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Control Environment of Linear Induction Drive Dynamics Models

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Introduction

Any mechatronic system is provided by electric drive or actuator for changing of electric energy to mechanical. All types of motors can be used as electromechanical converters. Employment of linear induction motors reduces size and mass of electric drive, used for translation and results in developing new equipment with the linear motor as integrated part of that.

Application of linear induction motors (LIM) for translation has some advantages and disadvantages which are presented below [1].

Advantages:

- Direct electromagnetic force (no mechanical elements, no limitations for speed).
- Economical and cheap maintenance.
- Easy expansion for any linear motion of system topology.
- Exact positioning in closed loop systems.
- Possibility to provide inductor and windings separate cooling. The power factor developed by naturally cooling LIM is 1 N/cm^2. Almost 2 N/cm^2 can be obtained with an air cooling and from 2.5–3 N/cm^2 with liquids.
- All electro-mechanical controlled systems used for an induction motors can be adopted for a LIM without any bigger changes.

Disadvantages:

- Power factor and efficiency are less than of rotary motors because of a ratio of large air gap between inductors and pole pitch $(g/\tau) > 1/250$.
- The longitudinal end effect reduces power factor and efficiency. This can be noticed only with fast speed and small pole number motors. Influence of the longitudinal end effect can be reduced with special motor design methods.
- Extra vibrations with distortions can be noticed because of uncompensated normal force.

Nowadays, drives with linear induction motors are used in these areas: rapid transport systems and catapults, systems of industrial transport, industry of semiconductors and electronics, explosion localizing systems, industrial robots and machine-tools, protection and control systems of power energetic, medical instruments, computer engineering. Carried out analysis of LIM application areas indicate problems of developing and investigation of linear drives being topical and important [2].

Breaking of linear induction motors composes separate research and engineering problem [3, 4]. Linear motors usually operate in short time duty or intermittent periodic duty with electric breaking. Both duties are characterized by transients. Developed computer models for investigation into starting transients of linear induction drive [5, 6] and non-symmetrical breaking modes [7, 8, 9, 10] meet difficulties with changing of motor parameters or winding connection way. This paper deals with control environ-ment of dynamic models of linear induction drives for controlling of model and processing of simulation results.

Modeling software of linear induction motor

Linear induction drives are applied in different equipment; in which LIM operate in both motoring and breaking modes. At breaking, voltage may be attached to linear induction motor windings connected at different way [3]. Developed model on the base of software Matlab Simulink permit to investigate both motoring and non-symmetrical breaking modes of linear drive and evaluate the influence of the motor windings connection way to dynamic breaking characteristics and investigate LIM with different parameters. Nevertheless, changing of motor parameters, windings connection mode or evaluation of influence upon dynamic characteristics requires calculating and changing a lot of model parameters. Therefore the integrated model control environment, shown in Fig. 1, was developed. It comprises motor model, active program window and programs to process simulation results and to display them graphically.

Model of linear motor, supplied by unbalanced voltage, was developed in synchronous reference and comprises three LIM models, elaborated for direct, reverse and zero components of voltage [7].

Result of the model, developed for direct component, is force, developed by the motor and speed. Model, developed for reverse component gives force of opposite direction. Forces, developed by both models, are summed algebraically and this total force acts the secondary element forcing it to move with speed v. Zero component does not develop force and this model is used just for calculation of currents.

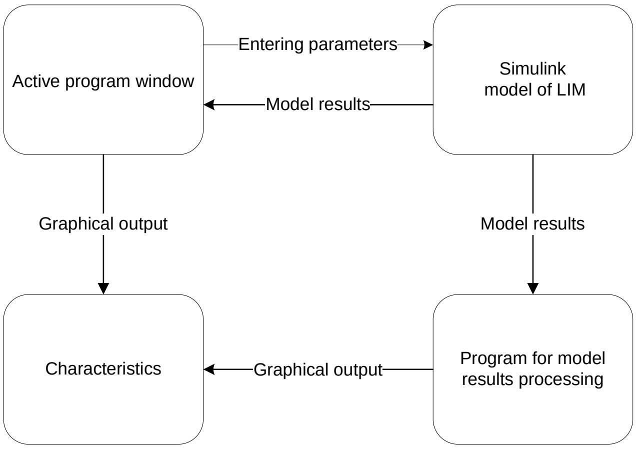

Fig.1. Integrated environment of modeling

The integrated environment of modeling allows choosing a windings connection type, operation mode, motor construction parameters, acceleration and braking time. For results program uses a special Matlab arrays. Then they are used to plot braking time dependences against secondary element resistance or static load by braking with continuous and alternating current.

