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[61] Speed Laboratory (2010). http://www.speedlab.co.uk/software.html


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Abbreviations

ASM    induction machine
CFO    calculation of field orientation
DC     direct current
DCM    DC machine
DFO    direct field orientation
DITC   direct instantaneous torque control
DSP    digital signal processors
FOC    field oriented control
IFO    indirect field orientation
IRTF   ideal rotating transformer
ITF    ideal transformer
MA     maximum ampere
MF     maximum flux
MMF    magneto-motive forces
MTPA   maximum torque per ampere
MTPF   maximum torque per flux
PM     permanent magnet
PMSM   permanent magnet synchronous machine
PWM    pulse width modulation
SM     synchronous machine
SR     switched reluctance
SRAF   SR axial flux
SRM    switched reluctance machine
UFO    universal field-oriented
List of symbols

\(a\)  
acceleration

\(\Theta\)  
angle in mechanical degrees

\(\theta\)  
angle in electrical degrees

\(C\)  
capacitance

\(I\)  
current

\(i\)  
current

\(D\)  
diode

\(e\)  
back e.m.f.

\(E\)  
energy

\(W\)  
energy

\(F\)  
force

\(\psi\)  
flux linkage

\(f\)  
frequency

\(Z\)  
impedance

\(l\)  
incremental inductance

\(L\)  
inductance

\(J\)  
inertia

\(K\)  
parameter

\(k\)  
factor (e.g. winding factor)

\(\kappa\)  
current ratio (e.g. between short circuit current and maximum current in PM machines)

\(\chi\)  
leakage factor

\(m\)  
mass

\(\phi\)  
magnetic flux

\(M\)  
mass

\(N\)  
number (e.g. Number of segments)

\(T\)  
period

\(\text{pf}\)  
power factor

\(P\)  
power

\(p\)  
power

\(p\)  
pole pair number
**List of symbols**

- \( r \) distance
- \( R \) radius
- \( r \) radius
- \( X \) reactance
- \( R \) resistance
- \( T \) simulation time
- \( s \) slip
- \( \Omega \) angular speed in mechanical degrees
- \( \omega \) angular speed in electrical degrees
- \( n \) speed
- \( S \) switch
- \( t \) time
- \( T \) torque
- \( V \) volume
- \( v \) velocity
- \( U \) voltage
- \( u \) voltage
- \( n \) winding number
- \( x \) auxiliary variable
- \( z \) auxiliary variable
- \( s \) laplace operator
- \( c \) damping coefficient
- \( K_i \) integral gain (e.g. of current controller)
- \( K_p \) proportional gain (e.g. of current controller)
- \( m \) modulation ratio
- \( \nu \) voltage ratio
- \( s \) displacement vector
- \( \tau \) time constant
- \( \kappa \) torsion coefficient
- \( \zeta \) damping factor
- \( Sw \) switching signal
List of indices

