## Abstract

The placement of the LC filter in between the pulse width modulated (PWM) voltage-source inverter (VSI) and an induction motor (IM) enhances the motor life cycle by delivering smooth sinusoidal voltages at stator terminals. This placement reduces high-bearing currents, common-mode voltages, and high dv/dt across stator terminals. However, this connection generates resonance frequency oscillations in stator voltages and may lead to closed-loop instability in the rotor flux-oriented (RFO) vector-controlled (VC) IM system. The closed-loop stability of the combined IM + LC filter system is complex and has not been appropriately analyzed in the literature.

This thesis presents a detailed closed-loop stability analysis of the IM + LC filter system based on stability region (SR) and designs the PI gains for dq axes stator current controller. Employing the SR method, the common SRs for the IM and IM + LC filter systems are derived, thereby proving that connecting an LC filter between the VSI and the IM system does not necessarily destabilize the closed-loop system. The thesis also presented that the PI controller being a first-order controller has limitations of stability margins and performance criteria for dq axes stator current control-loop of an IM + LC filter system. These limitations in the PI controller are demonstrated by deriving the complete range of stabilizing PI gains for the IM + LC filter system and segregating them to satisfy the desired frequency domain specifications. To remedy the limitations, the thesis proposes using a second-order controller instead of a PI controller in the inner-loop stator current control loop to provide better stability margins, attenuation at the resonance frequency, and more robustness.

Furthermore, the reactive power flow and its influences on the wide-frequency operation of IM + LC filter drives are explored. An LC filter, placed at the output of a voltage source inverter (VSI) to filter the pulse width modulated (PWM) voltages, unfolds a research opportunity in IM + LC filter drives, as the filter capacitors can also supply reactive power to the IM. The thesis comprehensively investigates this reactive power flow in an IM + LC filter system with filter capacitor values designed using two different methods. In continuation, the thesis analyses issues in the wide-frequency operation, such as reactive power imbalance, abnormal escalation in inverter currents, variation in power factor seen by the VSI, and high current stress on DC-bus capacitors and VSI. The method of filter capacitor selection for the wide-frequency operation of the IM + LC filter system is also proposed in terms of IM and LC filter parameters while resolving the above-mentioned issues.

On the other hand, owing to the phase delay and resonance oscillations introduced by the LC filter, the 'L' and 'C' design methodology is critical. Also, the closed-loop control and speed-sensorless operation of such drives are complex, without stator voltage sensors. This thesis addresses these issues by proposing a simple filter inductor (Lf) selection criterion for an LC filter-equipped IM drive that allows retaining the designed DC-bus capacitor, heat-sink, and power devices of VSI upon LC filter insertion in between the VSI and IM. Furthermore, an existing filter capacitor selection criteria is improved by adhering to the constraint on voltage drop (Vf) across Lf. In addition, the thesis also examines the existing active damping (AD) techniques to perform the speed-sensorless operation on the IM + LC filter (IMLC) drive without stator voltage sensors and improves one of them to achieve the same. Summarily, through the filter selection criteria and improved active damping technique, the thesis proposes to retrofit the LC filter into the IM drive and perform speed and voltage-sensorless operation.

The thesis also explores the influence of delays on closed-loop control of digitally-controlled induction motor (IM) systems with an inverter output LC filter. The delays are inevitable in a digitally controlled system; it influences the closed-loop performance, frequency response, and, consequently, the closed-loop system stability. Therefore, the delay (sampling and processing delays) is modelled and incorporated into the open-loop IM system while designing the closed-loop controllers to address the forenamed issues. These delays and impending stability issues are thoroughly analysed through the frequency-domain indices (Gain-Margin, Phase-Margin) for the IM system with an LC filter.

All the presented analyses and proposals on the IM + LC filter system are validated through MATLAB simulations and experiments on a 5 hp IM system."