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Modelling and control of segmented long-stator permanent-magnet linear synchronous motors

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Abstract

A novel control strategy for segmented long-stator permanent magnet linear synchronous motors is presented that is particularly suited to ropeless hoisting. The stator (primary) is segmented into modular sections that are shorter than the moving reaction plate (secondary) and a single voltage source inverter per conveyance is used to power the energised sections. Efficient partial excitation of the stator is achieved with an intermediate switching layer placed between the stator sections and the inverter. The common voltage supplied to the sections is controlled with any standard motor vector control technique. Computer simulation and a purpose-built laboratory prototype show the strategy to be effective. There is scope for future research into full sensorless control of the proposed arrangement and a method of further modulating the supply voltage for those stator sections that are only partially covered by the reaction plate, particularly when operating at higher speeds.

Stemming from initial efforts to mathematically model the linear motor, a novel electromagnetic modelling approach was formulated. This hybrid magnetic-equivalent-circuit (MEC) and finite element method (FEM) approach is suited to efficient dynamic simulation and is explicated with a worked example. The method yields accurate results when compared with pure FEM. An MEC formulation is used for highly-permeable polygonal regions, whereas the magnetic field outside these regions is solved, by superposition, as the combined effect of boundary conditions that interface with those MEC regions and any magnetic sources. The required parameter sets for solving the field outside the regions represented as MECs are purely dependent on the geometry of the problem space and are thus precomputed. The force acting on a chosen group of moving components is calculated using an approximation of the Maxwell Stress Tensor method. Future research could address the present limitation that the highly-permeable regions are meshed using exclusively-rectangular flux tube elements.

A dynamic simulation model that caters for the discontinuities of a segmented stator was ultimately derived using an extended space-vector approach and its implementation as a generic Simulink® blockset is detailed. The motor parameters are determined from static FEM solutions over the range of reaction plate displacement, assuming no magnetic saturation.