$\hat{X}$ amplitude
$X^A$ point in control diagram
$X^{\alpha\beta}$ fix stator coordinates
$X^{av}$ average
$X^B$ point in control diagram
$X^b$ base (e.g. base speed)
$X^{bS}$ base with constant stator flux (e.g. base speed with constant stator flux)
$X^C$ point in control diagram
$X^{comp}$ comparator
$X^c$ control (e.g. reference current for the current controller)
$X^D$ point in control diagram
$X^D$ dead time
$X^{dq}$ field oriented coordinates
$X^E$ point in control diagram
$X^F$ point in control diagram
$X^f$ falling edge
$X^l$ limit (e.g. stator frequency limit)
$X^{limit}$ limit
$X^e$ linear
$X^{max}$ maximum (e.g. maximum current)
$X^{noload}$ no-load (e.g. no-load current)
$X^{nom}$ nominal or rated (e.g. rated stator current)
$X^n$ normalized (e.g. normalized stator current)
$X^\omega$ operating point of DC machine (indicates maximum flux-linkage for a given speed and voltage)
$X^{pn}$ positive-negative (e.g. positive-negative sequence impedance matrix)
$X^*$ reference (e.g. reference current)
$X^{ripple}$ ripple
$X^r$ rise edge
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X^r$</td>
<td>in rotor flux oriented coordinate system</td>
</tr>
<tr>
<td>$X^{sc}$</td>
<td>short circuit (e.g. short circuit current)</td>
</tr>
<tr>
<td>$X^{sp}$</td>
<td>speed, single-phase (e.g. single-phase machine impedance matrix)</td>
</tr>
<tr>
<td>$X^s$</td>
<td>in stator flux oriented coordinate system</td>
</tr>
<tr>
<td>$X^v$</td>
<td>operating point of DC machine (indicates the no-load speed)</td>
</tr>
<tr>
<td>$X^{xy}$</td>
<td>rotor-oriented coordinates</td>
</tr>
<tr>
<td>$X^0$</td>
<td>point in control diagram</td>
</tr>
<tr>
<td>$X_a$</td>
<td>armature quantity (e.g. armature current)</td>
</tr>
<tr>
<td>$X_{a1}$</td>
<td>indicates the on-time of the first space vector at SVM</td>
</tr>
<tr>
<td>$X_{a2}$</td>
<td>indicates the on-time of the second space vector at SVM</td>
</tr>
<tr>
<td>$X_a^{\alpha}$</td>
<td>aligned rotor position</td>
</tr>
<tr>
<td>$X_{\alpha}$</td>
<td>real component of quantity in stator coordinates</td>
</tr>
<tr>
<td>$X_A$</td>
<td>amplitude</td>
</tr>
<tr>
<td>$X_{aux}$</td>
<td>auxiliary (e.g. auxiliary winding of single-phase induction machine)</td>
</tr>
<tr>
<td>$X_B$</td>
<td>bandwidth</td>
</tr>
<tr>
<td>$X_{\beta}$</td>
<td>imaginary component of quantity in stator coordinates</td>
</tr>
<tr>
<td>$X_b$</td>
<td>bottom</td>
</tr>
<tr>
<td>$X_C$</td>
<td>capacity</td>
</tr>
<tr>
<td>$X_c$</td>
<td>center</td>
</tr>
<tr>
<td>$X_c^{c}$</td>
<td>centripetal</td>
</tr>
<tr>
<td>$X_o$</td>
<td>characteristic value</td>
</tr>
<tr>
<td>$X_{conv}$</td>
<td>converter</td>
</tr>
<tr>
<td>$X_c^{i}$</td>
<td>correction</td>
</tr>
<tr>
<td>$X_f$</td>
<td>counter</td>
</tr>
<tr>
<td>$X_{cw}$</td>
<td>compensation winding</td>
</tr>
<tr>
<td>$X_d$</td>
<td>real component of quantity in field oriented coordinates</td>
</tr>
<tr>
<td>$X_{DC}$</td>
<td>DC (e.g. DC link voltage)</td>
</tr>
<tr>
<td>$X_\delta$</td>
<td>delta</td>
</tr>
<tr>
<td>$X_e$</td>
<td>indicates an inertia due to translational load</td>
</tr>
<tr>
<td>$X_e^{e}$</td>
<td>electric (e.g. electrical frequency)</td>
</tr>
<tr>
<td>$X_{eq}$</td>
<td>equal</td>
</tr>
<tr>
<td>$X_f$</td>
<td>excitation (e.g. excitation flux)</td>
</tr>
<tr>
<td>$X_f^{f}$</td>
<td>frequency</td>
</tr>
<tr>
<td>$X_{hom}$</td>
<td>homopolar (e.g. homopolar inductance)</td>
</tr>
<tr>
<td>$X_{in}$</td>
<td>input (e.g. input power)</td>
</tr>
<tr>
<td>$X_l$</td>
<td>inductive</td>
</tr>
<tr>
<td>$X_{1i}$</td>
<td>integral (e.g. integral component)</td>
</tr>
<tr>
<td>$X_{101}$</td>
<td>switching states for given voltage vector</td>
</tr>
<tr>
<td>$X_k$</td>
<td>integer variable used as counter (e.g. time step in discrete system)</td>
</tr>
<tr>
<td>$X_l$</td>
<td>line (e.g. line voltage)</td>
</tr>
<tr>
<td>$X_{1L}$</td>
<td>load (e.g. load torque)</td>
</tr>
<tr>
