THE RESEARCH INTO THE SELF-STARTING MODE OF THE INDUCTION MOTOR

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Keywords:* *the induction motor, mathematical model, start-up

Introduction

According to normative documents calculations of short-circuit currents and self-start of induction motors (IM) are necessary for carrying out as at designing, and while in service power industry objects, for example, on a voltage 6 and 0,4 kV short circuit currents are necessary for making check of the equipment annually. Definition of short-circuit currents is necessary for a electric devices choice and current-carrying wires, calculation of relay protection of electric connections circuit's elements of power station.

Now wide experiences of calculation of short-circuit currents and induction motors' self-starting is saved up.

The theory of self-start now is developed up to a level, allowing solving the problems showed by practice. As self-start understand a normal operating mode's automatic restoration process for non-disconnected electric motors after short-term power supply breakdown caused by disappearance or step-down of the feed voltage.

The feed short-term break of electric motors is observed at working feed switching-off and switching to the reserve power supply.The short-term deep voltage reduction appears at short distances short-circuit in the power supply system for the IM.

At switching-off of a feed and deep voltage step-down occur decreases of motors' rotation frequency under the influence of the restoring torque of mechanisms.

For the solving of various automation problems often prefers to the controllable induction electric drive. In this connection significant interest is represented with development of effective approaches to the analysis and synthesis of systems of the controllable electric drive, which basic and main element is the induction electric motor.

Research is carried out on models, therefore it is expedient to have well organized model of the induction machine, allowing modeling the basic operating modes of such drive, connecting model of the induction motor with models of various automatics devices.

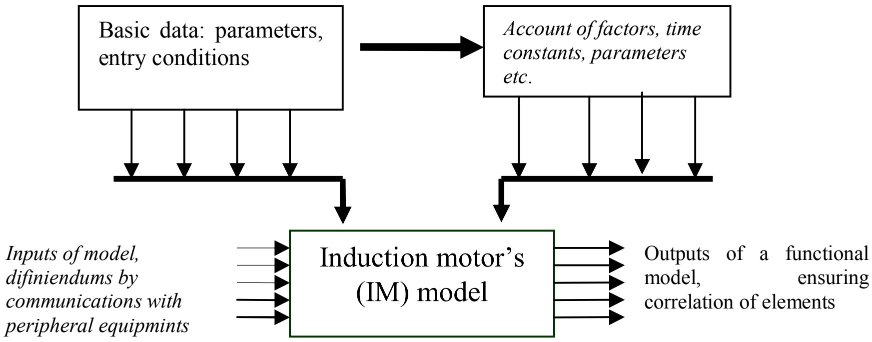

Figure 1. Structural scheme of induction motor model

Induction motors till now are widely used on power plants as the electric drive of the basic mechanisms. But, despite of long-term experience of these electric motors application, their opportunities aren't always completely used. It is connected with a number of restrictions concerning conditions of start-up and especially self-start of motors [1, 5]. To liquidate the reasons of such restrictions, it is necessary to specify and give the quantitative characteristic of the basic operational processes in electric motors at deviations from normal modes. The analysis of transitive modes of start-up, run-out and self-start of motors enables:

- Correctly to estimate circuits of start-up, control and protection of induction motors;
- To determine an admissibility of self-start and its maintenance with corresponding devices of protection and automatics;
- To increase the reliability of electric drives work.

For research of switching's modes of the motors working from one power supply, the mathematical model which is based on the Park – Gorev's equations has been used. The system of the algebraic-differential equations describing electromechanical processes in induction machines is received. Use of such model allows analyzing electromagnetic, mechanical and power parameters, both the induction motor and all electric drive as a whole.

$$\left.\begin{aligned}
U_{1d} &= R_1 i_{1d} - \omega_{0el}\Psi_{1q} + \frac{d\Psi_{1d}}{d\tau} \\
U_{1q} &= R_1 i_{1q} + \omega_{0el}\Psi_{1d} + \frac{d\Psi_{1q}}{d\tau} \\
U_{2d} &= R_2 i_{2d} - (\omega_{0el} - \omega)\Psi_{2q} + \frac{d\Psi_{2d}}{d\tau} \\
U_{2q} &= R_2 i_{2q} + (\omega_{0el} - \omega)\Psi_{2d} + \frac{d\Psi_{2q}}{d\tau}
\end{aligned}\right\}. \tag{1}$$

$$T_M \frac{d\omega}{d\tau} = \left[M_{em} - M_{StL}\right]$$

Where T_M - a time constant of the machine in electric radians,
and flux linkages are determined as

$$\left.\begin{aligned}\Psi_{1d} &= X_1 i_{1d} + X_{ad} i_{2d};\\ \Psi_{1q} &= X_1 i_{1q} + X_{ad} i_{2q};\\ \Psi_{2d} &= X_2 i_{2d} + X_{ad} i_{1d};\\ \Psi_{2q} &= X_2 i_{2q} + X_{ad} i_{1q};\end{aligned}\right\} \qquad (2)$$

