AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING

ELECTRICAL POWER AND MACHINES DEPARTMENT

A DIGITAL PWM INVERTER FOR WIDE SPEED A.C. MOTOR CONTROL

A Thesis Submitted in Fulfilment for the Requirement
of the degree of Doctor of Philosophy
(ELECTRICAL POWER AND MACHINE)

BY

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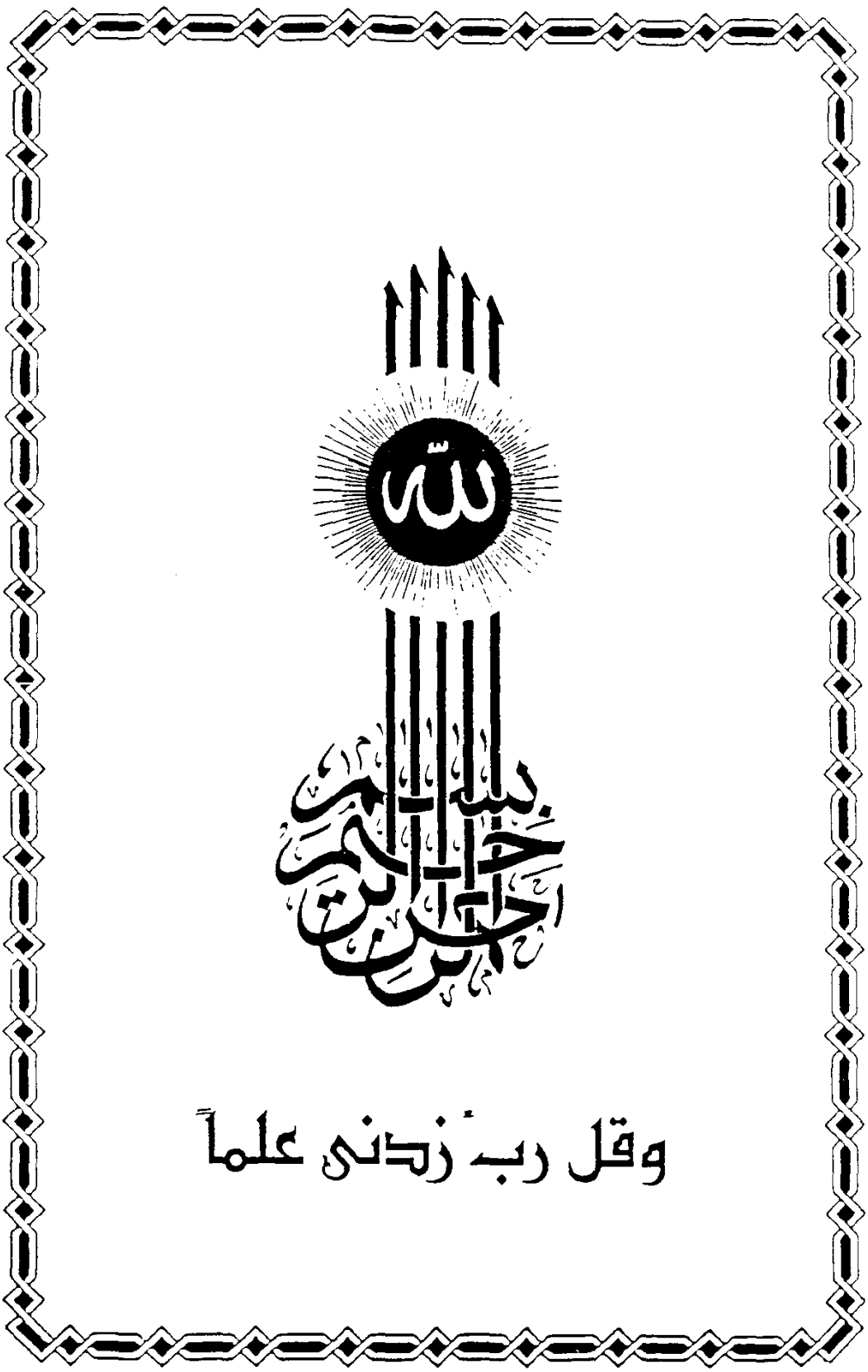