<td>$X_M$</td>
<td>transformed main quantity</td>
</tr>
<tr>
<td>$X_m$</td>
<td>main quantity (e.g. main inductance)</td>
</tr>
<tr>
<td>$X_m^{m}$</td>
<td>measured</td>
</tr>
<tr>
<td>Index</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>-------------</td>
</tr>
<tr>
<td>$\mathbf{X}_m$</td>
<td>mechanical (e.g. mechanical position)</td>
</tr>
<tr>
<td>$\mathbf{X}_{\text{min}}$</td>
<td>minimum</td>
</tr>
<tr>
<td>$\mathbf{X}_-$</td>
<td>negative sequence (indicates a negative rotational direction)</td>
</tr>
<tr>
<td>$\mathbf{X}_M$</td>
<td>model based quantity</td>
</tr>
<tr>
<td>$\mathbf{X}_o$</td>
<td>characteristic value (e.g. eigenfrequency)</td>
</tr>
<tr>
<td>$\mathbf{X}_{\text{off}}$</td>
<td>off</td>
</tr>
<tr>
<td>$\mathbf{X}_{\text{on}}$</td>
<td>on</td>
</tr>
<tr>
<td>$\mathbf{X}_{\text{out}}$</td>
<td>output (e.g. output power)</td>
</tr>
<tr>
<td>$\mathbf{X}_{\text{ph}}$</td>
<td>phase, e.g. number of phases</td>
</tr>
<tr>
<td>$\mathbf{X}_D$</td>
<td>phase (e.g. phase voltage)</td>
</tr>
<tr>
<td>$\mathbf{X}_1$</td>
<td>phase 1</td>
</tr>
<tr>
<td>$\mathbf{X}_a$</td>
<td>phase a</td>
</tr>
<tr>
<td>$\mathbf{X}_2$</td>
<td>phase 2</td>
</tr>
<tr>
<td>$\mathbf{X}_b$</td>
<td>phase b</td>
</tr>
<tr>
<td>$\mathbf{X}_3$</td>
<td>phase 3</td>
</tr>
<tr>
<td>$\mathbf{X}_c$</td>
<td>phase c</td>
</tr>
<tr>
<td>$\mathbf{X}_4$</td>
<td>phase 4</td>
</tr>
<tr>
<td>$\mathbf{X}_d$</td>
<td>phase d</td>
</tr>
<tr>
<td>$\mathbf{X}_i$</td>
<td>phase index</td>
</tr>
<tr>
<td>$\mathbf{X}_a$</td>
<td>motoring pinion</td>
</tr>
<tr>
<td>$\mathbf{X}_r$</td>
<td>generating pinion</td>
</tr>
<tr>
<td>$\mathbf{X}_+$</td>
<td>positive sequence (indicates a positive rotational direction)</td>
</tr>
<tr>
<td>$\mathbf{X}_\pm$</td>
<td>positive and negative sequence (indicates a positive and negative rotational direction)</td>
</tr>
<tr>
<td>$\mathbf{X}_p$</td>
<td>power (e.g. power circle)</td>
</tr>
<tr>
<td>$\mathbf{X}_p$</td>
<td>proportional (e.g. proportional component)</td>
</tr>
<tr>
<td>$\mathbf{X}_{\text{pu}}$</td>
<td>torque pulses e.g. number of torque pulses</td>
</tr>
<tr>
<td>$\mathbf{X}_{\text{PWM}}$</td>
<td>pulse-width modulation</td>
</tr>
<tr>
<td>$\mathbf{X}_q$</td>
<td>imaginary component of quantity in field oriented coordinates</td>
</tr>
<tr>
<td>$\mathbf{X}_R$</td>
<td>transformed rotor quantity</td>
</tr>
<tr>
<td>$\mathbf{X}_r$</td>
<td>rotor quantity (e.g. rotor resistance)</td>
</tr>
<tr>
<td>$\mathbf{X}_{\text{rp}}$</td>
<td>rotor pole</td>
</tr>
<tr>
<td>$\mathbf{X}_{\text{run}}$</td>
<td>run (e.g. run winding of single-phase induction machine)</td>
</tr>
<tr>
<td>$\mathbf{X}_s$</td>
<td>sampling (e.g. sampling time)</td>
</tr>
<tr>
<td>$\mathbf{X}_{\text{seg}}$</td>
<td>segments</td>
</tr>
<tr>
<td>$\mathbf{X}_{\text{sense}}$</td>
<td>controlled</td>
</tr>
<tr>
<td>$\mathbf{X}_{\text{sl}}$</td>
<td>slip (e.g. slip frequency)</td>
</tr>
<tr>
<td>$\mathbf{X}_S$</td>
<td>transformed stator quantity</td>
</tr>
<tr>
<td>$\mathbf{X}_s$</td>
<td>stator quantity (e.g. stator resistance)</td>
</tr>
<tr>
<td>$\mathbf{X}_{\text{step}}$</td>
<td>step</td>
</tr>
<tr>
<td>$\mathbf{X}_\sigma$</td>
<td>stray or leakage (e.g. stray or leakage flux)</td>
</tr>
<tr>
<td>$\mathbf{X}_{\text{supply}}$</td>
<td>supply e.g. supply current</td>
</tr>
<tr>
<td>$\mathbf{X}_\pi$</td>
<td>vector which contains the duty cycles/ switching signals of all phases</td>
</tr>
<tr>
<td>$\mathbf{X}_t$</td>
<td>tangential</td>
</tr>
</tbody>
</table>
$X_i$ indicates a certain instant in time
$X_t$ top
$X_{\text{total}}$ total
$X_u$ unaligned rotor position
$X_w$ winding
$X_x$ real component of quantity in rotor-oriented coordinates
$X_y$ imaginary component of quantity in rotor-oriented coordinates
$X_0$ zero
$X_{\text{air-gap}}$ air-gap (e.g. air-gap power)
$\vec{X}$ phasor
$\chi$ space vector
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