Induction Motor Torque–Slip from the Equivalent Circuit

Torque, current and power factor of an induction motor at a slip, with breakdown and starting torque, from the per-phase equivalent circuit.

Method: Chapman; Electric Machinery Fundamentals; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Line voltage (parameters per phase of the star equivalent, V/√3)	415.00	V
Frequency	50.000	Hz
Poles	4.0000	
Stator resistance per phase	0.20000	Ω
Stator leakage reactance	0.60000	Ω
Rotor resistance referred to stator	0.25000	Ω
Rotor leakage reactance referred	0.60000	Ω
Magnetising reactance	20.000	Ω
Slip	3.0000	%

Calculated results

Parameter	Value	Unit
Torque at the slip	116.33	N·m
Stator current	30.039	A
Power factor	0.87138	
Breakdown torque	372.32	N·m
Slip at breakdown	20.846	%
Starting torque	161.97	N·m

Notes for this case

- Standard per-phase equivalent circuit with core loss neglected; torque from the Thevenin form. Parameters come from no-load and locked-rotor tests.

Formula and method

$$T = \frac{3V_{th}^2 R'_2/s}{\omega_s\left[(R_{th}+R'_2/s)^2+(X_{th}+X'_2)^2\right]}, \quad s_{max} = \frac{R'_2}{\sqrt{R_{th}^2+(X_{th}+X'_2)^2}}$$

Variables

V	Line voltage (parameters per phase of the star equivalent, V/√3)	V
f	Frequency	1/s
p	Poles	-
R_1	Stator resistance per phase	Ω
X_1	Stator leakage reactance	Ω
R'_2	Rotor resistance referred to stator	Ω
X'_2	Rotor leakage reactance referred	Ω
X_m	Magnetising reactance	Ω
s	Slip	-

T	Torque at the slip	N·m
I_1	Stator current	A
$\cos\phi$	Power factor	-
T_{max}	Breakdown torque	N·m
s_{max}	Slip at breakdown	-
T_{st}	Starting torque	N·m

Method and standards

Equivalent circuit.

Assumptions and limits

- Constant parameters (no saturation or deep-bar effect).
- Parameters per phase of the star equivalent with phase voltage V/√3; convert delta-connected test data to star first (divide impedances by 3).
- Poles an even whole number. When the breakdown slip exceeds 1 it is shown as 100 % and a note explains that T_max is not reached in motoring.

References

• Chapman
• Electric Machinery Fundamentals
• 5th ed. (McGraw-Hill, 2012)
• ch. 6 (induction motor equivalent circuit and torque–speed characteristic)

Report details

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Release checks	2 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.



This calculator online

https://calc.firecad.com/electrical/motors/induction-motor-torque-slip

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Reopens the calculator with the inputs of this report.