by guide vanes in gas path of boiler [14];

- similar characteristics in joint work of fan and smoke exhauster when position of their vanes guide vanes coincided with setpoints according the standard modes of boiler [15].

The energy characteristics of electric fan VDN-9 was experimentally determined by changing angle of rotation blades it directing device when the aerodynamic drag of other devices installed along gas tract was minimal (guide vanes of induced draft fan and dampers on burners are completely open) [16]. The results of experimental measurements designed in form a graph (figure 1), which shows changes in electric quantities characterizing energy consumption of fan motor from mains (the voltage on stator currents of stator and power) depending on angle of guide vanes fan. The rotation angle is specified in percent of full travel range lever electric drive at entrance of directing devices, i.e., as is customary specialists of factory floor KIP: when θ_{HA}= 0% gas path is completely blocked when θ_{HA}= 80 % is open as much as possible, as they allow design features of particular diffuser.

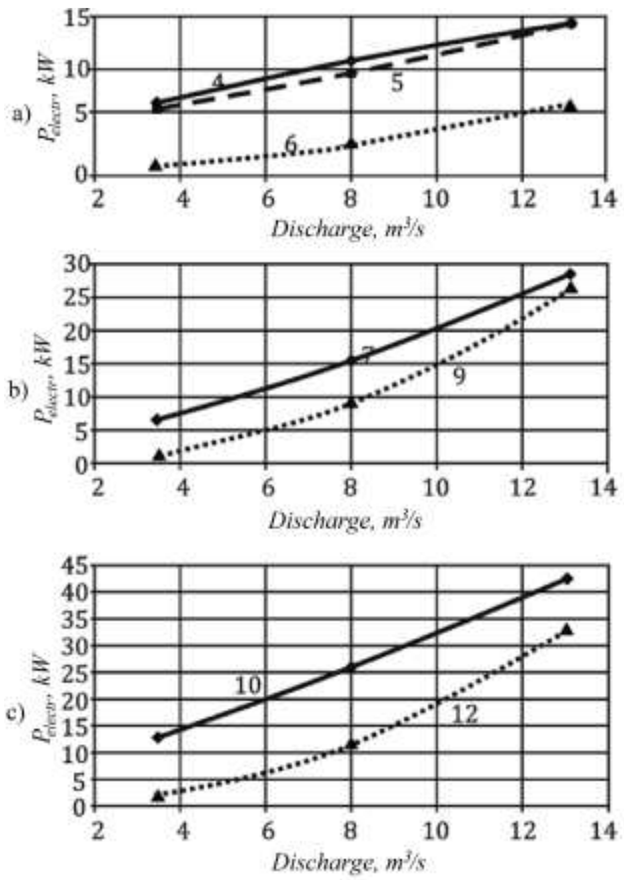

Figure 1. Changes in electric quantities characterizing energy consumption of fan motor.

Noteworthy is a relatively large value (8.5 kW) power consumed by electric drive, when inlet guide vane fully blocks the air path [17, 18]. This is because angular velocity of motor circuit is not regulated, remains quite high, and therefore high, and loss of useless agitation air by fan blades. Of course, if this mode failed, angular velocity of unit lower, extra aerodynamic losses could have been avoided. The amount of power consumed from network by electric drive at full open guide unit (about 18.6 kW) will be used to determine aerodynamic resistance of gas path boiler [19].

5. Calculated scheme and estimation of energy consumption traction-blowing mechanisms

The energy consumption of electric vehicles in draft regulation air flow by changing angular velocity of shaft [20, 21].

This method of flow control in addition to knowledge of aerodynamic characteristics of traction-blowing mechanisms also implies knowledge of aerodynamic characteristics of air conducting channel only of boiler, since this way of regulating fan speed and exhaust fan happens to most open guide vanes. In this case, we can offer following sequence to determine amount of mechanical power on shaft of traction-blowing mechanism.

The calculation is based on characteristics $H = f(Q)$ of traction-blowing mechanism when fully open guide unit (usually θ_{NA} = 00). On same plane have aerodynamic characteristics of air tract boiler $H_K = f(Q_K)$ (figure 1 a, curve 4). Get this curve experimentally by blowing cold air through boiler at full opening of directing devices fans and exhaust fans, installed in air path.

The equilibrium regime, corresponding to intersection called aerodynamic characteristics of traction-blowing mechanism and air path boiler (point G of intersection curves 1 and 4 in figure 1 a), at nominal motor speed of traction-blowing mechanism in real installations far exceeds desired maximum flow value Q_{MAX}. To provide desired operating parameters of air path of boiler, it is necessary to reduce angular velocity of traction-blowing mechanism. Aerodynamic characteristics of air path of boiler has form a quadratic parabola passing through origin and point of intersection named curves. Therefore, flow rate varies in proportion to the first degree of angular velocity traction-blowing mechanism, and value of differential pressure, the second.