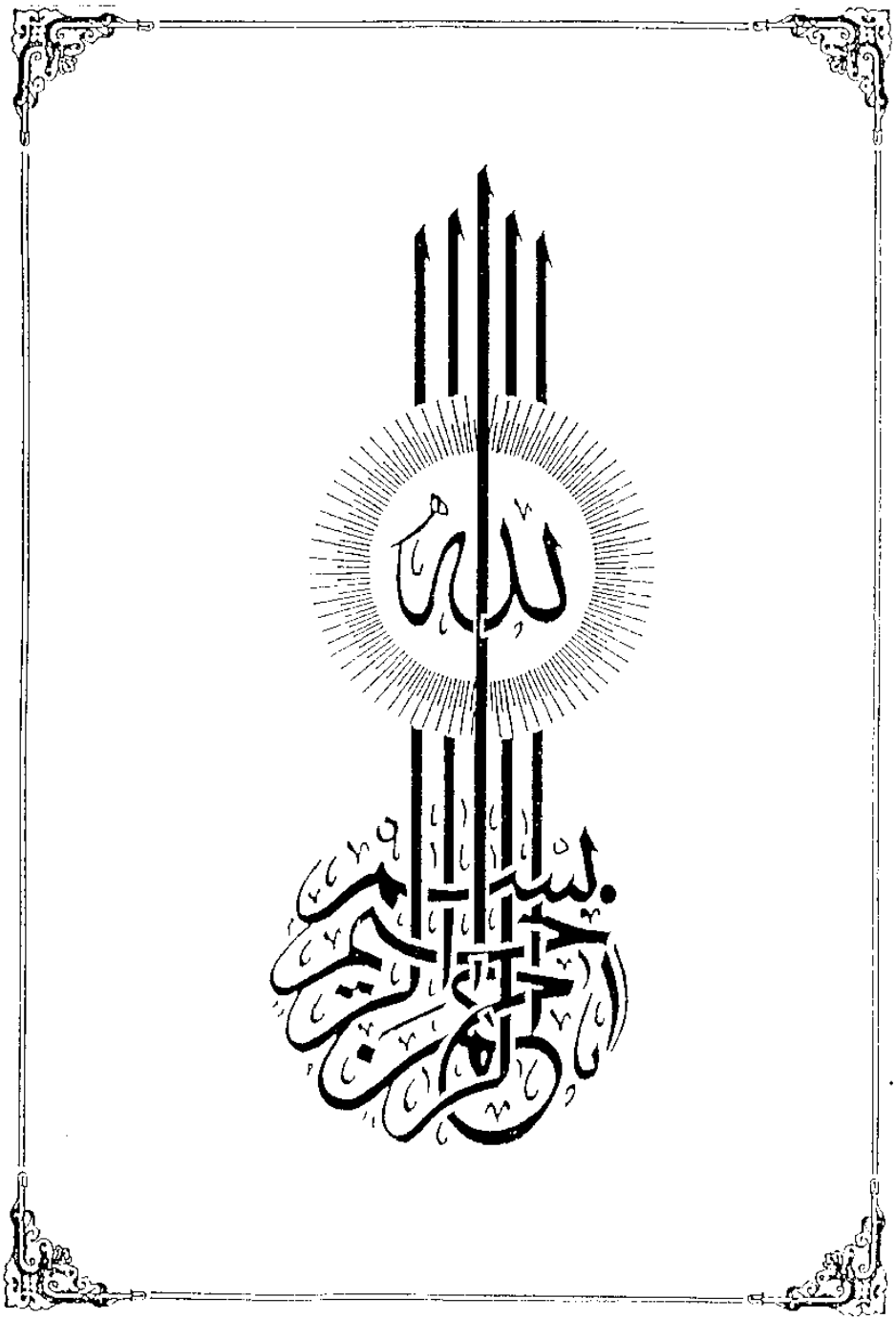

ABSTRACT

Digital pulse width modulation (PWM) inverter for A.C. motor speed control is a new and versatile technique that has considerable potential. With powerful microprocessors, an accurate on-line generation of the required switching patterns is attained. There are many switching strategies such as sinusoidal PWM, optimal PWM, and pulse position modulation which can be used to control the low order harmonic content in the inverter output voltage. From these the optimal PWM strategies, which rely on optimizing a particular characteristic of the PWM waveforms, are superior in eliminating a pre-defined low order harmonic content in the inverter output voltage at low switching frequencies, compared to other strategies. The main disadvantage associated with the optimal PWM strategies is how to define the initial guesses required for solving the nonlinear harmonic voltage equations to calculate the switching angles.

