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To Control of Excitation of Synchronous Motors of Pump Stations

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ABSTRACT: Large pumping stations incorporating synchronous motors with powers reaching several tens of megawatts can be used as reactive power compensators in electrical systems and minimize energy losses in networks. The method described in the article can be used in systems for automatic control of the excitation of large synchronous motors.

KEY WORDS: pumping stations, transient processes, excitation regulation, synchronous motors.

I. INTRODUCTION

The practice of operating electrical systems (ES) shows that if they include large pumping stations equipped with powerful synchronous motors (SM), they are taken into account as a constant load. At the same time, taking into account the regime properties of large SMs will improve the operating conditions of the ES, reduce losses in the system and increase its controllability. It all depends on the rational use of automatic excitation control (AEC) of the engine.

It is known [1-4] that in the case of a lack of reactive power in the electrical system, there may be a loss of operation stability not only of the engine itself, but of the entire load node. AEC changes the amount of reactive power output by the engine according to a certain law, depending on the size and nature of the load, as well as on the mode of the supply network, and maintains the voltage values at the SM connection point [4-9].

The paper describes a method for automatic control of the excitation current of a synchronous electric motor in post-emergency modes of the power system. The essence of the method lies in the fact that in the post-emergency modes of the power system, the value of cosφ of the motor, the current value of its load angle are measured and the value of cosφ is maintained at a level of about 1.0 by changing the setting value of the excitation current control loop in the appropriate direction according to the voltage deviation of the stator circuit, carried out according to proportional-differential law. The disadvantage of this approach is that in order to limit the maximum allowable value of the rotor current, the temperature of its winding is continuously monitored by indirectly measuring the active resistance of the winding [1, 10-15].

II. MATERIALS AND METHODS

A device is described that contains voltage and current meters of the stator of a synchronous motor, an angle φ meter, a rotor current meter, an amplifier, and a phase-pulse device. The disadvantages of this method include insufficiently effective damping of oscillations that occur with changes in the load and mains voltage, as well as insufficient static stability of the motor [2, 16-20].

A model of a fuzzy controller is presented, the output of which is connected to the input of a PID controller that performs fuzzy control in order to minimize energy losses in the electrical network. Here, the disadvantage is the selected control parameter in the form of a deviation of the rotor speed of the synchronous motor, which cannot sufficiently minimize energy losses without controlling the level of reactive power in the load node [3, 21-24].

III. MODELING

The objective of the proposed approach is to maintain the maximum value of cosφ of the load node in order to minimize energy losses in the network. The task is achieved by the fact that stabilization signals for the deviation of

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cosφ and reactive power in the load node are introduced into the system for controlling the excitation of a synchronous motor, which is a controller based on fuzzy logic [5, 25-29].

The essence of the proposed control approach is illustrated in Fig. 1, which shows a functional diagram of a synchronous motor powered by the network, which implements the proposed approach to excitation control.

The excitation control circuit of a synchronous motor (Fig. 1) contains a synchronous motor 1 connected to a three-phase electrical network, a measuring part 4 (MP) connected to one of the phase terminals of the stator winding 2 and neutral N of the synchronous motor 1, while the outputs of the measuring part 4 are the inputs of the adder 5, which in turn is connected to the fuzzy logic controller 6, the output of which is connected to the adder 7, the output of which is connected to the protection unit 8 (PU) connected to the excitation winding 3 of the synchronous motor 1. The excitation control of a synchronous motor is implemented as follows.

The measuring part 4 connected to the output of the stator winding 2 and neutral N of the synchronous motor 1 is designed to measure and convert the control parameter - cosφ. The signal of the measured cosφfact is fed to the input of the adder 5, in which it is compared with the specified setting cosφref and an error signal $e=\cos\varphi_{ref}-\cos\varphi_{fact}$ is generated, which, together with the signal of the pre-measured value of the reactive power Q_{load} consumed in the node, is fed to the input of the fuzzy logic controller 6. The fuzzy controller logic 6 is a non-linear control system that uses accurate input variables in the form of an error signal e and reactive power consumption in the node Q_{load} and, in accordance with the rule base, generates a control variable in the form of a signal for changing the excitation voltage ΔU_f. The output signal ΔU_f from the fuzzy logic controller 6 is fed to the input of the adder 7, where it is added to the excitation voltage setting ΔU_{f_ref} and forms the output signal U_f, which is fed to the input of the protection unit 8, designed to limit the increased voltage and overload current supplied to the excitation winding 3 synchronous motors 1.

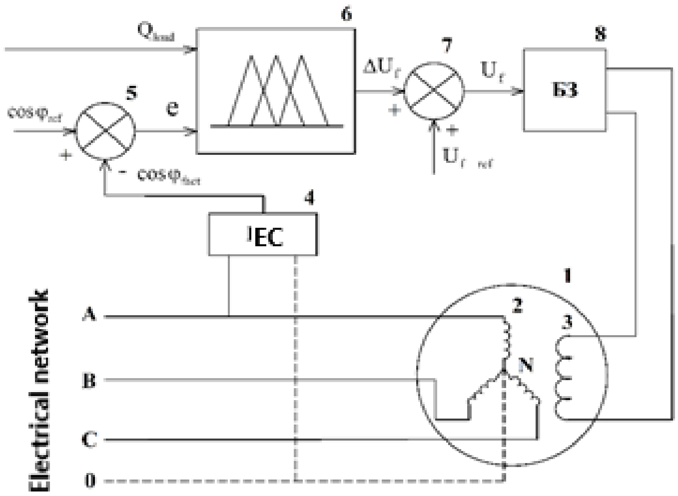

Fig. 1. Functional diagram of excitation control of a synchronous motor of a pumping station

Figure 2 shows the membership functions of the input parameters - changes in cosφ in the form of an error signal e (Fig. 2, a) and the level of reactive power consumption in the Q_{load} node (Fig. 2, b), as well as the output parameter - excitation voltage U_f (Fig. 2, c).