Was found on aerodynamic characteristics of boiler flow rate and pressure are basis for calculation of shaft power traction-blowing mechanism.

It must make a principled reservation. Almost all existing traction-blowing mechanisms regulating flow of air chokes (dampers) or guide vanes at a constant (nominal) speed of rotation of motor. Therefore, these processes have a large supply pressure. As a result, when these devices connect at full opening of directing devices to air tract, having low values of aerodynamic resistance, their efficiency drops significantly, and sometimes (two to three times or more). However, calculations show that literature sources [2, 10] and results of experiments, consumption energy is significant because a significant reduction in airflow capacity.

Of course, transition to frequency regulation ideally, it is advisable to accompany use of low-pressure units, but in context of modernization existing heat-and-power and electrical equipment is associated with large capital costs and cannot be considered rational.

We determine magnitude of mechanical power on shaft induction motor 5A160S4UZ P_N = 15 kW, n_N = 1450 rpm), rotating shaft fan VDN–9 (Q_N = 14900 m^3/h, N_N = 2830 PA) for two extreme values of air flow Q_{MIN} = 5460 m^3/h and Q_{MAX} = 14500 m^3/h flow rate air by changing angular velocity unit.

We use aerodynamic characteristics fan VDN-9 (figure 1 b) and equation of air path boiler DE–16–14.

When fully open directing devices of ventilator and exhauster limit value of air flow that run through boiler (which corresponds to point G of intersection curves 1 and 4 in figure 1 a), would be $Q_{TOP} = Q_G$ = 10 m^3/s.

If desired flow rate of air (point F on curve 2 in figure 1) $Q_F = Q_{MIN}$ = 1.52 m^3/s, in accordance with curve 4 H_F = 100 PA, and magnitude of efficiency fan η_F = 0,1...0,2.

At this point, required mechanical power

$$P_F = H_F \cdot Q_F / \eta_F = 100 \cdot 1.52 / (0.1...0.2) = 1.5...0.8 \text{ kW}.$$

Similarly, point E corresponds to $Q_E = Q_{MAX}$ = 4.9 m^3/s. At this point, H_E = 250 PA,

$$\eta_E = 0.2...0.3 \text{ and } P_{E\ SHAFT} = 3...5 \text{ kW}.$$

6. Comparison of various schemes energy consumption

In number of sources, values of energy consumption are given by the objects traction-blowing mechanisms with throttling regulation and control directing devices. Attention is drawn to fact that when electric drive is operated under reduced loads, effect of regulation transition by directing devices is substantially increased if technological object operates at reduced pressure substantial part time. This effect is significantly weakened when operating at main pressure in system.

The same trend is maintained for regulated AC drives. However, when operating at main speed at full pressure, power on motor shaft, as calculated, is equal to $P_{\mathrm{E\ SHAFT}}$ = 3 ... 5 kW and it is significantly lower, compared to unregulated electric drives approximately 30%. This is explained fact that in regulated electric drives it is possible reduce share of power losses in start-up areas, reduce speed and braking of fan mechanism.

In zone of small loads, effect from introduction regulated AC drive increases significantly and amounts to (50-70) % compared to throttle control and (20-30) % compared control of directing devices. Such an effect is achieved by reducing losses in the gas-air tract, but also by reducing electric losses in the motor.

Transition to regulated electric drive allows not only save operating costs, but also reliability increase of system. This is explained fact that in start-up braking modes it is possible significantly reduce starting currents of the motor. In this case, motor itself operates in more favorable mode and when load is lowered, it is allowed reduce excitation current, and variable regulation itself is performed while maintaining constant slip of motor.

7. Conclusion

Paper demonstrates that the transition to regulated agricultural AC drive can significantly reduce operating costs, as reducing power consumption and by increasing the reliability of the electric motor, in which windings in areas of starting and braking modes pass currents are close to nominal values.

It is established that regulated electric drive of traction-blowing mechanisms consumes energy (50-70%) lower than with throttle control and (20-30%) lower than with controlled by directing devices.

The obtained values allow to estimate the efficiency of implementation and the payback period of the regulated electric drive. So, if in near future cost of electricity will increase approximately (20-30%), system "Frequency converter - asynchronous motor" payback period will be 1.5-2 years.

The shown effect can be significantly refined if one takes into account that reliability of system parameters in transition regulated AC electric drive increases. The electric drive, which operates at rated starting currents, according data in, has an increased resource approximately (30-40%).

Acknowledgement

South Ural State University is grateful for financial support of the Ministry of Education and Science of the Russian Federation (grant No 13.9662.2017/BP).

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