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Principles for Controlling the Excitation of Synchronous Motors of the Compressor Installation

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ABSTRACT: The general requirements for a system for automatically controlling the excitation of synchronous motors of a compressor unit are given, taking into account its operating modes. The principles of regulating the excitation of synchronous electric drives of the compressor installation, with the aim of increasing its efficiency and reliability, are grounded. A method is proposed that makes it possible to simplify the system of automatic control of excitation and increase the efficiency of stabilization of the set value of the power factor of the synchronous motor of the compressor unit, this eliminates intermediate and additional transformations in the electromechanical control system. A block diagram of a synchronous motor with automatic excitation control is presented.

KEY WORDS: automatic excitation control, compressor installation, excitation control principles, synchronous motor.

I. INTRODUCTION

In large compressor stations, as a rule, synchronous motors (SM) are used as a drive motor for compressors [1-3]. The widespread use of a synchronous motor is due to the fact that they allow the rational use of electrical energy from the mains, have high static and dynamic stability. The main advantage of a synchronous motor over asynchronous motors is that by changing the excitation current of the SM, it is possible to change the reactive power. Depending on the excitation current, reactive power can be supplied to the network (during over excitation) and consumed from the network (under over excitation) [4-12].

Excitation systems must satisfy the operation of synchronous machines in normal and emergency conditions. Moreover, they must provide [13]:
- the necessary power of the excitation sources;
- the required range of changes in excitation as a function of the parameters of the synchronous machine mode and the range of action of the automatic controller;
- the appropriate limit value of the excitation;
- the certain slew rate of the rotor current of the synchronous motor.

Some of these parameters determine the design of the excitation systems and, therefore, their cost. When considering the rational requirements for them, take into account the properties of automatic controllers and other controls.

Automatic control of excitation (ACE) is an effective means of increasing the static and dynamic stability of SM at given loading modes, as well as maintaining normal voltage in the load node within the allowable thermal regime of the engines.

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Synchronous motors have a high power factor equal to unity for low power installations, and operate, as a rule, with a leading cosφ in high power installations. The efficiency of modern synchronous motors reaches a value of 0.96 - 0.98. The detailed description of the technical and economic advantages of diabetes is given in the literature [14].

The rational mode of operation of synchronous electric drives of compressor stations is considered to be those modes of operation that ensure the best operating modes of the supply network in terms of reducing energy losses and the best use of the engines in terms of electromechanical properties and characteristics, cosφ and efficiency.

The required modes of SM and the mains supply can be carried out by ACE systems as a function of voltage, reactive power, stator current, angle of phase shift of the current relative to voltage, angle of shift of the axes of the stator and rotor of the angle θ, and a combination function of these values.

In some cases, it may be appropriate to control the SM excitation according to a more complex law, for example, two-channel control by voltage and current of the stator, by voltage and angle θ by the active component of the stator current and power factor, and finally, by the principle of strong control, which regulates deviations of the mode parameters and their derivatives.

In general, the following requirements are imposed on ACE-SM systems:
1. Saving stable operation when changing the parameters of the supply network (voltage, frequency, cosφ, reactance, etc.);
2. Stability in ensuring a given mode;
3. The simplicity and reliability of measuring the parameters by which the engine ACE is carried out, as well as the high sensitivity of the measuring elements;
4. High operational reliability of the regulator and the entire system of the ACE engine.

An analysis of various laws regulating the excitation of diabetes is given in the literature [15-19]. Gas pumping units are mechanisms with long operating modes. The load on the drive shaft of the SM is calm. Therefore, when choosing a rational law of regulation of excitation, one must proceed from the following recommendations.

With a uniform load and a stable voltage level, it is advisable to work with SM with a modified excitation current, which ensures the optimal energy consumption and stability of the electric drive system. It is necessary to provide for the formation of excitation in the event of an emergency voltage drop below the set value. With a uniform load and a changing voltage level, it is advisable to regulate the excitation on the constancy of voltage on the tires.

II. METHODOLOGY

For SM of a wide range of capacities operating with a slowly varying load on the shaft, it is possible to apply the law of regulation of excitation to a minimum of losses or to the constancy of the power factor of the engine or on the tires of the power substation of the compressor station.

The economic efficiency of a synchronous motor depends on the choice of the excitation system, which includes the excitation winding of the synchronous motor and the excitation device electro machine, static and brushless.

