Abstract

High-power induction motor (IM) (power rating $>$ 750 kW and fundamental frequency, f_1 $<$ 100 Hz) and high speed permanent magnet synchronous motor (PMSM) (power rating $<$ 100 kW and fundamental frequency, f_1 $>$ 500 Hz) drives are widely used in traction, energy, and transportation applications. These drives commonly utilize IGBT based two-level voltage source inverter (VSI) due to its simple structure, ruggedness and reliability. Due to restrictions on switching energy losses in high power IM drives, switching frequency (f_{sw}) is restricted within 750 Hz. Thus, VSI output voltage has only a few switching transitions ($<$ 30) in a line cycle. Similarly, output voltage of VSI in high-speed PMSM drives also encounters only a few switching transitions ($<$ 20) on account of limitations on maximum f_{sw} for an IGBT ($<$ 20 kHz). Thus, ratio of f_{sw} and f_1 (pulse number, P) is restricted below 15 in both high-power IM and high-speed PMSM drives. Operation at low P introduces significant low-order voltage harmonics which results into high distortion in motor line current, increased torque pulsations, high thermal stress, and reduce efficiency. This thesis aims to achieve near sinusoidal motor line current for aformentioned drives through a comprehensive approach involving novel drive configurations and suitable pulse width modulation (PWM) technique.

In order to achieve near sinusoidal motor line current, this thesis proposes three drive configurations for high-power IM drives - 1) passive filter based IM drive 2) parallel two-level VSI fed IM drive and 3) active harmonic filter based IM drive. First configuration, passive filter based IM drive, primarily introduces LCL filter between VSI and IM terminals. Here, motor leakage inductance is used as third arm of LCL filter. An optimised design for L and C is propsed for adequate filtering of line current harmonics under restricted separartion between resonance and switching frequencies. The proposed configuration is analyzed through small signal model for designing the damping factor. Secondly, the thesis proposes a parallel two-level VSIs fed high-power IM drive for improving the performance. Parallel converter configuration not only helps in distributing the power loss but also in cancellation of motor line current ripple through carrier interleaved synchronous sine-triangle PWM. Same is illustrated through current ripple analysis for parallel converter fed IM drive. An optimal interleaving angle is proposed on basis of this analysis. The performance of IM drive is further improved through active harmonic filter (AHF) based configuration. A two-level VSI called as AHF-VSI is connected in parallel to the main VSI for filtering out the line current harmonics. Active and

reactive powers are supplied to IM though main VSI. Thus, AHF VSI primarily generates ripple current in phase opposition to main VSI. Sizing of AHF VSI and interconnecting inductors is carried out based on well defined constraints. Suitable mathematical models and control block diagrams are developed for all three proposed configurations of IM drive. The proposed configurations are validated through detailed simulations on an 850 kW, 2.2 kV, 65 Hz squirrel-cage induction motor (SCIM) drive. Experimental verification is performed on a scaled-down 3.7 kW, 415 V, 50 Hz SCIM laboratory prototype using a TMS320F28379D DSP-based control platform. The obtained results demonstrate significant improvement in motor current quality, reduction in torque pulsations, enhanced efficiency, and stable low-speed operation, under restricted f_{sw} conditions.

The proposed passive filter based drive configuration is extended to high-speed PMSM drive as well. A 50 kW, 916 Hz, 20 pole, 245 V and 6000 rpm PMSM is selected for this purpose. Suitable design for LC filter parameters are proposed for filtering out line current harmonics. f_{sw} of VSI is restricted to 10 kHz. Small signal model based analysis is presented for suitable design of controller parameters. Proposed configuration for high speed PMSM drive is validated through extensive simulation.