IOP Conference Series: Earth and Environmental Science

A study of the system “thyristor exciter - synchronous motor of a pump unit” in the conditions of a deep voltage drop

IOP Conf. Series: Earth and Environmental Science **377** (2019) 012043 doi:10.1088/1755-1315/377/1/012043

A study of the system "thyristor exciter – synchronous motor of a pump unit" in the conditions of a deep voltage drop

M V Kipervasser[1], S A Laktionov[1], S D Davydov[1] and Sh R Gulamov[2]

[1]Siberian State Industrial University, 42 Kirova str., Novokuznetsk, 654007, Russia
[2]"IM Nassojii Tajik" LLC, Saadi Sherozi ave, Dushanbe, 734042, Republic of Tajikistan

E-mail: kipervasser2012@yandex.ru

Abstract. A mathematical model of the system "synchronous motor of a pump unit – thyristor exciter" was developed. The operation of the system model was investigated in the MatLab environment. The situation of a deep voltage drop in the power supply network was investigated. Graphs of changes in the currents of the stator and rotor windings during a voltage drop in the supply network were obtained and their analysis was performed.

1. Introduction

Synchronous electric motors are designed to drive pumps, fans, smoke exhausters and other mechanisms with high power and rotary moment that do not require rotational speed control. At mining and processing enterprises synchronous electric motors are used to drive main ventilation fans, drive motors of conversion units of quarry excavators, turbo-compressors of compressor stations, drainage systems and circulating cycle pumps.

The problem in the operation of the units that use a synchronous electric motor as a wires is the reduction of the motor torque when the supply voltage drops. When it happens, the electric motor may be out of synchronism, which will further lead to overheating of the stator windings and motor failure [1]. In order to examine the behavior of the complex "pump unit with a synchronous electric motor – thyristor exciter" during the voltage drop of the supply mains, the operation of NDZ-20 pump unit with a drive of a synchronous motor SDZ-2-1000-1000UZ was studied.

2. Methods of research

The electric drive system consists of a synchronous motor, a centrifugal pump NDZ-20, relay protection and automation devices, a thyristor exciter TE 8-320-5. The synchronous motor is powered from a cable line with a voltage of 3kV.

The thyristor exciter feeds the excitation winding of a synchronous motor with rectified voltage. In order to stabilize the operation of a synchronous machine, excitation is forced as a standard function when the network voltage drops [2]. The exciter increases the rotor current of the motor for a short time while the mains voltage drops by more than 15-20%.

The device of relay protection is made using MiCom P11 terminal. Among others, the terminal implements protection against maximum current and overload current. The maximum current protection settings are from 7.0 to 9.0 I_v, and in case of overload, to 1.5 I_v at a certain response time.

The schematic diagram of the electric drive system and the main elements of the power supply network are shown in figure 1.

IOP Conf. Series: Earth and Environmental Science **377** (2019) 012043 doi:10.1088/1755-1315/377/1/012043

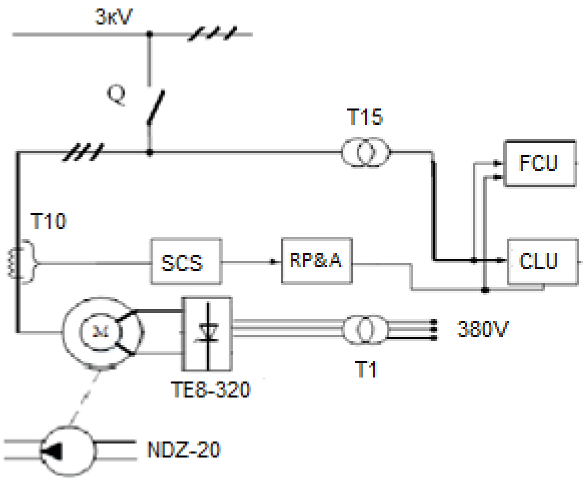


Figure 1. Schematic diagram of the electric drive and elements of the power supply network:
M – synchronous electric motor;
NDZ-20 – centrifugal pump;
TE 8-320 – thyristor exciter;
T1 – isolation transformer of the exciter;
T15 – measuring voltage transformer;
T10 – measuring current transformer;
SCS – stator current sensor;
Q – high voltage switch;
RP&A – relay protection and automation device;
FCU – force control unit;
CLU – current limiting unit.