Created software gives possibility to control model and investigate various non-symmetrical modes as breaking with direct current, single phase breaking, to compare obtained characteristics and consider influence of motor parameters to dynamic characteristics [10]. Fig. 2 shows the main program active window for all input parameters of the LIM construction.

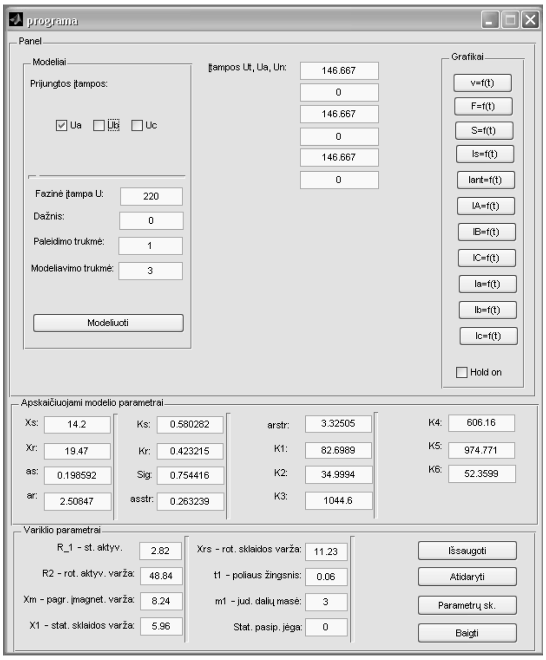

Fig. 2. Active window of developed program

In a lower part of the program window these parameters can be entered:

- inductor phase resistance, R_1;
- resistance of the secondary element, $R_2^{'}$;
- the main magnetizing reactance, X_m;
- leakage reactance of inductor, X_1;
- leakage reactance of the secondary element, $X_2^{'}$;
- secondary element weight , m;
- pole pitch, τ;
- load force, F_{st}.

Input parameters can be saved and again displayed and changed. That results to quick change of motor parameters permit to compare dynamic characteristics of motors with different parameters. Algorithm of the program is shown in Fig. 3.

