LINEAR SYNCHRONOUS MOTORS FOR ELEVATORS

by Dr. Richard Thornton

Introduction

Many articles in elevator-industry publications and elsewhere have discussed the potential advantages of using linear motors (LMs) for elevator propulsion. Advantages include the ability to eliminate ropes and counterweights, achieve higher speed at no increase in cost, independently control multiple cabs in a single hoistway and switch cabs between adjacent hoistways. This article describes recent improvements in linear synchronous motor (LSM) technology that make the LM a cost-effective option for high-performance elevator propulsion.

Background

In the 1990s, the U.S. Patent Office issued more than 30 patents involving the use of LMs for elevator propulsion. The major elevator manufacturers sponsored many of these patents, so it may seem surprising that there are no major elevator installations using LM technology. Most of these patents used the linear induction motor with power transmitted to the motor primary, which was either on the cab or the counterweight with power transmitted by a tethered cable. This type of design is less expensive than some other LM alternatives, but it is more expensive than a rope hoist and sacrifices many of the potential advantages that an LM can offer.

The LSM has been used for many years in a few applications, but has never been used for a major elevator installation. There are a few elevator-related patents that use the LSM, but not as many as you might expect. The most promising LSM is the long-stator version, which has the motor primary on the hoistway and permanent-magnet (PM) arrays on the cab, so there are no ropes or power cables attached to the cab. The small amount of power needed for lights and communication can be provided by inductive power transfer from the LM, so the cab can move freely in all dimensions.

Recently, MagneMotion Inc., a provider of advanced electromagnetic transportation, assembly automation and logistics solutions, completed testing a prototype LSM-based weapons elevator for a U.S. Navy aircraft carrier. The prototype was for lifting one corner of a platform with lift capability of 5.44 Mg (6 tons per LSM, 24 tons per platform) at speeds up to 0.75 mps (150 fpm) and with emergency mechanical braking that is automatically applied in the case of power failure.

The company also completed the design phase of a project to construct an LSM conveyance system capable of moving 100 tons per minute up a slope of 40º at 10 mps (22 mph) for any desired distance. Both of these projects benefit from improvements in enabling technologies, including PMs, power semiconductor devices, microprocessor-based controllers and computer-based design tools. They also take advantage of a careful integration of electrical, electronic and thermal design with major concern for manufacturing economies and reliable operation. For elevator applications, an important property of the LSM is that the individual stator segments operate with low-duty cycle, so it is possible to get a much higher thrust than one might infer by scaling the force capabilities of rotary motors. The ability to overload a LSM without affecting its reliability is probably the single most important fact that makes these motors practical for elevators.

LSM Propulsion System

Figure 1 is a drawing of the aforementioned LSM high-thrust stator developed for lifting munitions on an aircraft carrier. This stator has a protective cover and is mounted between steel rails that support guidance wheels and mechanical brakes. Current in the stator windings creates a magnetic field that can move relative to the stator when powered by a microprocessor-controlled inverter. The field moves in synchronization with PMs on the elevator and produces a controllable thrust and speed based on precise knowledge of position and commands from a central control. For commercial elevator applications, a string of scaled versions of these stators can produce almost any desired force and speed.

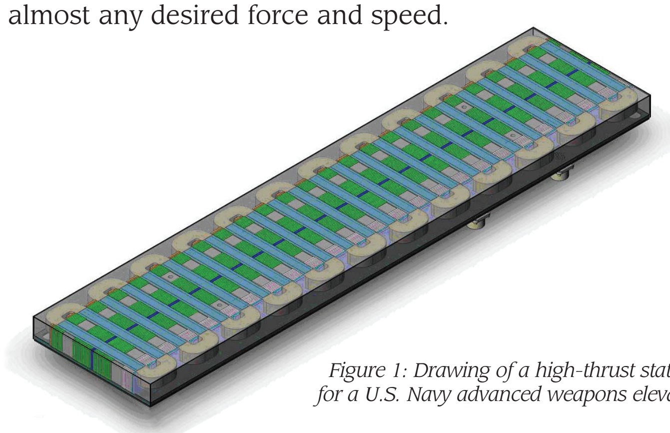

Figure 1: Drawing of a high-thrust stator for a U.S. Navy advanced weapons elevator

For high-rise buildings with elevator speeds over 10 mps (22 mph), the motor efficiency is over 85%. Energy generated by a descending elevator can be used by an ascending elevator, stored in a battery or returned to the mains. When there is more than one hoistway with a central controller, one can schedule movement to

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enhance the probability that regenerated power from a descending cab can be used to power an ascending cab, thereby mitigating much of the penalty of not using counterweights. Modern batteries developed for hybrid automobiles offer the possibility of even greater smoothing of power requirements while simultaneously providing backup power in case of a utility power loss.

