M. I. Burbelo, Dr. Sc. (Eng.), Prof.; A. V. Gaday, Cand. Sc. (Eng.); P. V. Dovgaliuk

USAGE OF SYNCHRONOUS MOTORS FOR REDUCING VOLTAGE FLUCTUATIONS

The paper studies the possibility to reduce voltage fluctuations at the synchronous motor terminals in abruptly-variable modes under different loads and establishes regularities of the motor excitation current control for improving voltage quality in the network.

***Keywords**: voltage, synchronous motors, reactive power compensation.*

Consideration of the problem and setting the task

In case of voltage deviations from the optimal value total diseconomies determined by technological and electromagnetic losses, increase [1]. Technological losses take into account damage caused by the technological process breakdown, deterioration of the product quality, productivity reduction. Electromagnetic losses involve increased losses of electric energy, failure of electrical engineering equipment, malfunction of automatic devices.

Automatic excitation control devices (AEC) of synchronous motors (SM) should be manufactured so that during each technological operation mode voltage in the load node will be kept at the optimal level. The existing AEC do not allow prediction and feedforward control of the voltage modes and electrical energy quality indicators. Optimal excitation current cannot be established under variable load and voltage of the motor. It must be automatically adjusted depending on the specific conditions characterizing power supply system and SM load.

The choice of AEC law must be made taking into account possible changes of the voltage level and electric drive operation mode. E. g., electric drive of the drilling rig winch must raise and lower the drill column at a given speed and variable mass of the string. For optimal electric drive application [2] constant power must be maintained throughout the entire range of the drill column mass variations during raising and lowering. If drilling rig is supplied from a limited-power energy delivering system, active and reactive powers of SM change considerably and load of the winch SM is of impact nature. This leads to deviations and fluctuations of the voltage at the drilling rig input and to SM vibrations. This results in accidents and premature failures of the motors [4].

Aim of the research

Research aim is to determine the possibility of SM application for reducing abrupt and deep voltage drops by dynamic compensation of the reactive power.

Substantiation of the results

While studying quasi-stationary modes of SM, Park – Gorev equation is used in d-q-coordinates written through actual values of quantities [5]. Equation system that characterizes electromagnetic transient processes of SM is presented in a matrix form as

$$\begin{bmatrix} L_d & 0 & M_{sf} & M_{sD} & 0 \\ 0 & L_q & 0 & 0 & M_{sQ} \\ 1{,}5M_{sf} & 0 & L_f & M_{fD} & 0 \\ 1{,}5M_{sD} & 0 & M_{fD} & L_D & 0 \\ 0 & 1{,}5M_{sQ} & 0 & 0 & L_Q \end{bmatrix} \begin{bmatrix} \frac{dI_d}{dt} \\ \frac{dI_q}{dt} \\ \frac{dI_f}{dt} \\ \frac{dI_D}{dt} \\ \frac{dI_Q}{dt} \end{bmatrix} = \begin{bmatrix} -U_d \\ -U_q \\ U_f \\ 0 \\ 0 \end{bmatrix} -$$

$$- \begin{bmatrix} R_s & \omega L_q & 0 & 0 & \omega M_{sQ} \\ -\omega L_d & R_s & -\omega M_{sf} & -\omega M_{sD} & 0 \\ 0 & 0 & R_f & 0 & 0 \\ 0 & 0 & 0 & R_D & 0 \\ 0 & 0 & 0 & 0 & R_Q \end{bmatrix} \begin{bmatrix} I_d \\ I_q \\ I_f \\ I_D \\ I_Q \end{bmatrix}, \qquad (1)$$

where R_s, R_f, R_D, R_Q are active resistances of the stator winding, excitation winding and damper windings respectively along the axes *D*, *Q*; L_d, L_q – inductances of the stator winding along longitudinal and lateral axes respectively; M_{sf}, M_{sD}, M_{sQ}, M_{fD} – mutual inductances between respective windings of SM; U_d, U_q, U_f – voltages of the stator winding along *d*, *q* axes and excitation winding respectively.

In order to solve the problem by the fourth-order numerical Runge – Kutta method, equation system (1) must be written in the normal Cauchy form and supplemented with equations characterizing electromechanical processes:

$$\frac{d\omega_r}{dt} = \frac{-\frac{P(t)}{\omega_r} - M_н(t)}{J}; \qquad \frac{d\theta}{dt} = \omega_r - \frac{\omega}{p_0}. \qquad (2)$$

In order to drive the winch, SM of СДЗБ-13 type with the power of 450 – 630 KW is used at the drilling rigs. Excitation system of such motors provides excitation control. Voltage and excitation current could be controlled with the application different control laws and parameters.