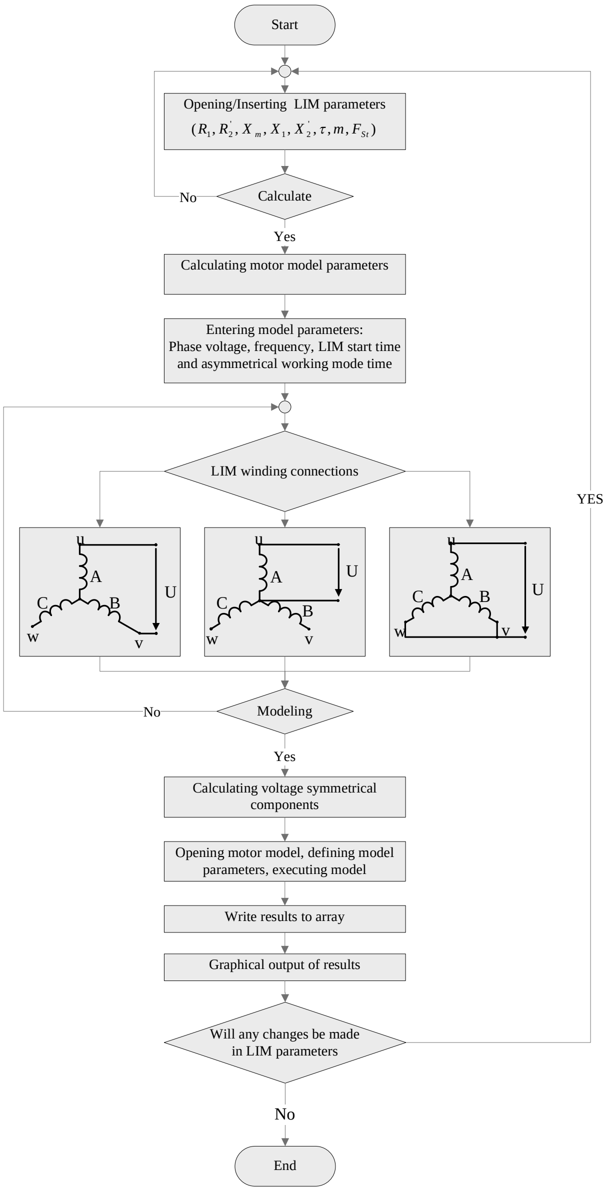

Fig. 3. Program execution algorithm

Parameters of motor are calculated after button "Calculate" is pressed: all input parameters, such as phase voltage, frequency, duration of starting and operating in non-symmetrical mode as well as windings connection way during breaking. Then the button “Modeling “is pressed and the motor model is opened and parameters of model blocks are being set up, as well as simulation is started. Results of simulation are sent to arrays. Then in the right hand side of control window the required characteristic can be chosen and results will appear in graphical form. As the parameters of the motor can be changed and the simulation repeated, dynamic characteristics of different motors or motors operating in different breaking mode can be compared.

The program allows calculation of speed, force, displacement, inductor phase currents and secondary element phase current transient dependences.

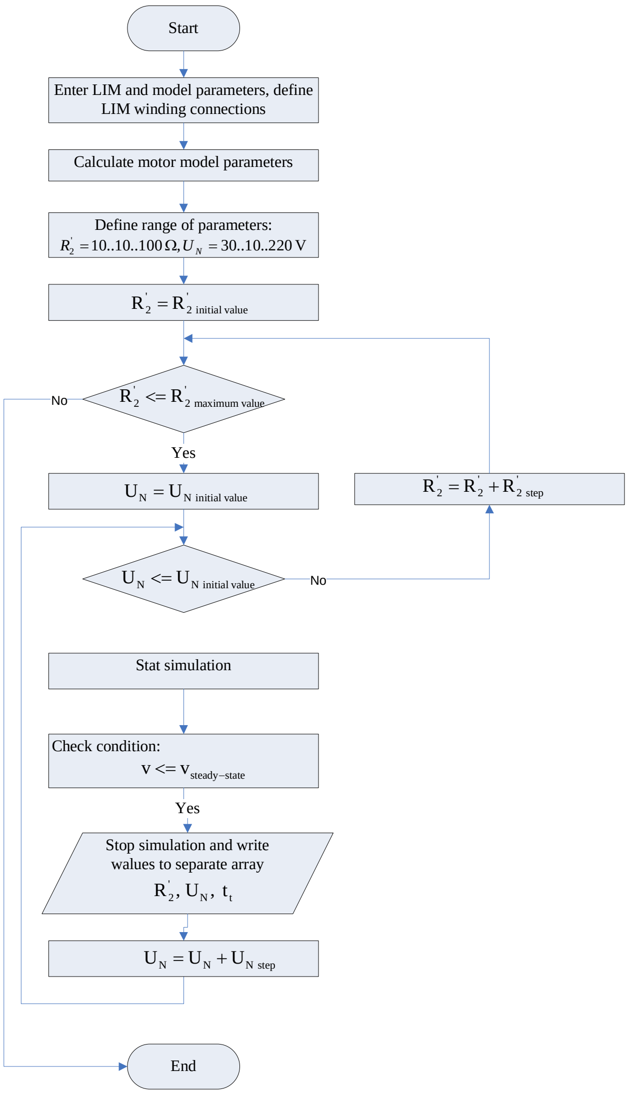

Fig. 4. Results processing program algorithm

Simulation results

Single phase breaking and breaking with direct current were examined using developed mathematical and computer models at different supply of voltage, i.e. to one winding, to two windings, connected in series and parallel and three series-parallel connected windings. Software for processing of results allowed getting dependences of transient duration upon motor parameters (voltage, resistance of the secondary and load).

Research of the motor parameters influence to the dynamic characteristics requires making a lot of simulation and all the time measure the LIM steady-state. In order to shorten time of simulation the program for an automatic parameters change and LIM transition time measurement was developed. The integrated modeling interface is created for easy exchange of parameters and comparing of different dynamic characteristics of the drive. The algorithm of program for processing obtained results is shown in Fig. 4. Array of results can be presented in graphical form.