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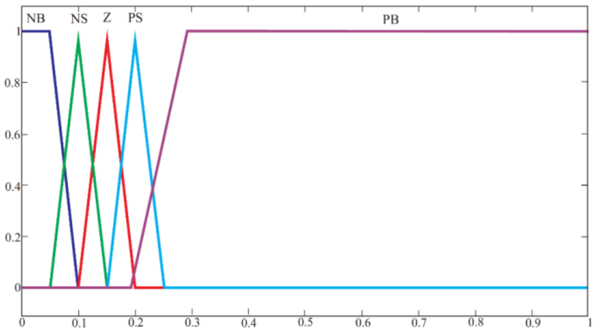
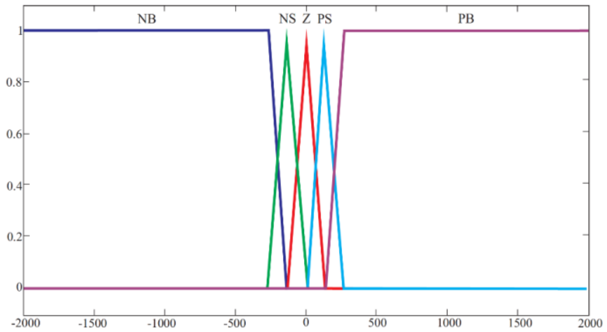
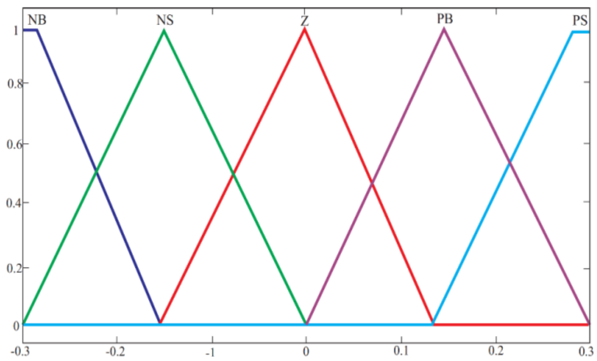


a)
e (error signal of cosφ deviation from the setpoint)



b)
Q_{load} (value of reactive power consumed in the load node)



c)
U_f (excitation voltage change)

Fig. 2. Membership functions of input and output parameters

The fuzzy controller functions based on the rule base shown in Table 1, where the following notations are used: NB (negative big), NS (negative small), Z (zero), PS (positive small), and PB (positive big).

Table 1. Parameters of synchronous generators.

Error signal (e)	The value of reactive power consumption in the load node (Q_{load})				
	NB	NS	Z	PS	PB
NB	NB	NB	NB	NS	Z
NS	NB	NB	NS	Z	PS
Z	NB	NS	Z	PS	PB
PS	NS	Z	PS	PB	PB
PB	Z	PS	PB	PB	PB

As an example of the implementation of the proposed method for controlling the excitation of synchronous motors of pumping stations using the Matlab software package from The MathWorks Inc, the circuit shown in Fig. 1 was simulated. Synchronous motor parameters: rated active power 800 kW; nominal power factor 0.85; rated voltage 10 kV; nominal speed 1000; starting current ratio 7; Efficiency - 0.94.
We will simulate the connection of a large asynchronous load to the connection node of a synchronous motor at the 2nd second of the simulation. The cosφ setpoint of the fuzzy controller is set to 0.85.
Figures 3,4 and 5 show graphs of the transient change in cosφ in the load node, torque and voltage of the synchronous motor. The curve of change in the moment of a synchronous machine under external disturbance indicates the preservation of stable synchronous operation of the motor.

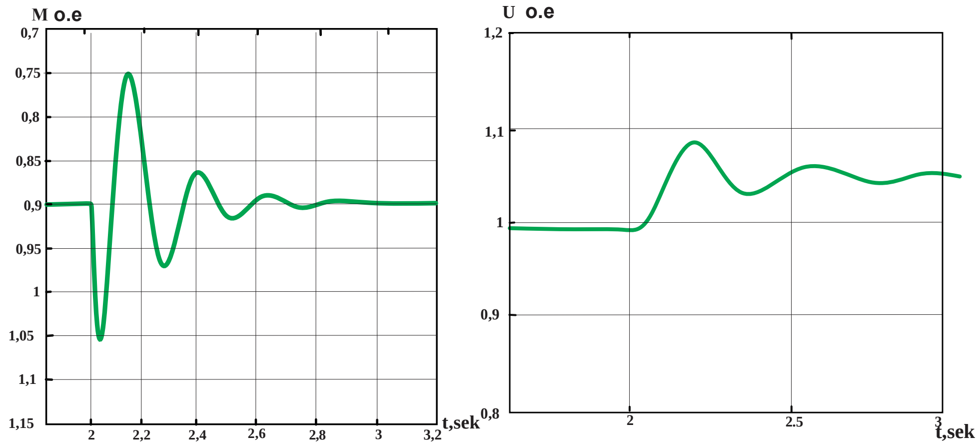


Fig. 3. Changing torque and voltage synchronous

VI. CONCLUSION AND FUTURE WORK

Thus, a synchronous motor equipped with a fuzzy controller as an AEC system is able to maintain cosφ by controlling the level of reactive power in the node. The described approach to controlling the excitation of synchronous motors of pumping stations ensures that the maximum value of cosφ is maintained in order to minimize energy losses in the network when the load changes in the connected node. Large pumping stations incorporating synchronous motors with power reaching several tens of megawatts can be used as reactive power compensators for load nodes to ensure minimization of energy losses in networks.

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