When excitation current is forced (Fig. 1), SM are capable of abruptly changing the reactive power (Fig. 2). In this case excitation current is forced from 235A to 325A and reactive power of the loaded SM is reduced from 400 KVAr to zero.

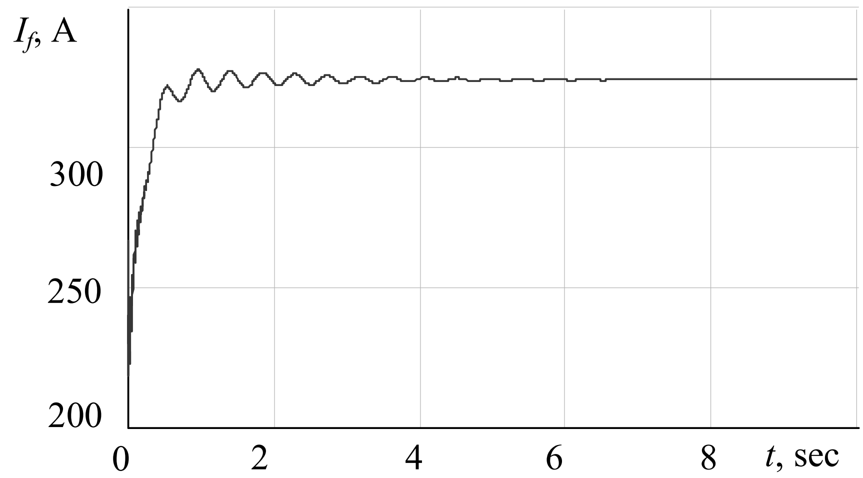

Fig. 1. Forcing of SM excitation current

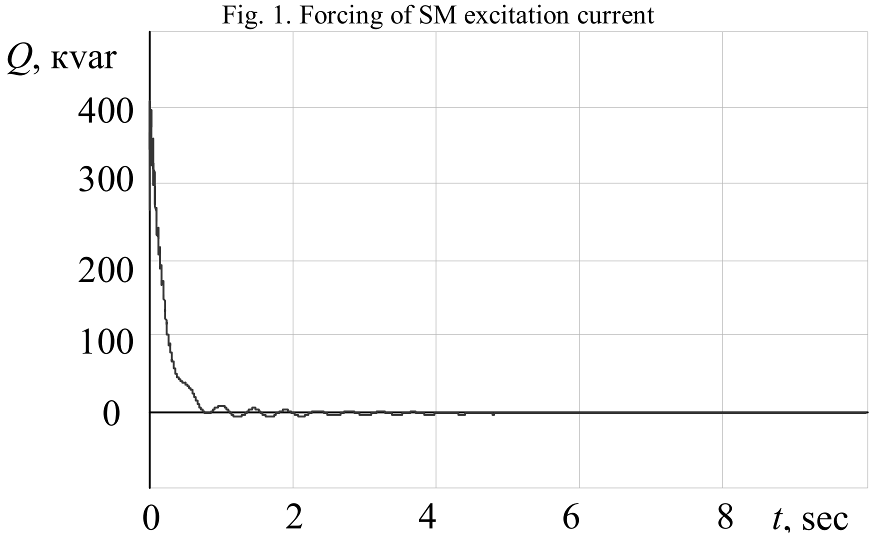

Fig. 2. Reduction of the SM reactive power consumption in the case when excitation current is forced

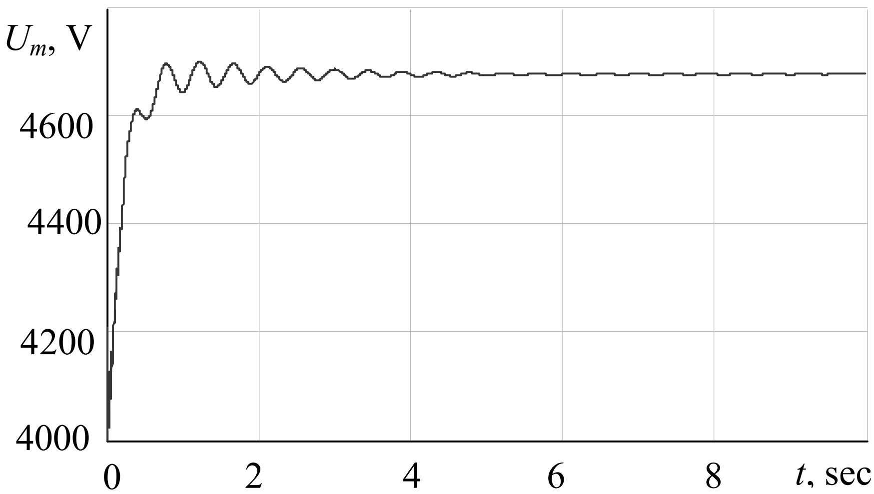

Fig. 3. Dependence of the phase voltage amplitude in the case when SM excitation current is forced