Electro machine excitatory devices are a direct current generator mechanically coupled to the shaft of the drive motor. The excitation winding of the exciter is powered either by a self-excitation circuit or by an independent excitation circuit. The main advantages of such exciters are the simplicity of the control circuit and the autonomy of the excitation devices, which is manifested in the fact that the excitation current does not depend on the voltage of the supply network. The disadvantage of electrical machine exciters is low operational reliability and lower efficiency.

Static excitation devices are the most common devices used to excite the synchronous motor and include the controlled rectifier, an electronic control system and a transformer through which the device is connected to the electrical network. Technical and economic indicators and the reliability of static excitatory devices are higher than that of electrical machines. Their significant advantage is speed.

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In static excitatory devices, various rectification schemes are used - a three-phase bridge circuit, a star circuit with neutral removed and a three-phase asymmetric rectification circuit. At low powers, it uses a star circuit with neutral removed, at higher powers, it uses a three-phase bridge circuit. In a three-phase asymmetric rectification circuit, the number of controlled gates is halved compared to the symmetric circuit, which greatly simplifies the control system of the exciter device.

Brushless excitation devices with rotating rectifiers do not have a sliding contact in the excitation circuit, which gives them a number of advantages. The disadvantages of this excitation system include the difficulties of monitoring and measuring the current and voltage in the field winding, as well as the design difficulties that arise when it is necessary to place a discharge resistor on the shaft to close the field winding when starting and damping the field of the field winding. Currently, the compressor stations have not implemented a brushless exciter system.

Currently, with the development of semiconductor technology, semiconductor static thyristor exciters are widely used. These exciters are designed to power the field winding and control the excitation current of the synchronous motor during direct or reactor start-up from the network. The use of thyristor exciters represents the following advantages:
-increases the efficiency of the entire installation by reducing operating costs for maintenance and repair;
-reduces energy consumption
- practical lack of inertia;
- wide regulatory possibilities and low power required for this;
- high efficiency.

When working, the exciter provides:
- starting a synchronous motor with automatic supply of excitation as a function of stator current or slip;
- smooth adjustment of the excitation current from 0.3 to 1.4 nominal with the possibility of adjusting the regulation limits;
- limitation of the excitation voltage to a minimum (within 0-0.5 of the nominal value);
- protection of the rotor from prolonged over current;
- forced voltage of 1.75 of the nominal value at the rated voltage of the network supplying the exciter. Excitation forcing is triggered when the voltage of the stator network drops by 15 - 20% of the nominal value;
- forced damping of the rotor field when the engine is switched off, engine power is interrupted and there is an additional signal to damp the field.

When operating in emergency control mode, the exciter provides a complete adjustment of the excitation current from zero to the boost value with the possibility of adjusting the regulation limits.

Based on the foregoing, it can be noted that it is of practical interest to control the excitation of synchronous electric drives of compressor stations to a minimum of losses or to the constancy of the SM power factor.

In accordance with the recommendations of the international meeting on excitation systems and devices for automatically controlling the excitation of synchronous motors, it is advisable to regulate the excitation currents of synchronous electric drives of compressor stations to a minimum of total energy losses in the SM and the power supply system.

In [18], an analytical way was considered to determine the law of regulation of the excitation current of a synchronous electric drive, which ensures a minimum of total energy losses in synchronous drive motors and the supply network, taking into account changes in the supply voltage and load on the motor shaft.

The practical implementation of the obtained law of regulating the excitation current of SM presents certain difficulties due to the complexity of measuring the load moment entering it. However, one can measure this moment indirectly.

So, this moment is quite accurately determined by the pressure, which depends on the levels of the suitable and outlet channels of the compressor station, which are easily measured. On the other hand, we can assume that the moment on the shaft is proportional to the current of the motor stator, i.e. instead of the relative moment, the relative stator current can be set. In the latter case, a system for regulating the excitation current, which ensures a minimum of total losses, can be built using two feedbacks - according to the voltage of the stator through voltage transformers (VT) and current (CT). The signals, which, through a solving device (SD), which implements the adopted control law, affect the input of a thyristor converter (TC), consisting of a pulse-phase control system (PPCS) and a controlled rectifier (CR), which feeds the excitation windings of the LEDs are shown in Figure 1.