The Park – Gorev equations describe electromagnetic processes in a synchronous salient-pole machine and make it possible to determine the values of the stator currents in transient conditions. The system of differential equations of an salient-pole SM with a damper winding on the rotor has the form [1,2]:

$$\begin{cases} U_d = R_1 \cdot I_d + \dfrac{d\psi_d}{dt} - (1-s)\cdot\psi_d, \\ U_q = R_1 \cdot I_q + \dfrac{d\psi_q}{dt} - (1-s)\cdot\psi_q, \\ U_f = R_f \cdot I_f + \dfrac{d\psi_f}{dt}, \\ 0 = R_D \cdot I_D + \dfrac{d\psi_D}{dt}, \\ 0 = R_Q \cdot I_Q + \dfrac{d\psi_Q}{dt}, \end{cases} \tag{1}$$

where U_d and U_q are the components of the voltage vector U along the axes d and q; U_f – voltage of the excitation winding; I_d and I_q – components of the current vector along the axes d and q; I_f – excitation current; I_D and I_Q – the current vector components of the damper winding; R_l, R_f, R_D, R_Q – active resistances of the stator, rotor and damping winding along the axes d and q; $\Psi_{dl}, \Psi_f, \Psi_D, \Psi_Q$ – flux linkage of the stator, rotor and damper winding along the axes d and q; s – slip.

The flux linkages in (1) are defined (2):

$$\begin{cases} \psi_d = x_d \cdot I_d + x_{ad} \cdot I_f + x_{ad} \cdot I_D, \\ \psi_q = x_q \cdot I_q + x_Q \cdot I_Q, \\ \psi_f = x_{ad} \cdot I_d + x_{ad} \cdot I_f + x_D \cdot I_D, \\ \psi_{kq} = x_{aq} \cdot I_q + x_Q \cdot I_Q, \end{cases} \tag{2}$$

where x_d, x_q – synchronous inductive resistance along the axes d and q; x_{ad}, x_{aq} are the inductive resistances of the mutual induction of the stator and the rotor along the d and q axes; x_f – inductive resistance of the excitation winding; x_D, x_Q – are the inductive resistances of the damper winding along the d and q axes.

To study transients (1), it is required to add a description of the electromagnetic moment:

$$M = \psi_d \cdot I_q - \psi_q \cdot I_d \tag{3}$$

Taking into account expressions (2) and (3), the joint system will be written (4) [3]:

$$\begin{cases} U_d = R_1 \cdot I_d - (x_q \cdot I_q + x_{aq} \cdot I_Q), \\ U_q = R_1 \cdot I_q + (x_d \cdot I_d + x_{aq} \cdot I_f + x_{ad} \cdot I_D), \\ U_f = R_f \cdot I_f + (x_{ad} \cdot \frac{dI_d}{dt} + x_{ad} \cdot \frac{dI_f}{dt} + x_D \cdot \frac{dI_D}{dt}), \\ 0 = R_D \cdot I_D + (x_{ad} \cdot \frac{dI_d}{dt} + x_{ad} \cdot \frac{dI_f}{dt} + x_D \cdot \frac{dI_D}{dt}), \\ 0 = R_Q \cdot I_Q + (x_{aq} \cdot \frac{dI_q}{dt} + x_Q \cdot \frac{dI_Q}{dt}), \\ M = \psi_d \cdot I_q - \psi_q \cdot I_d, \\ M - M_r = J \cdot \frac{d\omega}{dt}, \end{cases} \tag{4}$$

where M_r is the moment of resistance on the shaft of a synchronous motor created by the pump NDZ-20 [3].

The pump unit is characterized by equality of flow and pump head to the pressure in the network. In the general case, the pump energy is used for lifting the fluid to a height $z_2 - z_1$, creation pressure in the system $p_2 - p_1$ and overcoming the total resistances $h_n = h_{n1} + h_{n2}$ [4].