Breaking time with the change of resistance of the secondary element gets the minimal value at the same braking voltage (Fig. 5). Fig. 5 indicates that the minimum value of breaking time can be achieved by changing resistance of the secondary element.

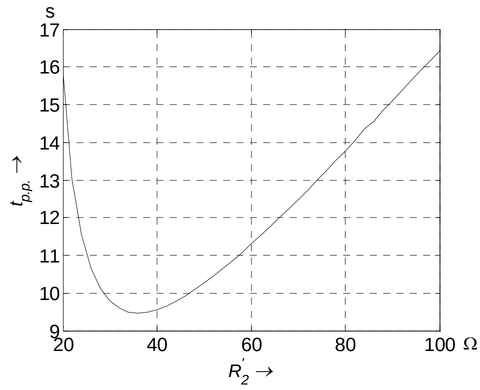

Fig. 5. Dependence of breaking time against resistance of the secondary at applied breaking voltage of 100 V

Fig. 6 shows dependence of breaking time on the breaking voltage and resistance of secondary element when breaking voltage attached to two phase windings, connected in series. At small voltage breaking time dependence on resistance of secondary element is grater.

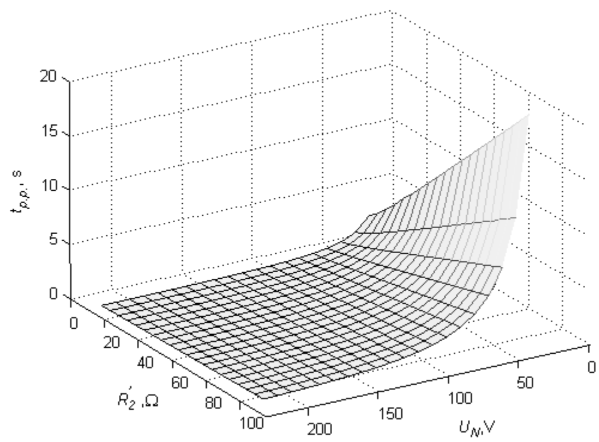

Fig. 6. Breaking time dependence upon breaking voltage attached to series connected two phase windings and resistance of the secondary element

Conclusions

1. Developed software allows controlling model and investigating non-symmetrical modes of single phase breaking and breaking by direct current, compare obtained characteristics and examine influence of motor parameters on that.
2. Breaking time dependence on the resistance of the secondary element has minimum value.
3. Presented dependence of breaking time against resistance of the secondary element and the breaking voltage allows choosing these parameters for obtaining of desirable braking time.

References

1. **Boldea I., Nasar S. A.** Linear electric actuators and generators // Proc. of the IEEE International Conference on Electric Machines and drives. – 1997. – P. MA1/1.1–MA1/1.5.
2. **Budig P. K.** The application of linear motors. The third International Power Electronics and motion Control conference. – 2000. – Vol.3. – P. 1336–1341.
3. **Smilgevičius A.** Tiesiaeigių asinchroninių variklių stabdymo tyrimai Lietuvoje // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2005. – Nr. 1(57). – P. 42–47.
4. **Smilgevičius A.** Tiesiaeigių asinchroninių variklių stabdymas. – Vilnius: Technika, 1992. – 52 p.
5. **Rinkevičienė R., Lisauskas S.** Tiesiaeigių mechatroninių sistemų modeliai // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2003. – Nr. 4(46). – P. 69–73.
6. **Rinkevičiene R., Petrovas A.** Modelling AC Induction Drive in PSPICE // Electronics and Electrical Engineering. – Kaunas: Technologija, 2007. – No 1(73). – P. 29–32.
7. **Rinkevičienė R., Lisauskas S.** Dinaminiai tiesiaeigių pavarų stabdymo režimai // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2005. – Nr. 4(60). – P. 38–41.
8. **Rinkevičienė R., Lisauskas S., Petrovas A.** Dynamic modes of single phase braking of linear induction motors // 3rd International Symposium "Topical problems of education in the field of electrical and power engineering". – Doctoral school of Energy and geotechnology. – Kuressaare, 2006. – P. 72–77.
9. **Rinkevičienė R., Lisauskas S.** Tiesiaeigės elektros pavaros vienfazio stabdymo dinaminis modelis // Energetikos ir elektrotechnikos technologijos: Konferencijos pranešimų medžiaga. – Kaunas, 2005. – P. 122–127.
10. **Rinkevičienė R., Lisauskas S.** Tiesiaeigio asinchroninio variklio nesimetrinių dinaminių stabdymo režimų tyrimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2006. – Nr. 1(65). – P. 60–63.

