THE DEVELOPMENT AND TESTING OF A LINEAR INDUCTION MOTOR BEING FED FROM THE SOURCE WITH A LIMITED ELECTRIC POWER

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***Abstract* – The report provides results of the research related to the single-phase linear induction motors (LIMs) for high voltage switch drives with the usage of inexpensive standard single-phase transformers for power supply. The LIMs' design and investigations for other applications are described as well.**

***Keywords* – single- phase linear induction motors supplied from the limited power sources: construction, investigations, calculation.**

I. INTRODUCTION

The most urgent task of modern power industry is to further increase the reliability of power sources.

One of the key aspects for the technical implementation of this task is the automated distribution of electrical power through the use of the partitioned grids with back-up lines equipped with the sufficiently simple, reliable and inexpensive shut-off and diverter switching hardware.

It is known that one of the ways to improve electric actuators of such switchgears is to use linear induction motors (LIMs) which enables conversion of electrical power into linear or reciprocating movement of the working body (secondary element) directly, that performs the switching operation.

II. DESIGN FEATURES

Using LIMs we can significantly simplify the layout of the switchgear, reduce its dimensions and weight, reduce material consumption and increase its performances and reliability. Besides, such a switching device equipped with the power supply (step-down transformer) can be placed high off the ground at the level of the power transmission supports, hence increasing external damage resistance.

Switching devices, based on the LIMs, can work in three-phase and in single-phase networks of high and low voltage as disconnectors, switches, remote earthing switches and other similar devices.

Machines with linear or reciprocating movement of the working body also became widespread in the mining and processing industry, in particular, in potash ore mining enterprises and mineral fertilizers producers. These are various dampers, valves, tappets, emergency locks and tech clips, shut-off valves, flow dividers, samplers, etc. [1-5].

Linear induction motors for some of them are shown on Fig. 1, 2.

Fig. 1. The tubular linear induction drives for mining industry.

Currently actuation of such mechanisms is effected by a geared motor equipped with a mechanical converter of rotational-to-linear motion of the working body at the outlet of the Converter.

Hands-on experience demonstrates that these Linear Actuators (LAs), for example PTV-type (in Russian-'ПТВ'), are not sufficiently reliable and are not easy to maintain (especially when operating in aggressive saline environments), at the same time they have a very significant size, weight and cost. In addition, in some cases, response performance (speed of acting) of these linear actuators is unsatisfactory.

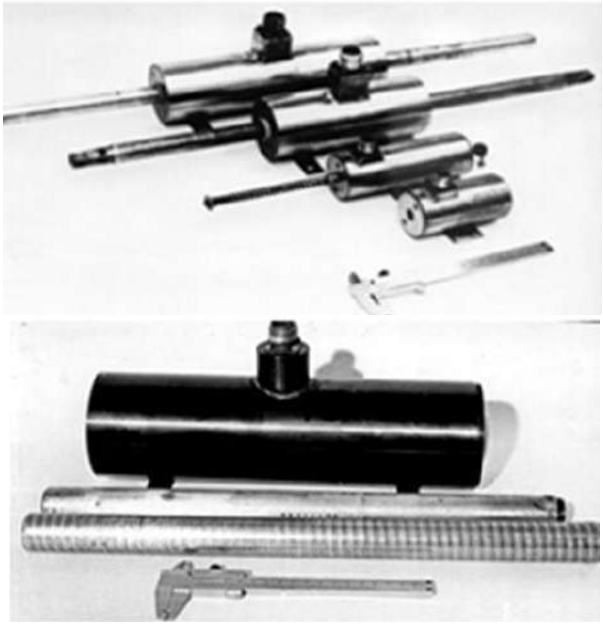

Fig. 2. The tubular linear induction motors for switching equipment and for other applications.

III. Description of the LIMs' design

Aiming to find a solution for this issue of creating a linear actuator on the basis of LIMs for power and mining industry we have designed the series of three-phase and single-phase LIMs of 50-1000 N pulling capacity (see, for example, Fig.1). Its design features and characteristics are presented in the report.