The power of a centrifugal pump is expressed [4]:

$$P_p = H_{cm} \cdot Q = M_r \cdot \alpha_{cync} \text{, where } H_{cm} = \frac{p_2 + p_1}{\rho g} + (z_2 - z_1) \tag{5}$$

Then the engine torque will be:

$$M_r = \frac{H_{cm} \cdot Q}{\alpha_{cync}} \tag{6}$$

Taking into account (6) the general system of equations is written (7) [4,5]:

Based on (7) model of an electromechanical complex was competed in the MatLab environment the Simulink extension package (figure 2) [6,7].

$$\begin{cases} U_d = R_1 \cdot I_d - (x_q \cdot I_q + x_{aq} \cdot I_Q), \\ U_q = R_1 \cdot I_q + (x_d \cdot I_d + x_{aq} \cdot I_f + x_{ad} \cdot I_D), \\ U_f = R_f \cdot I_f + (x_{ad} \cdot \dfrac{dI_d}{dt} + x_{ad} \cdot \dfrac{dI_f}{dt} + x_D \cdot \dfrac{dI_D}{dt}), \\ 0 = R_D \cdot I_D + (x_{ad} \cdot \dfrac{dI_d}{dt} + x_{ad} \cdot \dfrac{dI_f}{dt} + x_D \cdot \dfrac{dI_D}{dt}), \\ 0 = R_Q \cdot I_Q + (x_{aq} \cdot \dfrac{dI_q}{dt} + x_Q \cdot \dfrac{dI_Q}{dt}), \\ M = \psi_d \cdot I_q - \psi_q \cdot I_d, \\ M - \dfrac{H_{cm} \cdot Q}{\alpha_{cync}} = J \cdot \dfrac{d\omega}{dt} \end{cases} \quad (7)$$

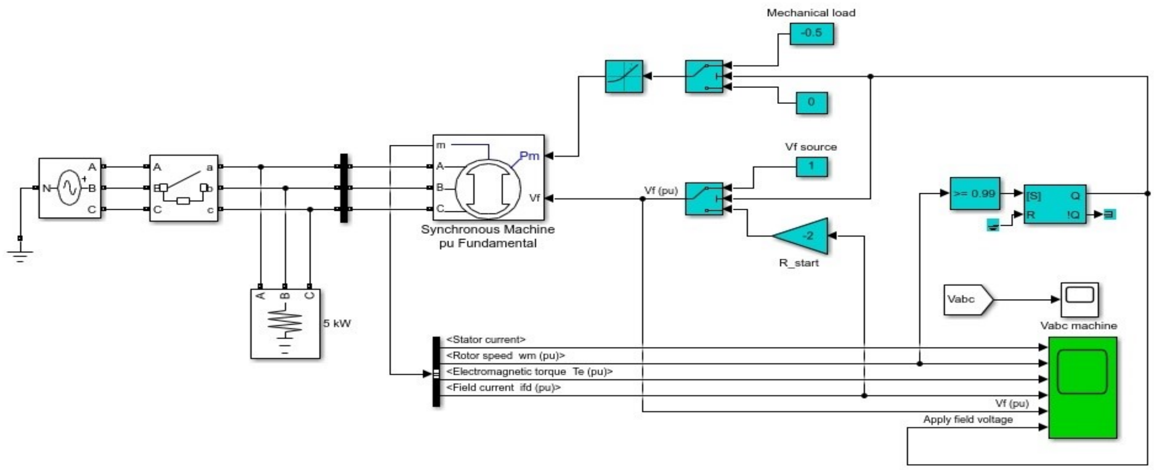
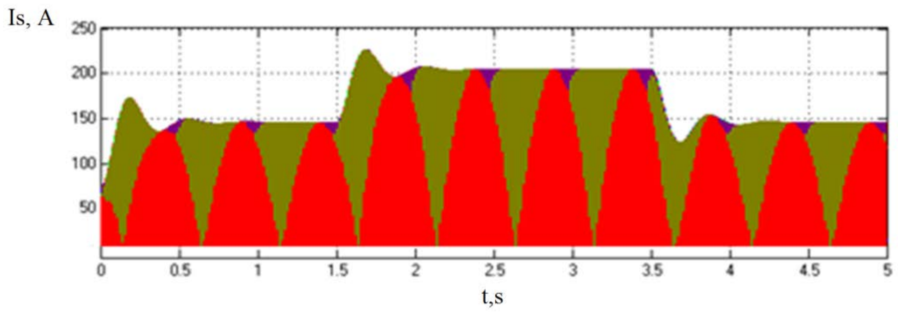


Figure 2. Diagram of the TE-SM system of a pump unit in MatLab Simulink.