Where $u_{1d}, u_{1q}, u_{2d}, u_{2q}$ are components of stator and rotor voltage;

$\psi_{1d}, \psi_{1q}, \psi_{2d}, \psi_{2q}$ are components of flux linkages;

$i_{1d}, i_{1q}, i_{2d}, i_{2q}$ are components of stator and rotor currents;

$x_1, x_2, x_{ad}, r_1, r_2$ are parameters of induction motor drive;

M_{em}, M_c are electromagnetic moment and driving mechanism's resistance moment.

Having resolved system of the equations concerning derivative currents, we receive mathematical model with which help the estimation of process is carried out at which non-disconnected electric motors at restoration of a feed are capable to gain momentum up to nominal rotation frequency.
At submission of a feed the mode actually self-start of electric motors of own needs when rotation frequency grows is carried out. Self-start will be successful if the units of own needs participating in this mode, to be developed up to working rotation frequency for allowable time. Success of self-start depends on time of a feed break, parameters of a power line, total power of non-disconnected motors and their load, mechanical characteristics of mechanisms and other factors.
Self-start is considered executed if after restoration of power supply under the working or emergency circuit the induction motor was dispersed till normal rotation frequency and continues long to work with normal productivity of the resulted mechanism and loading of the motor. Self-start allows using the automation system means of power supply most full.
If the fault caused step-down of voltage is quickly liquidated by action of relay protection and automatics devices at the executed self-start it is not failure or a reject in work of power supply system. The fault practically does not arise.
If self-start is not carried out, the induction motor stops, and though automatics devices have worked, the fault can be significant, is especial at frustration of a complex work cycle.
The program is developed, allowing to model modes of start-up the IM, voltage reductions and the subsequent restoration of a voltage, that as a matter of fact and reflects process of self-start.
As modeling object was used the induction motor with the following parameters: P_{2nom} =110kW; 2p=4; s_N=0,035; GD^2=205 Nm^2; R_1=0,01; R'_2=0,015; X_1=0,1; X'_2=0,12; X_{ad}=4,5.
On fig. 2 are submitted curves of change of a current, the electromagnetic moment and rotation speed of the induction motor with step-down of a feed voltage up to 0,6U_N. In the beginning of this mode the induction motor passes in a generating mode. After a voltage restoration there is a self-start mode.

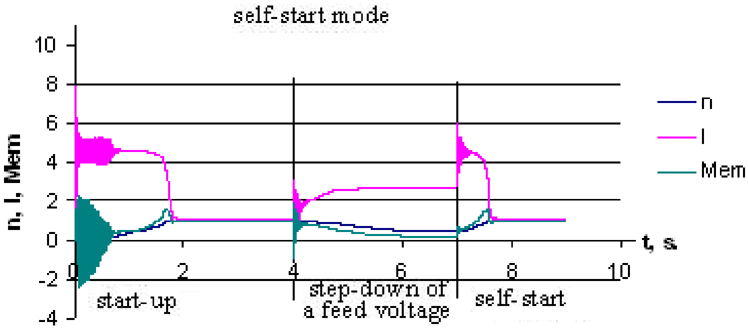

Figure 2. Curves of change of a current, the electromagnetic moment and speed of rotation of the induction motor with step-down of a feed voltage up to $0{,}6U_N$.

Other case is self-start after a short-term break of power supply at operation of devices of automatic turn on to the reverse (ATR) or automatic repeated turn on (ART). Here in self-start participates motor which at disappearance of a voltage was disconnected from a feed and has been again connected to them after action of automatics.

Switches of electric motors with voltage higher than 1000B, subject to self-start; in most cases during a break of power supply remain included. Motors, which self-start cannot be executed or it is not required in production criterions, should be disconnected before restoration of a feed from a network by the switches with the help of the minimal relay of a voltage, frequency relays, etc.

All process of self-start can be divided into two stages.

The first stage – run-out of the electric motor. Single refers to run-out at which one electric motor appears disconnected from a network and from other motors, or such when other motors, electrically connected with it, do not render appreciable influence on run-out process. Usually it occurs, if between the considered motor and others the reactor or the transformer is included. Any motor which has been switched - off from the power supply, develops at run-out EMF in a stator's winding. At induction motors EMF it is insignificant, at synchronous it is significant. The more EMF, the current of turn on there is more at restoration of a voltage (at an adverse phase of turn on). From this point of view it is desirable to have enough big time intervals before restoration of a voltage, which is increase of action time ATR or ART devices to provide sufficient decrease EMF.