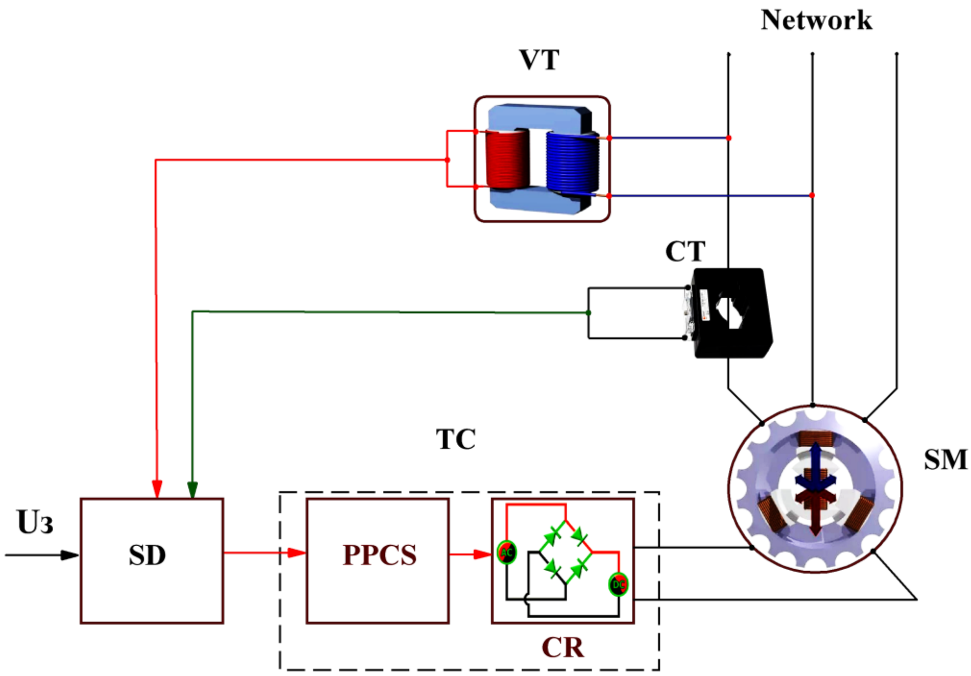

Fig. 1. Block diagram of ACE SM for minimum energy losses

III. RESULTS

Consider an ACE system that ensures the constancy of a given optimal value cosφ of a synchronous compressor electric drive. Known methods and systems for antiretroviral therapy based on various management principles are quite complex in terms of technical implementation and multi-element.

To increase the efficiency of cosφ stabilization and simplify the ACE scheme, an ACE electro machine system is developed, developed in the laboratory of the Automated Electric Drive Institute of Energy and Automation of the Academy of Sciences of the Republic of Uzbekistan, the functional diagram of which is shown in Fig. 2. Here are indicated: VT – voltage transformer; CT – current transformer; PS – power source, ShCP – shaper of control pulses; U_3 – set point voltage in the IGF; CR - controlled rectifier; R_p – regulatory resistance in the exciter circuit of the exciter; E – exciter; EWE - excitation winding of the exciter; I_0 – rectifier current; I_{ec} - exciter current; i_f – excitation current of the SM; EWSM - excitation winding of a synchronous motor.

Note that, in principle, any known rectification scheme can be used as a shock wave.

As can be seen from Fig. 2, the CR is fed from the secondary winding of the VT. The output CT winding is connected to the input of the ShCP, from the output of which we obtain control pulses shifted by the set voltage U_3 by a certain angle relative to the output voltage of the VT transformer in order to set the set value of the cosφ SM. The CR output is connected in parallel with the regulating resistance and counter-sequentially with the exciter armature and the EWE. The exciter output is connected to the excitation winding of the SM.

This goal is achieved by the proposed ACE system by applying power to the excitation winding of the SM, determined by the difference between the exciter power and the additional power received from the controlled rectifier, and the

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valves of the latter are controlled by pulses that are synchronized by the current signal of the phase winding of the SM stator without intermediate transformations (filtering, rectification, gain comparisons, etc.).