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Developed dynamic models of linear induction drives allow examining various dynamic characteristics of linear induction drives according to results of simulation. Nevertheless, changes in motor windings connection way or motor parameters require recalculating and renewing set up of model parameters. The integrated control environmental of model is discussed. Developed software allows controlling model and investigating non-symmetrical modes of single phase breaking and breaking by direct current, compare obtained characteristics and examine influence of motor parameters on that. Active program window is presented, where the motor parameters, winding connection way, operation mode and desired simulation results can be set up. Algorithm of simulation program and algorithm for processing of simulation results are presented. Breaking time dependence on the resistance of the secondary element has minimum value. Presented dependence of breaking time against resistance of the secondary element and the breaking voltage allows choosing these parameters for obtaining of desirable braking time. Ill. 6, bibl. 10 (in English, summaries in English, Russian and Lithuanian).

Р. Ринкявичене, С. Лисаускас. Управляющая среда динамическими моделями релейного асинхронного злектропривода // Электроника и электротехника. – Каунас: Технология, 2007. – № 8(80). – С. 63–66.

Динамические модели линейных асинхронных электроприводов позволяют исследовать разные динамические характеристики на основе результатов суммирования. Но при изменении вида соединения обмоток и параметров двигателя, приходится перечислять и заново настраивать много параметров модели. В статье рассматривается разработанная интегрированная система управления моделированием динамических режимов торможения линейного асинхронного двигателя. Разработанная программа позволяет контролировать модель и исследовать несиметричиские режимы однофазного торможения и торможения постоянным током, сравнивать полученные характеристики и исследовать влияние параметров двигателя. Разработанные программы позволяют установить параметры двигателя, вид соединения обмоток, режим двигателя и выбирать желаемые результаты симулирования. Приведен алгоритм программы симулирования и алгоритм обработки данных симулирования. Представлена полученная зависимость времени торможения от сопротивления вторичного элемента имеет минимум. Полученная зависимость времени торможения от сопротивления вторичного элемента и напряжения торможения позволяет выбрать эти параметры для получения желаемого времени торможения. Ил.6, библ. 10 (на английском языке; рефераты на английском, русском и литовском яз.).

R. Rinkevičienė, S. Lisauskas. Tiesiaeigės elektros pavaros dinaminių modelių valdymo aplinka // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2007. – Nr. 8(80). – P. 63–66.

Tiesiaeigių elektros pavarų dinaminiai modeliai leidžia tirti įvairias dinamines charakteristikas pagal imitacijos rezultatus. Bet, keičiant apvijų jungimo būdą ar variklio parametrus, reikia perskaičiuoti ir iš naujo nustatyti daug modelio parametrų. Straipsnyje nagrinėjama sukurta tiesiaeigio asinchroninio variklio dinaminių stabdymo režimų integruotoji modeliavimo aplinka. Sudarytoji modelio valdymo programinė įranga leidžia valdyti modelį ir tirti vienfazio stabdymo ir stabdymo nuolatine srove nesimetrinius dinaminius režimus, palyginti gautas charakteristikas ir ištirti variklio parametrų įtaką joms. Pateiktas programos aktyvusis langas, kuriame nustatomi variklio parametrai, apvijų jungimo būdas, darbo režimai, ir pasirenkami norimi gauti imitacijos rezultatai. Pateiktas imitacijos programos algoritmas ir imitacijos rezultatų apdorojimo algoritmas. Pateikta šia programa gauta stabdymo trukmės priklausomybė nuo antrinio elemento varžos turi minimumą. Gauta stabdymo trukmės priklausomybė nuo antrinio elemento varžos ir stabdymo įtampos leidžia parinkti šiuos parametrus norimai stabdymo trukmei gauti. Il. 6, bibl. 10 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).