

The Analysis of Motivation Factors in Application on Linear Induction Electric Drives

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Introduction

During improvement of technological equipment with recurrent movement of controlling element it is important to analyze possibility of application of linear electric drive in this equipment. Replacement of rotating electric drive with linear one gives possibility to simplify kinematics of equipment, reduce its size and improve its dynamic characteristics by giving to the equipment new below considered features.

Linear induction motors are the most general-purpose motors [1]. Nevertheless their performance and speed-force characteristics are worse than rotary motors. Therefore an argument of kinematics simplification is not sufficient to base the application of LIM. It is proposed to solve the problem by the principles of system engineering [2-6], when characteristics of all automatic control system are considered. It is multi-variant problem which solution algorithm is not clearly defined. The article considers the main factors of LIM application to facilitate the solution of this problem.

The factor of equipment construction simplification

Application of electric drive with LIM eliminates kinematics chains of equipment, which are used to transform the rotating movement of a motor to translation one of controlling element. This problem is important at modernizing systems comprising star-chain kinematics elements (for example, in the knitting machine-tools drives).

Often the conducting part of controlling element is aligned with the LIM secondary element. This solution gives the greater simplification of equipment construction. To close dampers and pipers are used switching elements (commutators) with LIM, whose secondary element fulfils the functions of moving commutator element [4].

Factor of application of LIM features in elaboration flexible production systems

On the base of electric drives with LIM it is possible to design flexible systems by the view of system widening

and route changing. Example of such system is automatic storage of information, where the information recorded by holograph principle to microplates (microfiches) is stored in the store elements. When controlling computer input data is the code of required microfiches and address, where it must be moved (address of projector or operating station), microfiches is automatically transferred onto transporter. A bogie fulfils functions of a transporter. It moves by directives made from separate segments. One conducting element of bogie is used as the secondary element of LIM. Inductors of LIM are displaced along the route, where the microplates must be delivered and catapult the bogie from one position to other (Fig. 1). This system distinguish itself by route flexibility (load can be delivered to any station or returned back to storage at any order) and system widening flexibility (the number of stations can be changed freely without stopping of functioning of the rest system part) features [5].

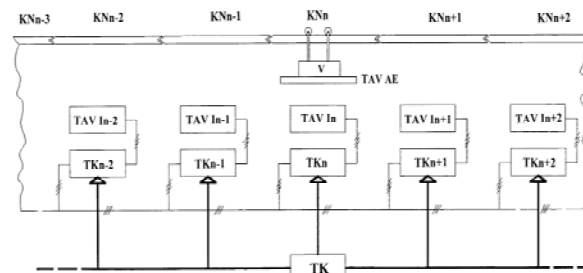


Fig. 1. Scheme of electric catapult: KN – segments of route of bogie movement; V – bogie; TAV AE – secondary element of linear induction motor; TAVI – LIM inductors; TK – thyristor (reversible) commutator

The factor of possibility to apply of non-traditional control and regulation methods

Electric drives with linear induction motors are reducer-less ones, therefore they need to warranty not only required speed range, but also the absolute values of the smallest and the greatest speed. Synchronous speed of LIM depends on pole pitch and inductor current frequency. Therefore it is quite difficult by constructional means to

get the synchronous speed of LIM less than 3–4 m/s when inductor is supplied by the current which frequency is 50 Hz. Nevertheless such speed is greater than speed of controlling elements of mostly technological equipment. Due to worse power characteristics of linear drives than rotating ones, their force, speed and other parameters can be controlled by simple, but not efficient ways: regulation of inductor voltage at constant frequency, methods of superposition, shifting one inductor with respect to other in electrically and magnetically double-sided linear electric motors, pulse control of supply voltage at commutators operation in less than 50 Hz frequency and etc. The last control mode can be applied for drives without requirements to keep constant speed and in the case when LIM is switched on at no-load (for example, in the drives of pushers) as well as afterwards the speed of LIM should be reduced to soften the shock the pushed to the transported product. This method of control of linear electric drives dampers allows selecting mean value of opening and closing time to weaken shocks of moving element to shock-absorber. Pulse control circuits are simpler and cheaper than frequency converters. For example, the reversible pulse controlled electric drive with electrically and magnetically double-sided LIM can be composed just of 6 thyristors and 6 diodes (Fig. 2).

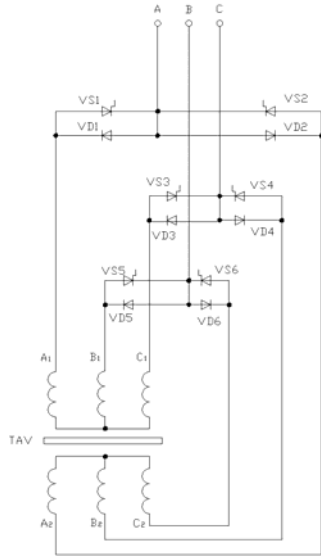


Fig. 2. Electrical circuit of reversible linear electric drive

In the case when LIM break-down slip is equal or greater than unity the single phase braking or braking by pulse current can be applied for drive braking [7].