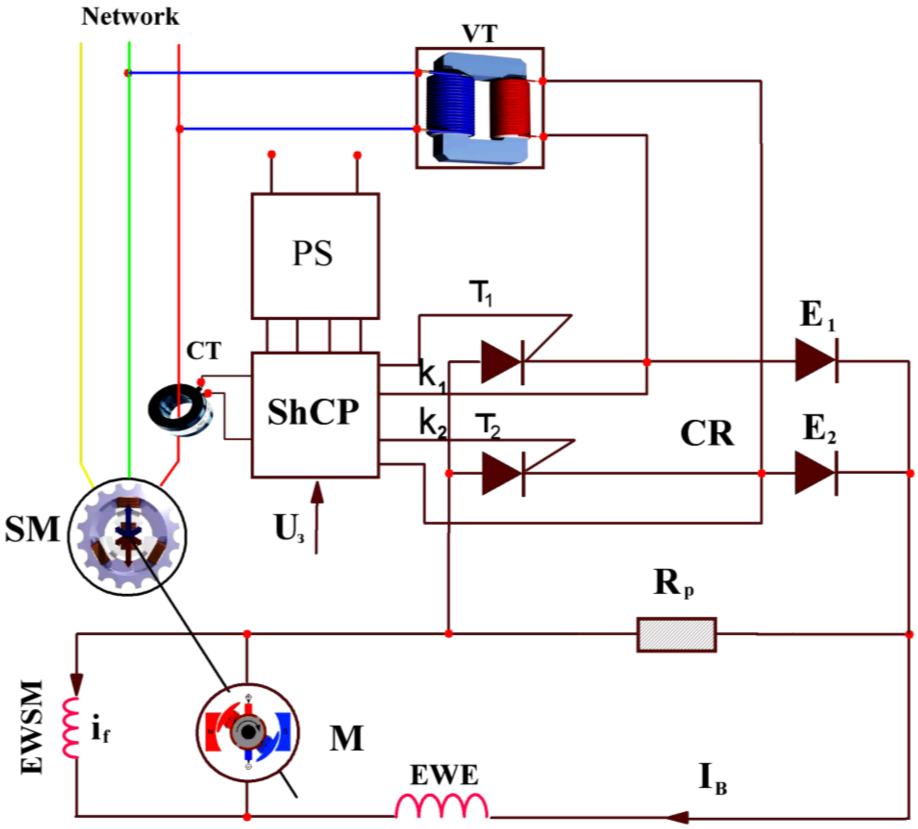

Fig. 2 ACE scheme for the constancy of cosφ

In this ARV system, with an increase in the angle φ, a decrease in the additional regulated power occurs, which will lead to an increase in the excitation power of the SM, since the latter is determined by the difference between the exciter power and the additional power. An increase in the excitation power of SM will lead to a decrease in the angle φ. With decreasing angle φ, the process is opposite.

For the practical implementation of the proposed ACE system, we use control rectifiers with the property of sensitivity phase. With an increase in the angle of regulation (the angle φ is used as the angle of regulation), the output voltage, and therefore the power of the angle at constant load, decreases, and with a decrease in the angle of regulation, the opposite is true.

Consider the principle of operation of this ACE system. Assuming that the phase of the output voltage of the transformer VT in time is fixed, we will shift the control pulses at the input of the ShCP with respect to this voltage using the setpoint voltage U_3, so that the power factor of the SM beat, for example, to unity.

Suppose the load on the shaft of the SM has increased. This will lead to a decrease in cosφ (cosφ becomes inductive) and, consequently, to an increase in the angle of the stator current with respect to the voltage at the output of the V, i.e. the control pulses will shift by an angle Δφ, the latter will lead to a decrease in the value of the rectified current, i.e. to reduce the output power of a controlled rectifier, which is an additional adjustable power. This will lead to a decrease in the voltage drop at the regulating resistance R_p, which will lead to the imbalance of the voltage in the circuit: the exciter armature - the control resistance - exciter winding.

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Since the voltage of the exciter armature depends only on the excitation current in the EWE winding (the speed of rotation of the exciter armature is constant), this voltage remains constant at the initial moment. Due to the decrease in the voltage drop across the regulating resistance, the voltage on the EWE winding increases, which will lead to a gradual increase in the current of the EWE winding, and therefore, the main excitation power of the exciter? An increase in this current leads to an increase in the electromotive force (EMF) of the armature and the voltage at the terminals of the exciter, i.e. excitation winding voltage SM. The steady state in the system at a new load with an initial set power factor will occur when equilibrium occurs in the self-excitation winding circuit, i.e. when the voltage of the armature compensates for the voltage drop on the regulatory resistance and on the winding of the EWE. This is achieved by the fact that the process of voltage increase is accompanied by a corresponding increase in the SM excitation current and a decrease in the mismatch angle Δφ. Thus, stabilization of the set value of the SM power factor occurs.

IV. CONCLUSION

1. Using the proposed method allows to simplify the ACE system and increase the stabilization efficiency of a given value of the SM power factor, i.e. intermediate and additional transformations in the control system are excluded.

