Abstract of PhD Thesis - Angshudeep Majumdar - 12EE91R05

Title of the Thesis:
Estimation of End Effects in Linear Induction Machines using the Peak-to-Peak Ripple in Propulsive Force

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Abstract

In a Linear Induction Machine (LIM), as the primary moves, previously un-magnetized portions of the secondary continuously come under the influence of the primary at the leading edge (Entry End) of the machine while previously magnetized secondary material goes out of the influence of the primary at the trailing edge (Exit End). Both these phenomena add exponentially decaying components to the air gap flux travelling at synchronous speed. Thus, the air gap flux is distorted, and this distortion is widely known as "End Effects" in literature.

Due to end effects, there is a net decrease in flux at the entry end of the machine while the flux tends to build up at the exit end. A net reduction in the value of air gap flux happens, causing a net reduction in the value of propulsive force. The loss of flux and the consequent drop in propulsive force increases with increase in speed of the LIM. At zero speed, end effects is negligibly small, and hence the LIM behaves quite similar to a rotating induction machine.

In the equivalent circuit of the LIM, the magnetizing inductance exponentially decreases with increase in speed, thus accounting for the loss of flux and the consequent drop in propulsive force. The magnetizing inductance remains unaffected at zero speed, hence the equivalent circuit of a LIM at zero speed exactly resembles that of a rotating induction machine.

However, even at zero speed some distortion of flux does exist, as the magnetic circuit of the LIM does not close on itself. This implies that the windings of the three phases are not placed symmetric to each other. This makes the LIM an inherently unbalanced machine. Due to this unbalance, the propulsive force contains a ripple component over and above its mean value. Since the ripple results from a phase-to-phase unbalance, hence the frequency of the ripple is twice the supply frequency of the LIM. This phenomenon exists even at zero speed, and is sometimes referred to as "Static End Effects".

In this thesis, the per unit ripple in propulsive force has been introduced as an indicator that can be used to estimate the amount of end effects existing in a LIM. It has been shown that flux distortion due to end effects increases with increase in speed of the LIM but is independent of the value of primary current and primary voltage of the LIM. Also, the flux distortion decreases with increase in number of poles of the LIM, but it remains unaffected by the number of turns in the primary winding of the LIM. It has been shown that the variation of per unit force ripple is similar to the variation of flux distortion due to end effects w.r.t. the above mentioned design criteria and operating conditions. Hence, the per unit force ripple can be used as an indicator for estimating end effects in a LIM.

Experiments have been performed on a 5 pole Disc LIM. It has been shown that the per unit force ripple and its variation with speed can be experimentally recorded. This method of estimating end effects does not require flux sensors to be installed in the air gap of the LIM. Also, it is independent of the equivalent circuit parameters of the LIM.

- **Keywords:** Linear Induction Machine, Finite Element Method, End Effects, Flux Distortion, Magnetic Asymmetry, Phase-to-Phase Unbalance, Force Ripple