

Wound Rotor Induction Machine for Medium Voltage Applications fed From Series-Connected Inverter Modules

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Abstract: This thesis presents a novel Wound Rotor Induction Machine (WRIM)-based topology designed for medium-voltage (MV) motoring and generating applications. Unlike the conventional approach where the WRIM is supplied by Parallel-Connected Inverter Modules (P.C.I.M.), the proposed topology employs Series-Connected Inverter Modules (S.C.I.M.). This series connection at the inverter dc-links results in a high-voltage dc-link, making the topology well-suited for high-voltage dc (HVDC) transmission applications.

A comprehensive control scheme is developed for deploying the proposed topology in Doubly-Fed Induction Generator (DFIG)-dc applications, operating it either as a voltage generation system or when interfaced with a constant-voltage dc grid. In both scenarios, the mid-point of the series-connected dc-link remains floating. To address this, the proposed control strategy incorporates a unique feature of mid-point voltage regulation to ensure stable and efficient power generation. The control methodology is validated through experimental results, demonstrating its effectiveness for DFIG-dc applications.

Additionally, the thesis proposes a control approach for using the topology in motor drive applications, covering both configurations — where the dc-link mid-point is either connected to the neutral point of a three-level Neutral Point Clamped (3L-NPC) Front-End Converter (FEC), or left floating. In the latter case, a thorough analysis of mid-point voltage imbalance during four-quadrant operation (forward motoring, forward braking, reverse motoring, and reverse braking) is carried out. A key contribution of this work is the formulation of a unified control approach that actively regulates the mid-point voltage across all the four operating modes ensuring reliable and stable drive operation.

Further, the thesis introduces a novel dual-Direct Current Control (DCC) technique, based on three-level hysteresis controllers applied to the stator

and rotor current components. This approach eliminates the need for PI-controllers, thereby reducing the dependency on machine parameters. The method delivers fast dynamic performance comparable to Direct Torque Control (DTC), without requiring torque estimation — overcoming challenges related to torque estimation under specific operating conditions, as discussed in the later part of the thesis.

Two variants of the DCC strategy are explored. In the first, three-level hysteresis control is applied to the $\alpha\beta$ components of the current, and this method is experimentally validated on the proposed WRIM drive topology fed from S.C.I.M. In the second variant, the hysteresis controller operates on the flux-oriented dq components of current, and this scheme is experimentally validated (in the later part of the thesis) for the conventional WRIM drive topology fed from P.C.I.M.

In addition to this, the thesis explores an optimized and fault-tolerant operation of the conventional drive topology based on WRIM fed from P.C.I.M. The optimized mode of operation offers lesser system losses leading to better efficiency, thermal performance and reliability. The proposed solutions of optimized and fault-tolerant operation are supported by detailed comparative analysis, thermal simulations using PLECS, and experimental validations, establishing their effectiveness and efficiency for industrial drive applications.