The second stage - dispersal and restoration of operating conditions. Dispersal occurs at the reduced voltage which value depends on parameters of the network, dispersed motor and other attached loads.

The induction moment developed by the motor during dispersal, is proportional to a square of a voltage. Self-start can be counted executed if at the lowered voltage the superfluous moment of the motor is sufficient for finishing the mechanism up to rated angular speed and if during dispersal the temperature of heating of windings will not exceed allowable value. From this point of view time of a break of power supply should be as it is possible smaller.

For modeling such mode start-up the IM (fig. 3) is carried out, run-out (fig. 4.) on the basis of modeling process run-out the IM can be received hodographs of a rotor current and a voltage on stators terminals (fig. 5).

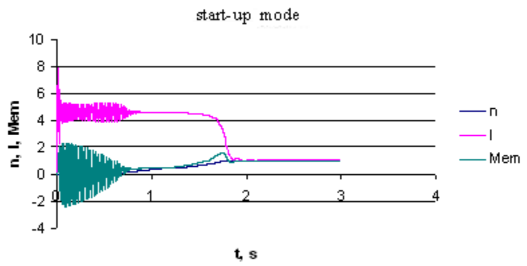

Fig.3. the induction motor start-up process

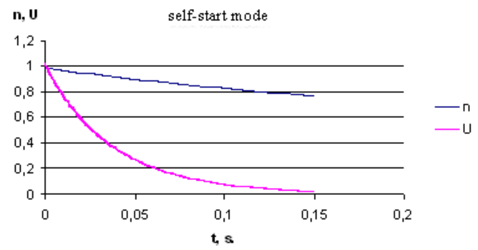

Fig.4. the induction motor's self-start process (voltage and rotation speed in time)

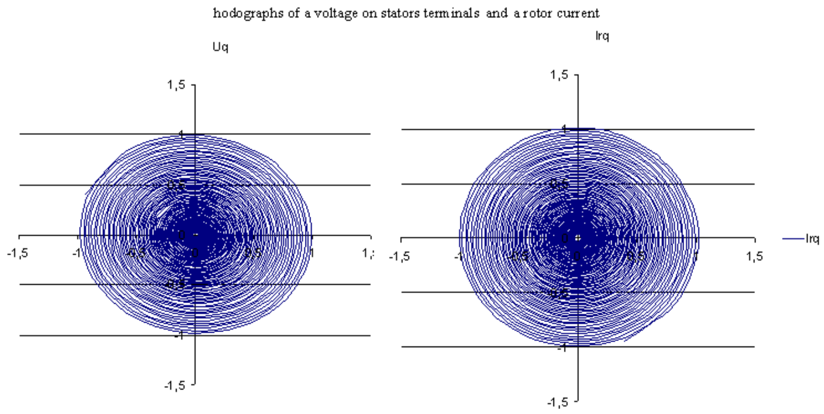

Fig.5. hodographs of a rotor current and a voltage on stators terminals

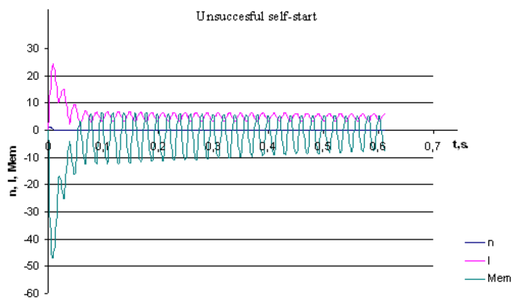

Fig.6 Self-start mode. The curves of rotation speed, current and moment in time. Process is unsuccessful.

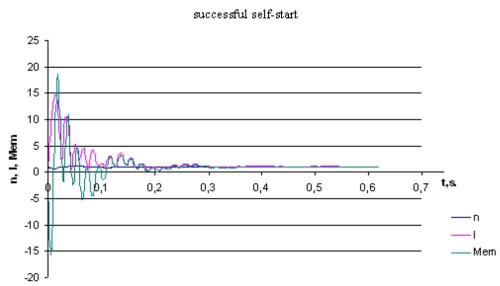

Fig.7 Self-start mode. The curves of rotation speed, current and moment in time. Process is successful.