The report also provides the results of the research of single-phase LIMs for high voltage switches drive using inexpensive single-phase transformers of the OM - type (single-phase oil with natural circulation of oil and air) and NOL-type (inductive voltage transformers type 'single phase cast resin 08-10.05.1') (or their equivalents) from the networks of 6.3 or 10 kV in the short-term overload mode (at the time of tripping power lines). This allows us to significantly simplify and reduce the cost of complete package linear actuators for different purposes and, in particular, for switching devices.

The common single-phase oil transformers (series OM, power capacity 0.63-1.25 kVA, voltage of the HV/LV 10; 6.3/0.23 kV, frequency of 50 Hz) are mainly intended to supply power to the rail-road locking equipment and electrical power centralized control. A scheme and winding connection group of the transformers is 1/1-0. They have a different climate design for outdoor and indoor installation with ambient temperatures from minus 50°C to plus 45°C. The transformers are manufactured as leak-tight items due to valves in a body design, and have a special bracket for installation at the power line support.

The inductive voltage transformer, type: 'NOL 08-10.05.1' (single phased, cast resin) are designed to supply power to instruments and vacuum circuit breaker actuator type HVTP ('high-voltage three-pole'), and also for installation in mining electrical switchgears for a voltage of 10 kV for underground potash mines networks. Theirs data: voltage HV/LV 10/0.1, 0.127 kV; power capacity 630 VA; 50 Hz; scheme and winding connection group 1/1-0. The windings and magnetic circuit are encapsulated in epoxy resin to form a robust monolithic block, which includes threaded sleeves for the transformer erection at the installation site.

To verify single-phase capacitor LIMs efficiency to be used for high voltage disconnector, power, LIM was supplied from the limited power source, namely OM-type transformer (single-phase oil transformer with natural circulation of oil and air). We used one of a cylindrical single-phase linear motor with length and diameter of respectively 256 and 72 mm. We used a variety of combined working bodies (copper-plated secondary ferromagnetic element, secondary ferromagnetic element with the 'twisted' (rolled up or ring-shaped) squirrel cage in a ferromagnetic array, etc.) with the outer diameter of 20 mm. At the same time, in the laboratory conditions we measured pulling force (F), currents in both phases of the two-phase winding ($I_{A,\ B}$.); total motor power capacity (P_w) at different supply voltage U_T. These phase relationships are shown in Fig. 3, 4.

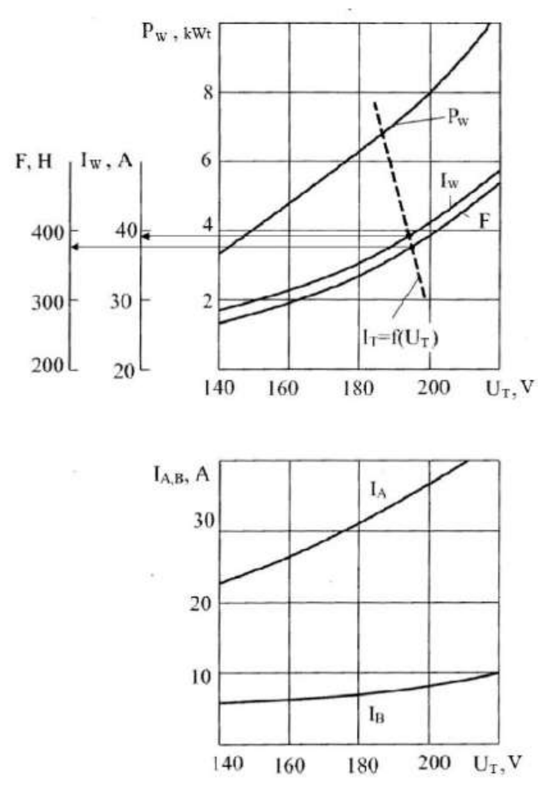

Fig. 3. The linear motor's and feeding transformer's characteristics:

(—) – motor's characteristics; (----) – approximate external inversed characteristic of the transformer.