The factor of LIM secondary element catapulting (and levitation)

The current of small power and small speed LIM inductors (TAVI) almost does not depend on slip, therefore it is useful to apply such LIM for electric catapults, for example, in the system described above, employed to catapult the bogie from one fixed position to other (Fig. 2)

[4]. The current and speed-force characteristic of such LIM is convenient to calculate according to simplified formulas:

$$I = \frac{U_1(1 + \varepsilon_0^2)}{\sqrt{[r_1(1 + \varepsilon_0^2) + d_{11}x_{p1}]^2 + [x_{11}(1 + \varepsilon_0^2) + d_{21}x_{p1}]^2}}; \quad (1)$$

$$F = \frac{m_1 U_1^2 (1 + \varepsilon_0^2) \left(\frac{2K_{Am} s_m s}{s^2 + s_m^2} + \frac{d_{3j} + e_{3j} s}{1 + \varepsilon_0^2 s^2} \right)}{2\tau r_1 \left\{ [r_1(1 + \varepsilon_0^2) + d_{11}x_{p1}]^2 + [x_{11}(1 + \varepsilon_0^2) + d_{21}x_{p1}]^2 \right\}}; \quad (2)$$

where U_1 is RMS value of LIM phase voltage; r , x_{p1} , x_{11} – parameters of LIM series equivalent circuit; ε_0 is magnetic Reynolds's number of stopped LIM; d_{11} , d_{21} , K_{Am} , s_m , d_{3j} , e_{3j} is approximation coefficients [4] and m_1 ; τ is number of LIM phases and pole pitch.

In the powerful systems, for example, passenger pipeline transport systems, the frequency converters are used to control motor speed and current. The catapulted carriage from the acting zone of TAVI uses to move from inertia in the space, where the vacuum is held (levitation) [8].

In the small power system the bogie moves along directives made from segments. The force required to movement (to catapult) is developed by interacting TAVI with the secondary element which functions can be delivered to constructional parts of bogie. The load is passed from one station to the other by switching on for short time one after other inductors of neighbour stations. Computer controls the thyristor commutators, supplying TAVI in accordance with path sensors signals, reacting to approaching of bogie to station or to arriving the intermediate (or required) station and leaving the station zone.

Factor of modular system designing

Possibility to design the mechatronic systems from different modulus allows creating various flexible systems. For example, the system described above consists of several independent modulus, composed of mechanical (directives) segment, electromechanical (TAVI) and electronic (reversal thyristor commutator) elements. The secondary element of LIM, fastened to the bogie and controlling computer are common for all system. Modular construction provides route and system widening flexibility features.

The other example of modular construction is the modular design of large cross area dampers, applied in automatic dust explosions localizing systems in order to increase the speed of damper closing [4].

Factor of control system simplification considering the LIM specific features

Small dynamic current amplitudes of LIM inductor and possibility to connect inductor winding in various ways often allow simplifying control systems of mechatronic equipment.

For example, in the power systems substations with alternating operating voltage, solenoid drives of high voltage circuit-breaker do not warranty reliable repeating switching-on of circuit breaker, if the short circuit did not disappear in the line to be switched on. To switch on the circuit breaker in the case of repeating short circuit at the closing instant of the circuit-breaker power contacts, when operating voltage is reduced very much, the inductive or capacitive power storage elements with electronic (thyristor) control system are used [4].

Application of alternating current electric drive with LIM of cylindrical construction, which secondary element mass is chosen in the way to connect reliably circuit-breaker power contacts due to kinetic energy, stored in the moving mass, instead of solenoid (direct current) drives, the system becomes significantly simplified (the complex power storage elements with electronic control system are not required).

The power systems are provided with circuit breakers having separately controlled contacts (the possibility to switch on any selected phase presents). They are used in the automatic systems to localize and shunt the damaged high voltage line in the systems with isolated neutral. Experiments indicated that switching on time of various circuit breakers differs significantly due to dissemination of mechanical parameters of separate circuit-breakers phases. This problem can be solved by simple means: the CLIM multi-coil winding can be connected in different ways and due to obtained phase current asymmetry and difference in RMS current values the required CLIM speed-force characteristics can be obtained [5]. This method allows avoiding complicated mechanical adjustment and thyristor phase voltage regulators.

Fast-operation factor

Electric drives of fire and explosions localizing dampers [4], fast operating levitation transport [8] must ensure high speediness of operation, which cannot be reached with application of rotating electric drives with reducers or multiplexers. Therefore the linear induction drives are employed in those systems.

Factor of multifunctionality

Electric drives with linear induction motors gives possibility to apply the same LIM to fulfil several functions. This problem arises, for example, at control of powdery materials batching systems, which are used in the industry of fertilizers, fodder, building materials, in packing of uniform materials or producing mixtures of powdery materials, consisting of desirable number of components of different materials. It is expedient to apply dampers with linear induction motors, fulfilling opening and closing the batcher hole and multiple breaking of damper moving element, coincided with the LIM secondary element in order to eliminate sediment from the batcher walls. In the same way the damper with LIM closes damper hole fast at primary combustible dust explosion [4] (Fig. 3).