In this investigation novel expressions are suggested for estimating the initial guesses of the switching angles for the single-phase and the three-phase harmonic elimination method (HEM) pulse width modulation strategy. In order to verify these expressions, complete digital PWM inverter systems were designed and built. The designed algorithm provides for generation of PWM waveforms up to nine chops per quarter cycle.

This allows the elimination of low order harmonics up to the 17'th in the single-phase and up to the 25'th in the three-phase (HEM) pulse width modulation systems.

Another novel expression, which allows the prediction of the magnitude and frequency of the dominant harmonic outside the desired eliminated band of harmonics is suggested. This in turn aids the design optimization of overall inverter systems.

The developed digital technique in this research is original and forms the basis of an effective control method with quality a.c. supply. Also the software control of the drive system includes open-loop and closed-loop operations for a three-phase induction motor.

A comprehensive analysis and evaluation of the (HEM) pulse width modulation strategy are presented with experimental results, which accurately match theoretical predictions.

EXAMINER COMMITTEE

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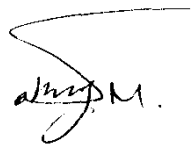
1 - Prof. Dr. Sabry Abd El-latif Professor, Head of the Dept. of Electrical Power and Machines, Faculty of Engineering, Monofia University, Cairo, Egypt.	
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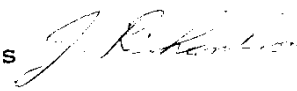
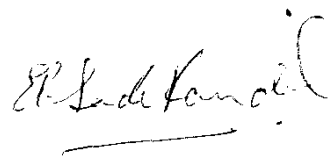
3 - Prof. Dr. Julian Richardson Dept. of Electrical Engineering and Electronics Brunel University, London, U.K.	
4 - Prof. Dr. El-sadik Amin Kandil Professor, Dept. of Electrical Power and Machines, Faculty of Engineering, Ain Shams University, Cairo, Egypt.	

STATEMENT

This dissertation is submitted to Ain Shams University for the degree of Doctor of Philosophy in Electrical Engineering.
The work included in this thesis was carried out by the author.
No part of this thesis has been submitted for a degree or a qualification at other university or institution.

Date : 22/12/1993

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LIST OF SYMBOLS

[A]	the partial derivative matrix.
A, B, C	model coefficients in the Least square regression method (in Hexadecimal).
A_n	the amplitude of the n'th harmonic.
A_s	sinusoidal peak value.
A_T	triangle peak value.
D	decimal
ΔM	increment of the modulation index.
$d\alpha_i$	increment of chop angles.
E or e	error.
F_r	reference frequency.
F_t	feedback frequency.
F(X)	a single variable function.
F'(X)	the derivative of F(X).
G(s)	open-loop transfer function.
J	moment of inertia, or cost function.
K	number of chops per quarter cycle.
K_I	integral controller constant.
K_P	proportional controller constant.
M	modulation index.
M_{ns}	modulation index in the natural sampled pulse width modulation.
n	harmonic order.
N_{cycle}	number of cycles.

N_f	number of frequency change.
P_i	the i'th pulse.
R	number of triangles in a cycle.
S	slip.
T_{st}	induction motor starting time.
V	resolved modulation index.
V_n	the n'th voltage harmonic amplitude.
Y	observed process output.
$\hat{Y}$	output from the modelling process.

GREEK LETTERS

α	chop angle.
ε_1	tolerance in harmonic voltage.
ε_2	tolerance in the diagonal elements of matrix [A].
Ω_o	output speed.
Ω_r	reference speed.
$\Omega_{s.s}$	steady-state speed.

LIST OF ABBREVIATIONS

A/D, or ADC	analogue to digital converter.
BTJ	bipolar junction transistor.
EPROM	erasable programmable read only memory.

FOLM	first order linear model.
GTO	gate turn off thyristor.
HEM	harmonic elimination method.
IGBT	isolated gate bipolar transistor.
MCT	MOS-controlled thyristor.
MOSFET	metal oxide semiconductor field effect transistor.
NSPWM	natural sampled pulse width modulation.
PPI	programmable peripheral interface.
PPM	pulse position modulation.
PWM	pulse width modulation.
PC	programme counter.
P+I	proportional plus integral controller.
QSW	quasi square wave.
RCD	resistance-capacitance-diode.
r.p.m	revolution per minute.
RSPWM	regular sampled sinusoidal pulse width modulation.
SDK	system design kit.
SOM	second order model.
TEXP	calculated experimental torque.
THD	total harmonic distortion.
TTH	calculated theoretical torque.
TTL	transistor-transistor-logic.