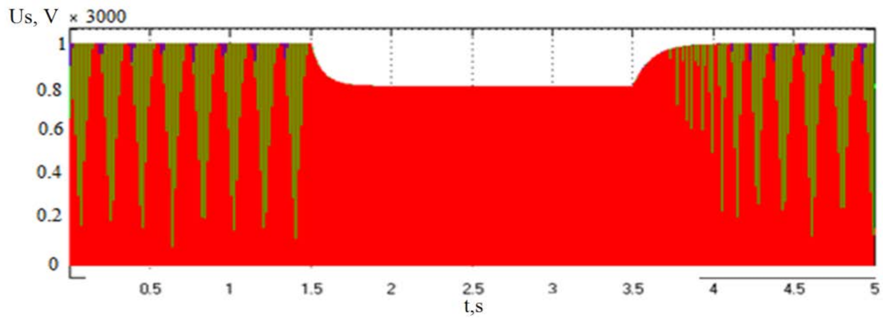
3. Results and discussion

In the model the mode of voltage drop in the power supply network was investigated at 20% of the nominal value. Transient graphs are shown in figure 3.

(a)



(b)



(c)

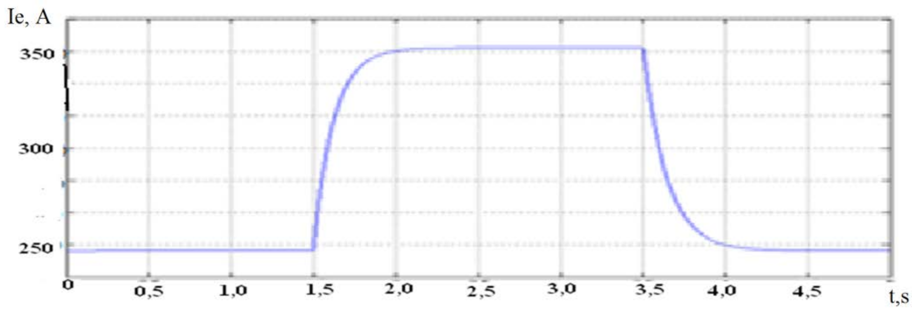


Figure 3. Transient diagrams in the SM when the mains supply drops: (a) graph of the stator current of the synchronous machine; (b) graph of the stator voltage of the synchronous machine; (c) graph of the excitation current of the synchronous machine.

Analysis of transient graphs in the machine shows:

- when the voltage drops, the currents in the rotor and stator windings increase. An increase in the stator current is caused by a change in the internal angle of the synchronous machine. The cause of the growth of the rotor current is the actuation of the excitation forcing scheme;
- the transient growth of the excitation current is aperiodic with a time constant of 0.27 s. The rotor current increases to the value determined by the forcing circuit of 350 A;
- current transient is oscillatory with a time constant of 0.34 s. The stator current when forcing excitation increases to 225 A, which is 34% of the value in the normal mode;
- the values of the stator current in the transient and at its end does not exceed the settings of the operation of the overcurrent and overload protection of the MiCom P11 terminal.

4. Conclusion

The use of excitation forcing makes it possible to increase the overload capacity of the motor quickly without triggering the complex of the synchronous motor relay. Increase in the rotor current during forcing improves the stability of the synchronous motor when the supply voltage drops, preventing interruptions in the operation of pumping stations.

References

[1] Sipailov G A et al 1987 *Electric Machines* (Special Course) (Moscow: Vysshaya Shkola) p 287
[2] Kovacs K P and Rats I 1963 *Transients in AC Machines* (Moscow-St.Petersburg: Gosenergoizdat) p 744
[3] Pugachev E V et al 2014 *Bulletin of the Tajik National University* **1/2 (130)** 117–124
[4] Bystritsky G F 2012 *Fundamentals of Energy: Textbook* (Moscow: Knorus) p 352
[5] Pugachev E V et al 2015 *Bulletin of the Kuzbass State Technical University* **2(108)** 122–127

[6] Gockenbach M S 2010 *MATLAB Tutorial to accompany Partial Differential Equations: Analytical and Numerical Methods* (SIAM) p 136
[7] Ansari A A, Deshpande D M 2010 *International Journal of Engineering Science and Technology* **2(5)** 1260–67