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Motor technology: Move, but don’t touch!

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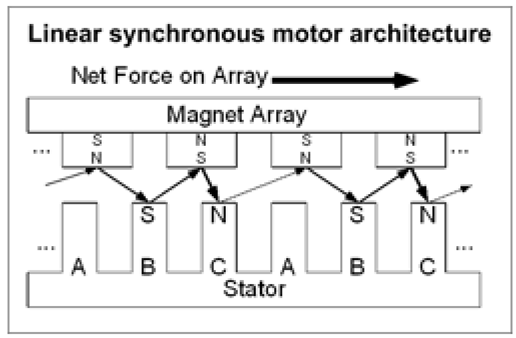
Take a three-phase synchronous electric motor with a permanent-magnet rotor and lots of poles, slice it radially from axis to housing, and unwrap it to lay out flat. (Video clip below.) If you do that, you'll get a linear synchronous motor (LSM) as shown in the related figure. Developers, such as MagneMotion of Acton, MA, are developing LSM technology for a wide range of applications, such as material transport within automated factories, light rail vehicles for passenger transportation, and even elevators for moving aircraft between decks in aircraft carriers.



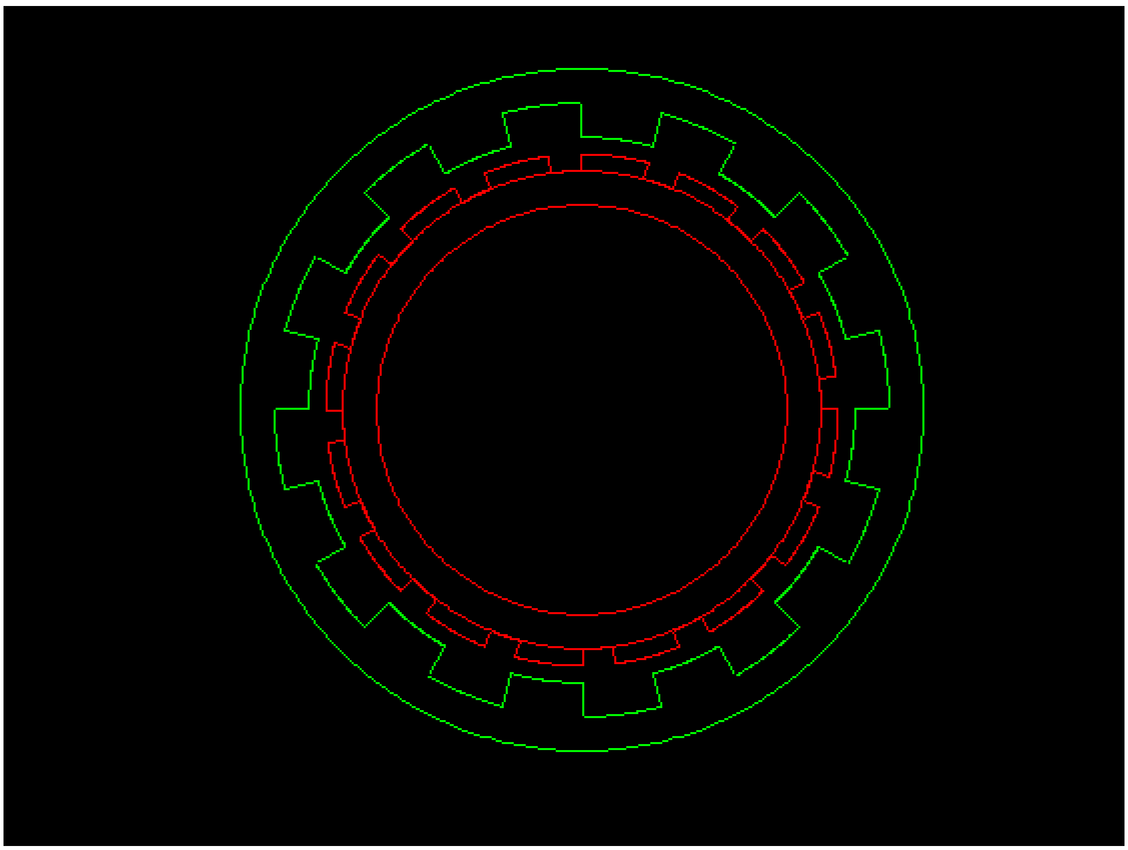
A three-phase LSM has an alternating-pole permanent magnet structure suspended over a straight electromagnet stator structure. Magnetic interaction between the permanent magnet poles and alternately energized electromagnet poles provides a net push in the desired direction. Source: MagneMotion