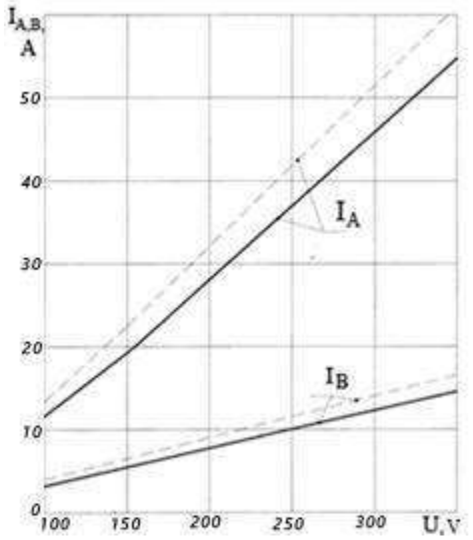

Fig. 4. The windings current of the linear motor with different secondary elements:

(—) – a secondary element with a combined layer;

(----) – a secondary element with a total cooper layer.

However, these dependencies were applicable when power to the motor was supplied from a stationary source of considerable power, and they gave no answer to the question of what parameters will have the motor when it is powered from a source of limited power - low-power transformer, for example, OM- type transformer. Therefore, graphs of experimental dependencies F, $I_W = f(U_T)$ were subjected to application of the calculated "upside-down" external volt-ampere curve $I_T = f(U_T)$ (see Fig.3) of OM-type transformer, being calculated according to the recommendations of the monograph [6].

The intersection points of this external curve with the curves F, $I_{W,T} = f(U_T)$ allow us to determine the real value of the pulling force and the power consumption of the motor in the 'motor - power supply transformer system' during a significant short-term transformer overload.

The resulting graph-analytical calculation values of the force and of the motor's current comply with the specifications for high-voltage loading switch.

Practical testing of the system of 'linear motor - transformer power supply with the limited power' at the existing facility proved its good performances and compliance of the calculated and experimental data with an accuracy of about 5%.

Based on the proposed methodology of graph-analytical determination of pulling force and current of linear induction motors we also investigated the possibility of single-phase LIM to be powered from a group of transformers of NOL – type which were connected in parallel during overload.

IV. CONCLUSION

The work we did, at the first step clearly shows the ability to power the linear actuators on the basis of LIMs from the high-voltage power lines through individual low-power step-down transformers in the short term overload mode.

In summary, we can say that the graph-analytical motors parameters determination methodology, developed during this work, is useful for practical engineering calculations and it is to be put to a number of uses, in particular of LIMs application in the short-term modes.

In accordance with the foregoing, the author is ready to consider the proposals which are concerned about the development of similar linear electric drives for the different systems which are similar in design for the installations described above.

There is a possibility of trade, on the principle of "as is", of already developed installations with nonconventional electric machines of different movement (for example, with motors of Linear Electric Drives, or Rotational Electric Drives, or Disk Drives, or Electric Rotationally Oscillatory Drives, etc.) with open and close magnetic circuit. A brief description of these motors for Electric Drives of some systems and installations is presented in [1- 5].

For those, who are interested in more detailed information concerning the theory and practice of LIMs, the author can offer English or Russian versions of the lecture's course of 8-16 hours [5], lecturer: Dr. Vasilii TIUNOV, Certified International Engineering Educator (ING-PAED IGIP, Register: RUS-35). The illustrative material of the course is contained in more than 600 slides for presentation, which might be very helpful for engineers and research workers, for the staff development, postgraduates' and students' study. The course or its fragments were presented and received a high appreciation in Austria, in China, in Spain, and in the USA (in four universities of California and at the meeting of Los Angeles Chapter of IEEE Industry Application Society) during the author's lecturing and presentations in the USA.

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