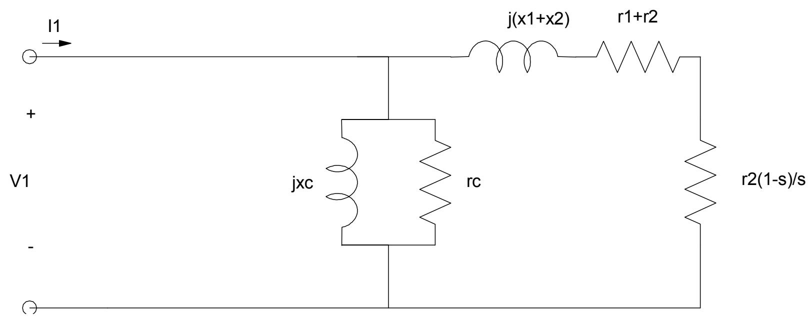
Testing Induction Motors

Problem: Determine the parameters for a 3-phase induction motor experimentally.



Per-phase model for a 3-phae induction morot. $R_m = r_2\left(\frac{1-s}{s}\right)$

Solution: An induction is essentially an N:1 transformer.

- The stator (primary side) sees 60Hz like it or not (it's connected to the power grid) (r1 + jx1)
- The rotor (secondary side) sees a frequency related to the slip speed: $f = s \cdot 60Hz$

Just like a transformer you use a no-load and short-circuit test

No-Load Test: Let the motor spin freely with no load. The slip speed should be close to zero. Measure Vin, Iin, Pin to compute a parallel RL model for the core.

Short-Circuit Test (Locked Rotor Test): Lock the rotor. Apply a smaller voltage to the motor and measure Vin, Iin, Pin to compute the series RL model for the copper: r1+r2 + j(x1+x2)

DC Test: You really need to know r2 to model the transformer. You can't measur r2 directly since it's in the rotor and not electrically connected to anything at DC. You can measure the DC resistance of the stator, however. This tells you r1, which in turns lets you find r2.

Example: Typical numbers from the lab are:

No-Load Test:

- VLL = 100.41V
- IL = 0.29A
- Ptotal = 18.47W

The model is a per-phase model, so convert everything to line-to-neutral

$$V_{LN} = \frac{100.41V}{\sqrt{3}} = 57.97V$$

The core impedance is

$$Z_c = \frac{57.97V}{0.29A} = 199.9\Omega$$

The power factor is

$$pf = \frac{18.47W}{3 \cdot 59.97V \cdot 0.29A} = 0.3662$$

(the 3 comes from the power out being mechanical (total) power. The power in has a '3' since this is a 3-phase circuit and V and I are per-phase.) The total core impedance is then

$$Z_c = 199.9\angle 68.517^0$$

The parallel RL model for the core is then

$$Z_c = 545.8\Omega \,||\, j214.8\Omega$$

Note: The no-load test has the motor running at full speed. The 545.8 Ohms lumps the rotational, eddy, and hysteresis losses all together. You can

- Include 545.8 Ohms in the core and say the rotational losses are zero, or
- Exclude the 545.8 Ohms in the core and say the rotational losses are 18.47W.

Just don't do both.

Locked Rotor Test: (slip = 1. Also same as the short-circuit test for a transformer)

Lock the rotor, reduce the input voltage, and measure the voltage, current, and power. This tells you the windings:

Data:

- VLL = 32.13V
- IL = 0.38A
- Ptotal = 8.82W

Like before, find the impedance.

$$V_{LN} = \frac{32.13}{\sqrt{3}} = 18.55V$$

$$Z_{cu} = \frac{18.55V}{0.38A} = 48.816\Omega$$

The power factor is

$$pf = \frac{8.82W}{3 \cdot 18.55V \cdot 0.38A} = 0.4171$$

so

$$Z_{cu} = 48.816\angle 65.35^0$$

or in rectangular form

$$Z_{Cu} = 20.36 + j44.36$$

R1 + R2 = 20.36

jX1 + jX2 = j44.36

It doesn't really matter how the j44.36 Ohms is allocated to jX1 and jX2. Just for simplicity, half is assigned to each term:

jX1 = jX2 = 22.1837

It *does* matter how the resistance is allocated to R1 and R2, however since R2 determines Rm. To separate these terms, measure the DC resistance of the stator. This tells you R1

DC Test:

- The DC resistance line-to-line is 24.709 Ohms..

This actually measures 2R1 since it is the resistance from one line to the other. Hence

R1 = 12.3547 Ohms

and

R2 = 20.36 - 12.35 = 8.01 Ohms