ГІРНИЧА ЕЛЕКТРОМЕХАНІКА

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STUDY ON THE START-UP OF NOT SALIENT-POLE OF SYNCHRONOUS ENGINE

The start of synchronous electric machines (SEM) intended for the mechanisms with large inertia moment must be carried out from the reduced voltage, with this aim start devices of different kinds and structures including on the basis of semiconductor converters of electric power are used [4,5].

One of the basic objectives in the determination of the direction and strategy of study concerning development and practical realization of energy efficient systems and laws of their control for synchronous electric machines SEM start is a formulation of an adequate mathematical model of a machine in the different systems of coordinates and analysis of transfer functions in different control actions.

In order to formulate the mathematical model the generalized system of differential equations of salient-pole Park-Gorev SEM in the vectorial form of record was taken as a principle [2,3,6].

As a rule, mathematical models SEM are built in the different systems of coordinates taking into consideration aims and convenience in problem-solving [1,3].

For the study it has been chosen the fixed ($\omega_K=0$) coordinate system α and β, coordinates of variable is denoted with indices $\rightarrow A, B$. (index s is referred to the parameters of a stator, index R is referred to the appropriate parameters of rotor winding; index f – to the parameters of drive winding).

The obtained quotations (1) have been used for the study. The model is nonlinear at the expense of the presence of cross couplings in the operating torque and counter-EMF rotation induced at the motor winding.

$$\left\{\begin{array}{c}
\frac{d\psi_{RA}}{dt} = -I_{RA} * R_R - \left(\psi_{RB} + \Psi_{fB} * \frac{L_{fR}}{L_f}\right)\omega + \\
U_R sin\theta_{Uf}\,\frac{d\psi_{RB}}{dt} = -I_{\mathbf{RB}} * R_R - \left(\psi_{RA} + \Psi_{fA} * \right. \\
\left. \frac{L_{fA}}{L_f}\right)\omega + U_R sin\theta_{Uf} \\
Esa = \frac{2L_{SR}}{3L_R}.\frac{d\psi_{RA}}{dt} + \frac{2L_{S\mathrm{a}}}{3L_{\mathrm{a}}}. \\
Esb = \frac{2L_{SR}}{3L_R}.\left(-0.5\,\frac{d\psi_{RA}}{dt} + 0.866\,\frac{d\psi_{RB}}{dt}\right) \\
Esb = \frac{2L_{SR}}{3L_R}.(0.5\,\frac{d\psi_{RA}}{dt} + 0.866\,\frac{d\psi_{RB}}{dt}) \\
\frac{dIa}{dt} = (Usa - IaRs - Esa)/Ls \\
\frac{dIb}{dt} = (Usb - IbRs - Esb)/Ls \\
\frac{dIc}{dt} = (Usc - IcRs - Esc)/Ls \\
M_E = \frac{3L_{SR}A(\Psi_{SA}\Psi_{RB} - \Psi_{SB}\Psi_{RA})}{2}
\end{array}\right. \qquad (1)$$

$$\frac{d\omega}{dt} = \frac{M_E + M_H}{j}\,\frac{d\theta}{dt} = \omega$$

The solution of equations (1) makes it possible to study the transient processes at salient-pole and nonsalient-pole SEM with different laws of formations of phase voltage of motor, excitation current and load.

In order to solve the assigned task Fortran software has been used. For the solution of nonlinear multiply connected differential equations the Runge-Kutta method of the 4th level has been used.

The model adequacy of the synchronous machine in the coordinates of the stator current - $\psi_{S}\,_{is}$ is confirmed with the results of the calculation, presented in Fig. 1,2,3 – that coincide with the results published in technical literature.

Actually, steel magnetic saturation can be observed at SEM. The calculation of saturation effect should be carried out by means of restriction of steel magnetic flow and rotor. The saturation effect can be obtained using the simple algorithm:

$$\begin{aligned} &\text{if } \psi_s > \psi_{Nas},\ \text{then } \psi_s = \psi_{Nas} \\ &\text{if } \psi_R > \psi_{Nas},\ \text{then } \psi_R = \psi_{Nas} \end{aligned} \qquad (2)$$

In Fig. 4-6 the machine modeling of the transient processes at synchronous machine with steel saturation have been shown. The steel saturation has been formulated by the system of equations (2).

The transient processes at the stator and rotor currents before synchronism input are analogue to the processes without saturation. At synchronism input currents contain high-frequency components causing higher electric power consumption.

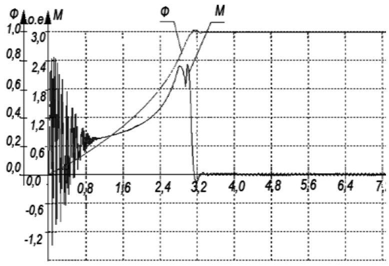

Fig. 1 The machine modelling of transient processes at moment *M* and rotation frequency *ω* of synchronous machine at direct start

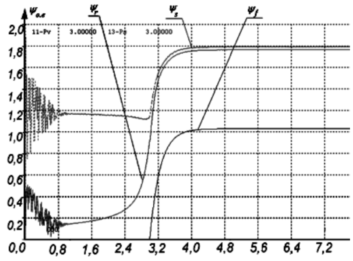

Fig. 2. The machine modelling of transient processes at interlinkage of stator, rotor and excitation of motor at direct start

