Cairo University

DIRECT TORQUE CONTROL OF A THREE-PHASE INDUCTION MOTOR USING A THREE-LEVEL INVERTER

By

Wael Abd El-Aziz Al-Dosokey Mahmoud

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Electrical Power and Machines Engineering

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Title of Thesis:

DIRECT TORQUE CONTROL OF A THREE-PHASE INDUCTION MOTOR USING A THREE-LEVEL INVERTER

Key Words:
Direct Torque Control, Field Oriented Control, Three-Phase Induction Motor, Three-Level Neutral-Point-Clamped Inverter, Switching Table

Summary:
In this thesis a direct torque control (DTC) system of three-phase induction motor (IM) using three-phase three-level (3L) neutral-point-clamped (NPC) inverter is proposed. An analytical study is performed to construct a novel switching table (ST) which is mandatory for 3L-DTC operation. Based on the analytical study, the ST is subdivided into three parts according to motor speed where different groups of voltage space vectors (VSVs) are assumed for each part to ensure best performance. The proposed 3L-DTC system is modeled and built in MATLAB/Simulink. Simulation analysis for 3L-DTC is held against two-level DTC (2L-DTC) in the three operating ranges. Results include speed response, torque and flux ripples, voltage and current quality, common-mode voltage and switching frequency. A simple solution for flux drooping problem related to DTC at low speed is also introduced. The problem of neutral-point (NP) voltage deviation related to the NPC inverter is also solved. Comparison results show the effectiveness of the proposed system with respect to 2L-DTC. A 3L-NPC inverter prototype is implemented in the laboratory. The advantages of 3L-NPC inverter over 2L inverter are verified experimentally.

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Dedication

I you wish to dedicate this thesis to my father and mother.

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J	Total moment of inertia of the rotor and load
L_{lr}	Rotor leakage inductance
L_{ls}	Stator leakage inductance
L_m	Magnetizing inductance
L_r	Rotor self-inductance
L_s	Stator self-inductance
abc	Three-phase system representation
d^e-q^e	Direct and quadrature axes of synchronously rotating reference frame
d-q	Direct and quadrature axes of stationary reference frame
$i_{ds}{}^e$ and $i_{qs}{}^e$	Stator direct- and quadrature-axis currents in d^e-q^e frame
$v_{ds}{}^e$ and $v_{qs}{}^e$	Stator direct- and quadrature-axis voltages in d^e-q^e frame
i_{as}, i_{bs} and i_{cs}	Stator phase currents in abc frame
v_{as}, v_{bs} and v_{cs}	Stator phase voltages in abc frame
e_λ	Error in stator flux magnitude
e_T	Error in electromagnetic torque
H_λ	Output of flux hysteresis controller
H_T	Output of torque hysteresis controller
E_λ	Width of band of flux hysteresis controller
E_T	Width of band of torque hysteresis controller
i_{NP}	Neutral-point current
p	Derivative operator (p = d/dt)
P	Number of poles
R_r	Rotor winding resistance
R_s	Stator winding resistance
T_e	Electromagnetic torque
T_L	Load torque
ω_e	Synchronous angular speed (electrical)
ω_r	Rotor angular speed (electrical)
θ_s	Stator flux vector angle
θ_r	Rotor flux vector angle
δ	Torque angle
σ	Total leakage factor
$\bar{v}_s$	Stator voltage space vector in the stationary reference frame