Don't confuse LSMs with conventional linear actuator motors, which consist of a small conventional servomotor mounted on a tube and driving a gear or worm whose teeth engage the teeth of a rack running back and forth inside the tube. Conventional linear actuators have all the bearings, rotors, gears, *etc*.—moving parts that plague maintenance engineers—that conventional gearmotors have.

LSMs, on the other hand, have *no moving parts*! The rotor equivalent (field array) is a linear array of permanent magnet poles. The stator is a series of fixed electromagnets. From that standpoint, an LSM is an extremely simple system.

LSMs do, however, present some serious control challenges. The problem is commutation. The three-phase current from the invertor energizing the electromagnets in the stator must have the correct phase to drive the field array in the proper direction at the proper speed. Unlike permanent magnet rotating synchronous motors, which, when properly wound, naturally fall into synchrony at the ac current, LSMs need to know precisely where the field array's poles are at all times. Solid-state magnetic and proximity sensors, low-cost PLCs, and advanced software and networking capabilities are just now making LSM systems practical.

The company demonstrated most system features at Promat 2007 in Chicago, IL. A host computer, which may be part an enterprise-level automation system, sends orders like 'Move vehicle X to location Y, at the max acceleration A and max velocity V' to a high-level LSM controller via Ethernet. The high-level controller keeps track of vehicle positions and provides next destinations for each vehicle to node controllers stationed at each transport network node.



MagneMotion http://www.magnemotion.com

A node occurs wherever a decision has to be made regarding vehicle motion. For example, a node would occur where a switch can send the vehicle along one path or another. A node controller would be assigned to control the vehicle at that node and along the section of track leading to the next node.

The LSM electromagnets are built in straight sections, which MagneMotion calls 'QuickSticks.' These are straight sets of LSM stator poles built in 0.1 m or 0.5 m sections. A QuickStick can have one, two, or 10 sections enclosed in a rectangular aluminum housing with a non-magnetic stainless steel top, along with the necessary closed-loop controllers.

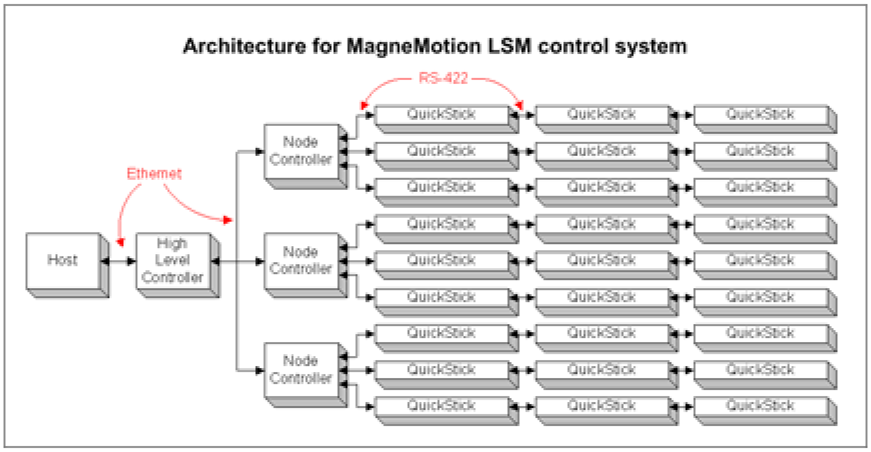
Magnetic field sensors in the QuickStick housing monitor where the LSM stator is at all times and can provide position accuracy of a fraction of a millimeter. Its controller then provides coil-energizing pulses that push the field array.

Nodes only communicate with the high-level controller and the first QuickStick in the section(s) they control, providing vehicle destination as well as speed and acceleration limits, over an RS-422 serial link. Upon receiving the information and the vehicle, the first QuickStick sends a message to the next QuickStick in line saying it has a vehicle routed for a certain destination at a certain speed and requesting permission to send it on.