Simulation of a self-start mode depending on position of a vector of a IM residual stator's voltage, allows to judge success of self-start and correctly to pick up an operating time automatic repeated switch on (after sufficient attenuation of a field of a rotor's winding) (fig. 6 and 7)
On fig.7 is shown the mode at restoration of a voltage conterminous on a phase with EMF on the IM stator's terminals. And on fig. 6. is shown the mode at restoration of a voltage taking place in an antiphase with EMF on the IM stator's terminals. Thus with the help of the enclosed model there is an opportunity to limit an area when it is allowable without the control of phase EMF the IM to carry out restoration of a feed.

Conclusions

The offered mathematical model of the induction motor allows at designing systems of the power supply including a drive of crucial mechanisms to make calculation of parameters of a short circuit and self-start mode.
The analysis of the carried out research of a mode of self-start has shown, that in case of short-term infringement of the power supply caused by deep step-down of the feed voltage, at restoration of a voltage self-start currents do not exceed usual IM starting currents. In that case when there is a short-term break of a feed to switching-off of a working feed and transition to a reserve source or restoration of a voltage to having trunks, self-start process at presence of a field of a rotor the IM can be dangerous if restoration of a voltage occurs quickly enough.

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Ketnere E., K.Ketners, Kļujevska S., Koņuhova M. Asinhronā dzinēja pašpalaides režīma īpatnības.
Mūsdienās pašpalaides teorijas izstrādē ir sasniegts līmenis, kas ļauj risināt praktiskus jautājumus. Īsslēguma strāvu praktiskie aprēķini un arī asinhrono dzinēju pašpalaišanas aprēķini ir jāveic elektroenerģētiskajos objektos. Šajā darbā tiek aplūkoti asinhronā dzinēja pašpalaides procesa matemātiskās modelēšanas jautājumi, kurus apraksta diferenciālvienādojumi d,q,0 koordinātu sistēmā. Pašpalaides režīma pētījuma rezultātā var secināt, ka īslaicīga elektroapgādes traucējuma gadījumā, ja to izraisījis dziļš barojošā sprieguma samazinājums, atjaunojot sprieguma padevi, pašpalaides strāvas nepārsniedz parastās palaišanas strāvas. Gadījumā, kad notiek īslaicīgs barošanas pārtraukums ar darba barošanas atslēgšanu un pāreju uz rezerves avotu vai sprieguma atjaunošanu barošanas kopnēs, pašpalaišanas process asinhronā dzinēja rotora lauka esamības gadījumā var būt bīstamāks, ja sprieguma padeve tiek atjaunota diezgan ātri.

Ketnere E., Ketners K., Klujevska S., Konuhova M., The research into the self-starting mode of the induction motor.
The theory of self-start has now been developed up to the level allowing for solving the problems that arise in practice. Feasible calculations of short- circuit currents and self-start processes in induction motors (IMs) are necessary for their designing and for functioning of the power industry objects including non-stop electric motors. The present work considers the mathematical modeling of self-start transients. A mathematical model of the induction motor is described by the algebraic-differential system of Park-Gorev's equations in the d, q, 0 coordinate system. The analysis of the research results on the self-start mode has shown that in the case of short-term interruption of power supply caused by a deep step-down of feed voltage the self-start currents at voltage recovery do not exceed usual IM starting currents. In the case of a short-term feeding interruption with the working voltage switched off and the transition to a reserve source or the voltage recovery on the power line, the self-start process in the presence of the IM rotor field can be dangerous if the voltage recovery proceeds quickly enough.

Кетнер Э., Кетнер К., Клюевская С., Конюхова М., Особенности процесса самозапуска асинхронного двигателя.
Теория самозапуска в настоящее время разработана до уровня, позволяющего решать задачи, предъявляемые практикой. Практические расчеты токов короткого замыкания и самозапуск асинхронных двигателей необходимо выполнять как при проектировании, так и в процессе эксплуатации электроэнергетических объектов, включающих в себя неотключаемые электродвигатели. В настоящей работе рассматриваются вопросы математического моделирования переходных процессов самозапуска. Математическая модель асинхронного двигателя представлена системой алгебро - дифференциальных уравнений Парка - Горева в системе координат d,q,0. Анализ проведенного исследования режима самозапуска показал, что в случае кратковременного нарушения электроснабжения, вызванного глубоким снижением питающего напряжения, при восстановлении напряжения токи самозапуска не превышают обычных пусковых токов АД. В том случае, когда происходит кратковременный перерыв питания с отключением рабочего питания и переходе на резервный источник или восстановление напряжения на питающих шинах, процесс самозапуска при наличии поля ротора АД может быть опасным, если восстановление напряжения происходит достаточно быстро.