Elevator Concepts That Should Be Explored

Unlike rope-hoist designs, LSM propulsion systems are less costly when the cabs are operated at relatively high speeds, because the stator duty cycle is low. The world's tallest building (Taipei 101) has two elevators operating at 17 mps, an amazing feat for a cable-hoist system, but one that would be much easier with LSM propulsion.

Another way to take advantage of LSM technology is to use multiple cabs or double-deck cabs. These are old ideas (a dual-cab elevator patent was issued in 1917), but they have recently been gaining prominence with double-deckers in Taipei 101 and dual-cab installations in Germany. Papers presented at Elevcon 2006[1] discuss variations on these ideas, but are all based on the use of rope-hoist designs.

Figure 2 shows a conceptual drawing of how LSM propulsion can create a dual-cab elevator. The cabs are propelled by a single magnet array mounted in the center of one side of each cab. A pair of steel rails is used by wheels to control motion, and by mechanical brakes to hold the cab when stopped. The attractive force of the PMs is more than enough to hold the suspension wheels against the steel rails.

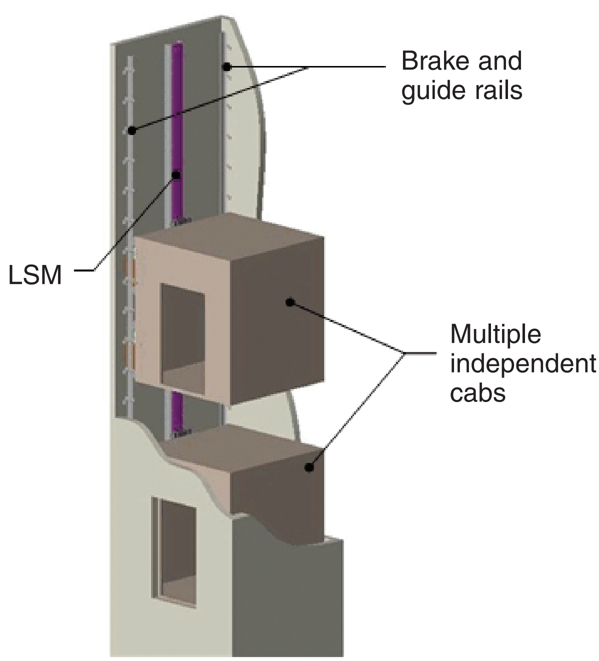

Figure 2: Conceptual drawing of an LSM-propelled commercial elevator

Scheduling and control of a dual-cab elevator has been discussed in a number of papers. With MagneMotion's propulsion system, the cabs move independently, encompassing the ability to occupy any pair of adjacent floors at the same time so that virtually any scheduling algorithm could be used. The only constraint is posed by safety considerations, which are always important when multiple vehicles operate on the same guideway. In this case, safety is enhanced because of the precise position sensing and the use of propulsion and braking systems that do not depend upon friction; mechanical braking is only used to hold a stopped vehicle or for emergency.

Conclusions

MagneMotion has found in other application areas that the LSM is increasingly cost effective because the technology has improved and manufacturing economies have been realized. The advantages of ropeless LSM propulsion are substantial. LSM-propelled elevators can be cost competitive today for some applications, and the market will grow as the technology matures. The most important advantages are the simplicity in which high speed can be achieved and the ability to have independently controlled vehicles operating in a single hoistway.

The most important future role for LSM elevator propulsion is for designs that use horizontal switching between adjacent hoistways. This allows scheduling to be similar to those used by automated people movers. The control options are almost unlimited, but they would very likely involve switching at intermediate levels and several cabs for each hoistway. MagneMotion has constructed LSM-propelled transport systems for horizontal travel, and has perfected a magnetic switch allowing path change without the need for any mechanical motion of components on the guideway. This same idea can be implemented for elevators, while still providing the high level of safety which has been a hallmark of the elevator industry. With horizontal switching, the capacity of each hoistway can be increased by a significant factor with minimal added cost for the switching system. It will take a few years for LSM technology to reach its full potential for elevator propulsion, but the topic is clearly worthy of serious consideration now.

References

[1] Helsinki, June 20-22, 2006: *Applications of Two Elevators in the Same Hoistway*, Rory Smith & Bruce Powel, ThyssenKrupp; *Double-Deck Destination Control System*, Janne Sorsa & Marja-Siisa Siikonen, KONE.

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