If the second QuickStick sees that its track section will be clear when the vehicle arrives, it sends back permission to send the vehicle. The first QuickStick then sends the vehicle along. The QuickStick system takes care of the complexity of moving the vehicle, so that a user need only worry about specifying the destination.

If there is a problem, such as that the second QuickStick has another vehicle in its section when the request arrives, it will not provide permission to proceed. Without permission to proceed, the first QuickStick will bring the vehicle to a halt. With this feature, the system is inherently safe. That is, a QuickStick carrying a vehicle will bring it to a halt until it receives permission from the next QuickStick to send it along.

Nodes also control trackside resources as well. For example, the demonstration track included two branch points where vehicles could be diverted left or right. An electromagnet pulled the vehicle onto the left or right path depending on signals from the node controller.

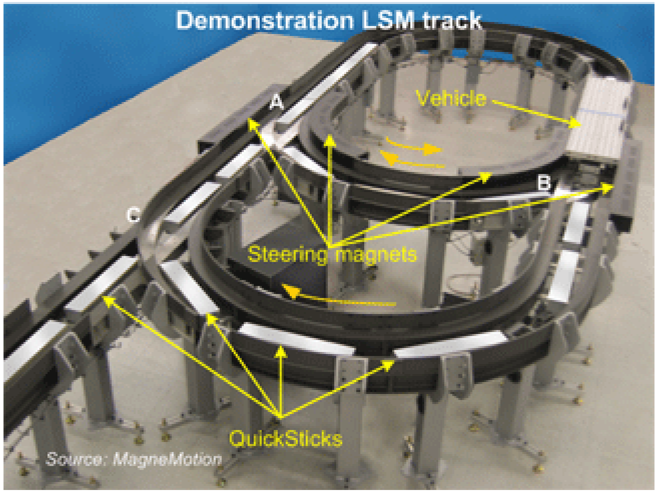


Standard network links carry control signals to progressively lower system levels. Closed loop motion control, however, stays at the bottom level where it is mediated by neighboring QuickSticks. Having QuickSticks move vehicles only when they have a valid token from the next QuickStick in line makes the system inherently safe. Source: MagneMotion

This architecture makes it possible to add or remove QuickSticks easily. Two connectors—one for power and one for RS-422 signals—connect each pair of QuickSticks. Thus, each has a pair of cables coupling to the upstream QuickStick and a pair for the downstream unit.

The Promat demonstration track consisted of a double oval track with common straight sections, and a straight section extending from one of the oval's straight sections. There are three nodes, one for each of the three track junctions.

The demonstration program allows the vehicle to move clockwise or counterclockwise on the smaller loop. It was programmed to only move clockwise on the outer loop.



The demonstration at Promat 2007 included a double oval track. The vehicle could go around the inner track in either direction. The network topology reflects the track topology, with nodes at track junctions marked A, B and C. Electromagnets mounted on either side at junctions A and B were able to switch the vehicle between the outer and inner tracks. Source: MagneMotion

The demonstration vehicle consists of an aluminum platform mounted on two 'bogeys' (pronounced bow-gies). Each bogey has two suspension wheels to hold the vehicle's weight, plus four guide wheels that keep the bogey centered between vertical anodized aluminum walls on either side of the track. A permanent magnet field array mounts at the center of each bogey. In action, the magnetic field generated by a QuickStick stator under a bogey pushes the field array along while the guide wheels steer the bogey to stay centered on the track. When the vehicle reaches a branch point, the node controller for that branch point energizes the right-hand steering magnet to force the vehicle to turn right or the left-hand magnet to make it turn left. These electromagnets pull mild steel plates attached between the guide wheels on either side of the bogey, forcing the guide wheels to ride along either the right- or left-hand guide walls.

A standard 1 m QuickStick has two 0.5 m LSM stator sections and can move a 91 kg (200 lb) load at 2.5 m/s (490 fpm). The company has developed custom alternative designs, such as an elevator system with QuickSticks mounted vertically and an automated magnetically levitated (Maglev) light-rail vehicle for passenger transport, where the stators mount upside down under a monorail track.

For more information, visit MagneMotion's website at www.magnemotion.com.

—C.G. Masi, **Senior Editor**