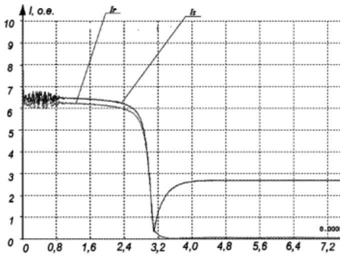

Fig. 3. The machine modelling of transient processes at current of stator, rotor of synchronous machine at direct start

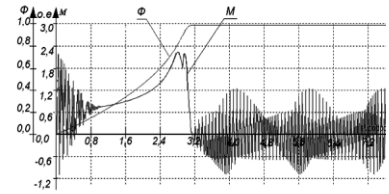

Fig. 4. The machine modelling of transient processes at moment – M and rotation frequency ω of synchronous machine at direct start with steel saturation

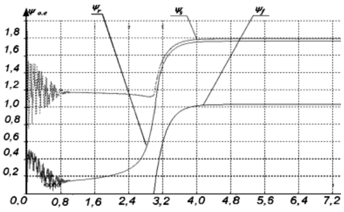

Fig. 5. The machine modelling of transient processes at interlinkage of stator, rotor, excitation and rotation frequency ω of synchronous machine at direct start with steel saturation

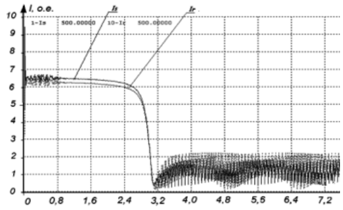

Fig. 6. The machine modelling of transient processes at current of stator and rotor of synchronous machine at direct start with steel saturation

It is possible to improve dynamic and energy indices at a start of synchronous machine by means of use of a soft start – voltage and frequency varying linear during the time. The machine modelling of transient processes at current of stator, rotor of synchronous machine at a soft start with steel saturation have been shown in Fig. 7.

The quality of the transient processes in currents at a soft start is improved to the moment of input of SEM in synchronism. Furthermore, the character of the transient processes will be the same as with excitation, taking into account the saturation.

Fig. 8. shows the curves of energy consumption for the cases under study.

According to the obtained results it can be noticed that at a linear start the energy consumption is 30-40 % lower in comparison with a direct start.

Taking into consideration above-mentioned information it is possible to make a conclusion:

1. The suggested mathematical models of the synchronous machine adequately reflect the processes performed in the real engine and can be used for the study concerning assessment of the effective use of different starting devices and laws of their control for SEM.

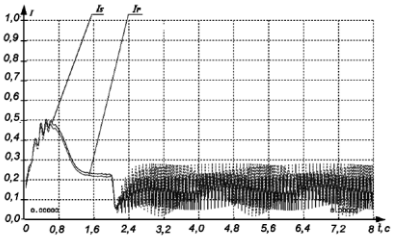

Fig .7. The machine modelling of transient processes at current of stator, rotor of synchronous machine at a soft start with steel saturation

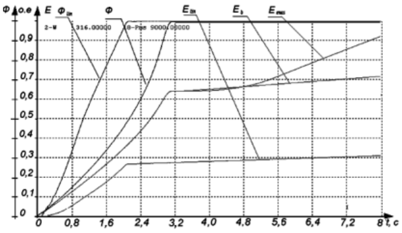

Fig. 8. The machine modelling of energy consumption at a direct start E_e, start with saturation E_{enas} and at a linear start E_{lin}

2. The steel saturation of the synchronous machine lead to high-frequency generation, modulated by low-frequency ones. The amplitude of peak current can achieve 40-90% of nominal values of the current.
3. The energy consumption at a linear start is 30 - 40% less than at a direct start.

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ДИНАМИЧЕСКИЕ И СТАТИЧЕСКИЕ НАГРУЗКИ В ДВУХДВИГАТЕЛЬНЫХ СИНХРОННЫХ ПРИВОДАХ БАРАБАННЫХ МЕЛЬНИЦ

Снижение удельных затрат на измельчение сырья идет по пути создания крупногабаритных барабанных мельниц большой единичной мощности. В связи с ограниченными возможностями механических передач при увеличении мощности свыше 4500–5000 кВт возникла необходимость в создании двухдвигательных приводов, позволяющих передавать необходимую мощность к барабану двумя силовыми потоками. В настоящее время наибольшая мощность двухдвигательных приводов, содержащих две приводные шестерни и зубчатый венец, составляет 15000 кВт [1]. Опыт эксплуатации двухдвигательных приводов с синхронными или асинхронными двигателями, работающими в синхронном режиме, показал, что существует проблема выравнивания нагрузки между линиями передач каждого двигателя. Кроме того, в двухдвигательных приводах возникают дополнительные факторы, вызывающие в механической системе вынужденные колебания [2].

Целью статьи является оценка факторов, влияющих на формирование и распределение нагрузки между линиями передач в двухдвигательных приводах барабанных мельниц.

Неравномерность распределения нагрузки определяется «углом рассогласования роторов». Под углом рассогласования роторов $\Delta\varphi$ будем понимать угол, на который необходимо повернуть ротор одного двигателя относительно другого, чтобы нагрузка распределилась равномерно.

Различают постоянную и переменную составляющую угла рассогласования роторов в синхронном двухдвигательном приводе. Постоянная величина угла рассогласования $\Delta\varphi_0$ состоит из электрической и механической составляющей, т.е.