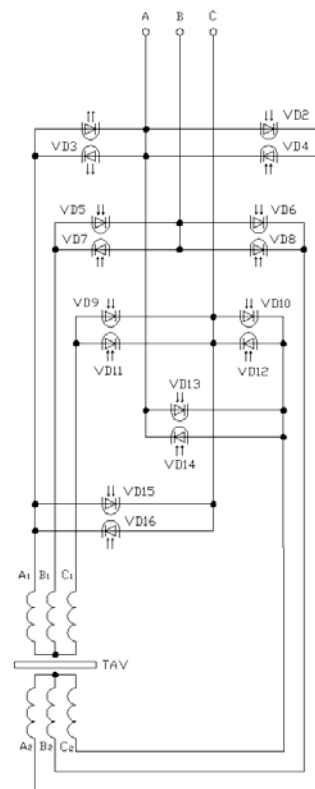


Fig. 3. Matching of functions scheme of linear electric drive

Factor of movement transfer to closed space

Usually there is no contact present between LIM inductor and secondary element, therefore any solid or liquid conducting materials as well as ferromagnetic disperse can be delivered by electromechanical action, developed by LIM. Mentioned materials or elements can be displaced behind the „wall“, i. e. in capacities with aggressive and explosive materials, closed premises with the vacuum, sterile closed vessels, pipes, troughs.

An example of such system is transportation of ferromagnetic shaves, crumbling onto nonferromagnetic trough, by translating electromagnetic field produced by LIM inductor. The shaves looks like asynchronized secondary element of synchronous reluctance motor. Stable movement of ferromagnetic shaves in opposite direction of electromagnetic field movement is supported by supply of inductor with voltage of low frequency (several hertz) current.

Conclusions

1. Linear inductor motors are not general-purpose ones, therefore its application in concrete electrical equipment must be proved by analysis of various factors, giving the priority of linear drive against rotating.
2. The factors, considered in the article are linked between themselves.

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The article deals with the factors of application of linear induction motors from the point of view of system engineering: the factor of equipment construction simplification, factor of application of LIM features in elaborated flexible production systems, the factor of possibility to apply of non-traditional control and regulation methods, the factor of LIM secondary element catapulting and levitation, factor of modular system designing, factor of control system simplification considering the LIM specific features, fast-operation factor, factor of multifunctionality, factor of movement transfer to closed space determined the successful development of real and exploited systems with LIM. The examples of developed automatic systems are presented; the principles of their performance are analyzed. Ill. 3, bibl. 8 (in English; summaries in, English, Russian and Lithuanian).

A. Пошка, Р. Ринкевичене, З. Савицкене. Анализ факторов обоснования применения линейных асинхронных электроприводов // Электроника и электротехника. – Каунас: Технология, 2006. – № 5(69). – С. 13–16.

С позиций системотехники рассматриваются факторы обоснования применения линейных асинхронных двигателей (ЛАД). Это фактор упрощения конструкции оборудования, фактор применения свойств ЛАД для создания гибких систем, фактор возможности применения нетрадиционных методов управления и регулирования, фактор катапультирования и левитации вторичного элемента, фактор создания модульных систем, фактор упрощения системы управления с учётом специфических свойств ЛАД, фактор быстродействия, фактор multifunctionality и фактор передачи движения в закрытые помещения, способствовавшие успешному созданию реальных и эксплуатируемых систем. Представлены образцы этих разработанных автоматических систем, проанализированы принципы их действия. Ил. 3, библи. 8 (на английском языке; рефераты на английском, русском и литовском яз.).

A. Poška, R. Rinkevičienė, Z. Savickienė. Tiesiaeigių asinchroninių elektros pavarų taikymo pagrindimo faktorių analizė // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2006. – Nr. 5(69). – P. 13–16.

Straipsnyje iš sistemotechnikos pozicijų nagrinėjami tiesiaeigių variklių (TAV) taikymo pagrindimo faktoriai. Tai įrenginio konstrukcijos supaprastinimo faktorius, TAV savybių panaudojimo lanksčiosios gamybos sistemoms kurti faktorius, netradicinių valdymo ir reguliavimo būdų panaudojimo galimybės faktorius, TAV antrinio elemento katapultavimo ir levitacijos faktorius, modulinės sistemos sudarymo faktorius, valdymo sistemos supaprastinimo, atsižvelgiant į savitąsias TAV savybes, faktorius, greitaveikos faktorius, daugiavališkumo faktorius, judesio perdavimo į uždara ar atitvertą erdvę faktorius, įgalinę sėkmingai sukurti realias ir eksploatuojamas automatines sistemas. Pateikti šių sukurtų automatinėsių sistemų pavyzdžiai, išanalizuoti jų veikimo principai. Il. 3, bibl. 8 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).

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