When SM excitation current is forced, displacement angle, the torque and active power are changing sharply. Voltage in this case has oscillatory character (Fig. 3). This requires increasing time constant of the proportionally-integrating controller to a value at which the voltage dependence becomes smooth in time (curve 1, Fig. 4). When the drilling column mass varies, adaptation of the controller time constant depending on the load is necessary for the electric drive of drilling rig winch due to the impermissibility of abrupt changes of mass at the shaft: maximal time constant value must be set for small load and as the load increases time constant should be gradually reduced. This, in particular, is represented by curve 2 in Fig. 4, built when the load at the machine shaft is reduced by 15 % for the same control parameters.

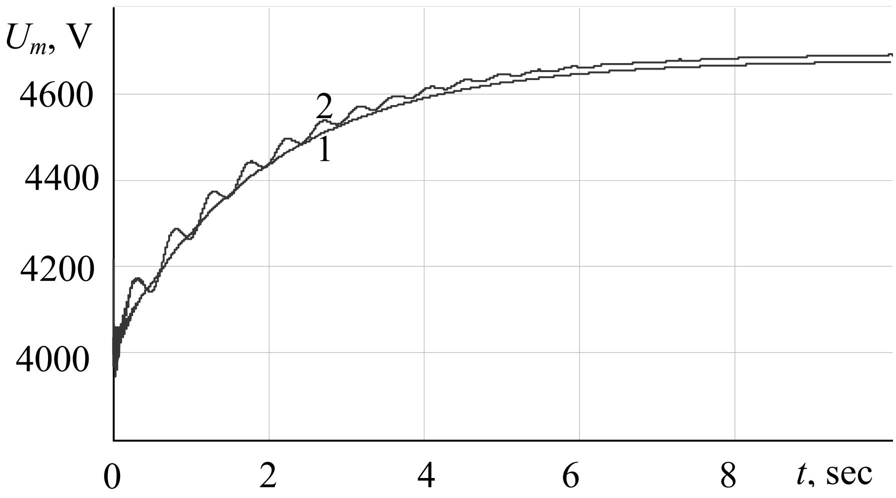

Fig. 4. Dependences of the phase voltage amplitude in the case when the controller time constant is increased for different SM loads

Conclusions

Thus, forcing of SM excitation provides the possibility to reduce voltage fluctuations through dynamic compensation of the reactive power. The choice of time constant for SM proportionally-integrating controller depends on the drilling column mass.

REFERENCES

1. Суднова В. В. Качество электрической энергии / В. В. Суднова. – М. : ЗАО Энергосервис, 2000. – 80 с.

2. Моцохейн Б. И. Электропривод буровых лебедок. / Б. И. Моцохейн, Б. М. Парфенов. – М. : Недра, 1978. – 304 с.

3. Саляк И. И. Исследование автоматического регулятора возбуждения приводного синхронного двигателя буровой лебедки. / И. И. Саляк, Р. А. Селепина, Г. С. Корниевич, В. Н. Холин. – Машины и нефтяное оборудование. – 1975. – № 8. – С. 30 – 35.

4. Абрамович Б. Н. Бесщеточные синхронные двигатели с повышенными эксплуатационными характеристиками для главных приводов буровых установок. / Б. Н. Абрамович, А. Б. Купцов, И. Ф. Лозовой. – М. : ВНИИОЭНГ, Машины и нефтяное оборудование. – 1982. – № 1. – С. 26 – 28.

5. Костюк О. М. Колебания и устойчивость синхронных машин / О. М. Костюк, М. И. Соломаха. – К. : Наукова думка, 1991. – 200 с.

Burbelo Myhailo – Professor of the Department of Electrotechnical Power Consumption Systems and Power Management.
Vinnytsia National Technical University.

Gaday Andriy – Ass. Prof. of the Power Supply Department
Lutsk National Technical University.

Dovgaliuk Petro – student of the Institute of Electric Power Engineering and Electromechanics.
Vinnytsia National Technical University.