2. It is shown that systems for automatically controlling the excitation of a synchronous electric drive of a compressor unit are rationally built according to the following principles:
- to maintain the constancy of the set value of the motor power factor to the constancy of the power factor on the buses of the power substation. When the power substation does not need fictitious power, the most economical will be the mode of operation of the engine with a power factor equal to one;
-to minimum of total electricity losses in a synchronous motor and power supply network.

REFERENCES

[1] Kamalov T.S. Frequency-regulated electric drive of pumping stations of machine irrigation systems, Monograph, Tashkent: Fan, 368 p., 2014.
[2] Olimjon Toirov, Utkir Mirkhonov. Overview of Compressor Installations and Issues of Their Energy saving, International Journal of Advanced Research in Science Engineering and Technology, Vol. 6, Issue 10 , P. 11446-11452, October 2019.
[3] Toirov O.Z., Mirkhonov U.K. General information about compressors, International Scientific conference “Innovative solutions of engineering and technological problems of modern production”, Bukhara, 16 November 2019.
[4] Gusev A.S., Svechkarev S.V., Fertile I.L. An Adaptable Mathematical Model of Excitation Systems for Synchronous Machines, Bulletin of Tomsk Polytechnic University, Vol. 308, No. 7, P. 211-215, 2005.
[5] Bukaros A.Yu., Romchuk N.O., Bukaros V.N. Adaptive compressor electric drive control system, Automation of technological and business processes, Volume 6, Issue 4, P. 84-90, 2014.
[6] Shewit Tsegaye, Kinde A. Fante. Analysis of Synchronous Machine Excitation Systems: Comparative Study, Energy and Power Engineering, Volume 10(12), P. 1492-1496, DOI: 10.5281/zenodo.1130957, 2018.
[7] Laijun CHEN, Tianwen ZHENG, Shengwei MEI, Xiaodai XUE, Binhui LIU, Qiang LU, Review and prospect of compressed air energy storage system, Journal of Modern Power Systems and Clean Energy, DOI: 10.1007/s40565-016-0240-5, 2016.
[8] Timoshchenko K.P., Yurganov A.A. Key Features of Designing Synchronous Machine Excitation Control Systems, Scientific and Technical Journal of St. Petersburg State Polytechnic University, No. 1 (190), P. 75-81, 2014.
[9] Temgenesvskaya T.V. Tuning methods for automatic controllers excitation of synchronous generators, Modern technology. System analysis. Modeling, No. 3 (55), P. 84-91, 2017.
[10] Wei Liu, Changqing Zhu. Modeling and Simulation of Excitation System for Third Harmonic Brushless Synchronous Generator, IOP Conference Series: Materials Science and Engineering, DOI: 10.1088/1757-899X/563/3/032038, 2019.
[11] Bondar I.M., Dudarev K.G., Momotov V.Yu. Voltage Regulation of a Synchronous Generator, Innovation Science, No. 1, P. 8-12, 2018.
[12] Voronkov V.I., Stepanov S.E., Titov V.G., Kryukov O.V. Vector control of the excitation of synchronous engines of gas pumping units, Bulletin of Tula State University. Engineering, No. 3, P. 204-208, 2010.
[13] Barkan Y.D., Orekhov L.A. Automation of power systems, Moscow: Higher school, 271 p., 1981.
[14] Syromyatnikov I.A. Operating modes of asynchronous synchronous motors. M .: Energoatomizdat, 239 p., 1984
[15] Glebov I.A., Loginov S.I. Excitation and regulation systems of synchronous motors, D.: Energy, 113 p., 1972.
[16] Petelin D.P. Automatic regulation of the excitation of synchronous motors, M .: Energoatomizdat, 192 p., 1961.
[17] Venikov V.A. and other. Strong regulation of excitation, Moscow: Gosenergoizdat, 152 p., 1963.
[18] Kamalov TS, Muminov K. Law regulating the excitation of synchronous motors of irrigation pumping stations to a minimum of total losses, Uzbek Journal of Informatics and Energy Problems, No. 3-4, p. 67-71, 1992.
[19] Ipotenko N.R., Ilyina L.V. To the definition of the law of regulation of excitation of synchronous motors for the constancy of the power factor equal to one, Deposited manuscript, Tula Polytechnic Institute, Bryansk Institute of Transport Engineering. Tulla, Bryansk, 1977.