# Wound-Rotor Motor: External Resistance for Maximum Starting Torque

Thevenin equivalent, slip at maximum torque, pull-out torque and the external rotor resistance that gives maximum torque at standstill for a wound-rotor motor.

**Method:** Thevenin equivalent circuit of the induction motor

## Input parameters

Unit system: SI

| Parameter | Value | Unit |
|---|---|---|
| Line voltage (star) | 460.00 | V |
| Frequency | 60.000 | Hz |
| Number of poles | 4.0000 | |
| Stator resistance per phase | 0.64100 | Ω |
| Stator leakage reactance | 1.1060 | Ω |
| Magnetising reactance | 26.300 | Ω |
| Rotor resistance referred to stator | 0.33200 | Ω |
| Rotor leakage reactance referred | 0.46400 | Ω |
| Stator-to-rotor turns ratio | 2.0000 | |

## Calculated results

| Parameter | Value | Unit |
|---|---|---|
| Thevenin voltage per phase | 254.79 | V |
| Slip at maximum torque (no external R) | 20.141 | % |
| Pull-out torque | 230.80 | N·m |
| Starting torque without external R | 106.56 | N·m |
| External resistance referred to stator | 1.3164 | Ω |
| External resistance per rotor phase | 0.32909 | Ω |

### Notes for this case

• Thevenin of the stator and magnetising branch: V_TH = V_φX_M/√(R₁² + (X₁ + X_M)²), Z_TH = jX_M(R₁ + jX₁)/(R₁ + j(X₁ + X_M)). Maximum torque occurs at s_max = R₂′/√(R_TH² + (X_TH + X₂′)²) and its value does not depend on rotor resistance. Adding R_ext′ = √(R_TH² + (X_TH + X₂′)²) − R₂′ puts maximum torque at standstill; on the rotor side it is divided by a². The resistor is cut out in steps as the motor speeds up.

## Formula and method

$$s_{max} = \frac{R_2'}{\sqrt{R_{TH}^2 + (X_{TH} + X_2')^2}}, \quad T_{max} = \frac{3V_{TH}^2}{2\omega_s \left[R_{TH} + \sqrt{R_{TH}^2 + (X_{TH} + X_2')^2}\right]}, \quad R_{ext}' = \sqrt{R_{TH}^2 + (X_{TH} + X_2')^2} - R_2'$$

### Variables

| | | |
|---|---|---|
| $V_L$ | Line voltage (star) | V |
| $f$ | Frequency | 1/s |
| $p$ | Number of poles | - |
| $R_1$ | Stator resistance per phase | Ω |
| $X_1$ | Stator leakage reactance | Ω |
| $X_M$ | Magnetising reactance | Ω |

| | | |
|---|---|---|
| $R_2{}'$ | Rotor resistance referred to stator | Ω |
| $X_2{}'$ | Rotor leakage reactance referred | Ω |
| $a$ | Stator-to-rotor turns ratio | - |
| $V_{TH}$ | Thevenin voltage per phase | V |
| $s_{max}$ | Slip at maximum torque (no external R) | - |
| $T_{max}$ | Pull-out torque | N·m |
| $T_{start}$ | Starting torque without external R | N·m |
| $R_{ext}{}'$ | External resistance referred to stator | Ω |
| $R_{ext}$ | External resistance per rotor phase | Ω |

### Method and standards

Rotor resistance.

### Assumptions and limits

- Steady-state equivalent circuit; constant parameters; star connection.

### References

Thevenin equivalent circuit of the induction motor

## Report details

| | |
|---|---|
| Report reference | FCC-WYYD-ARS0 (the same inputs always give the same reference) |
| Generated | 23 November 2026, 18:24 UTC |
| Calculator | Wound-Rotor Motor: External Resistance for Maximum Starting Torque |
| Method last reviewed | 17 November 2026 |
| Software release | FireCAD Calc, release of 22 November 2026 |
| Release checks | 3 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/wound-rotor-starting-resistance

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.