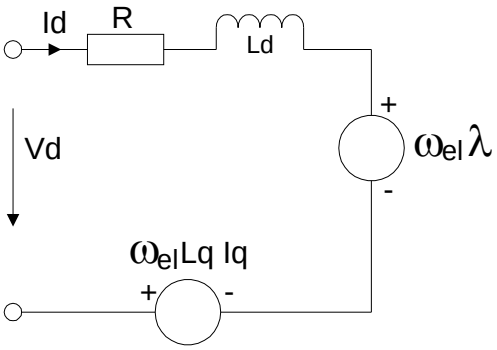
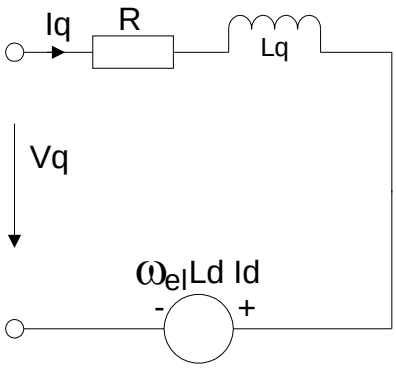
Determination of synchronous inductances Ld and Lq of IPMSM and PMSM

The equivalent phase model of PMSM and IPMSM are shown below (PSPM = permanent magnet synchronous motors). R represents the sum of ohmic losses (R_{ohm}) plus magnetic losses (Rm). Ld and Lq are the equivalent inductances along the d-axis (direct axis) and the q-axis (quadrature axis).



d-axis circuit

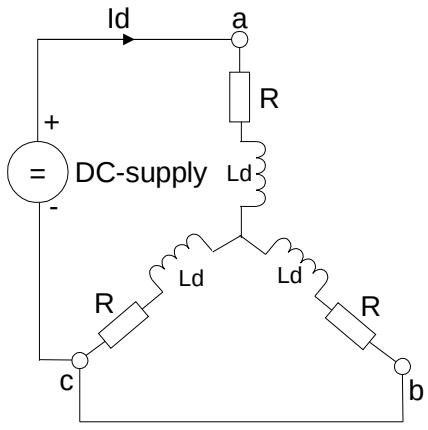


q-axis circuit

The ohmic losses are temperature dependent $R_{ohm} = R_o(1+\alpha\Delta t)$, the magnetic losses are magnetization dependent due to non-linearity.

Ld and Lq are measured in a locked motor shaft test. This implies $\omega_{el} = 0$, or the voltage sources of the equivalent circuits are zero.
Lq, and mainly Ld are somewhat current dependent.

Measure d-axis inductance Ld



Alignment into d-axis

Step 1: Align the rotor to phase a. Connect DC-supply as shown. The current Id aligns the rotor into the d-axis, electrical angle = 0°.

Step 2: Lock the rotor shaft.

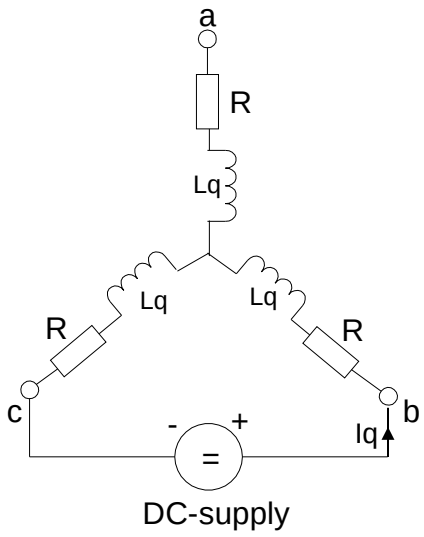
Step 3: Replace the DC-supply by a variable frequency AC-Source. Apply current Id.

Step 4: From the 108A display read frequency f, |Z01|, Phi01, (use current synchronization).

Step 5: Calculate: $R = 0.667 \bullet |Z01|\cos(Phi01)$
$Xd = 0.667 \cdot |Z01| \sin(Phi01)$
$Ld = Xd / 2\pi f$

Step 6: Repeat Step 5 at different current levels. Plot R and Ld versus current.

Measure q-axis inductance Lq



Alignment into q-axis

Step 1: Current Iq aligns the rotor into the q-axis, electrical angle = 90°.

Step 2: Lock the rotor shaft firmly, Iq generates torque.

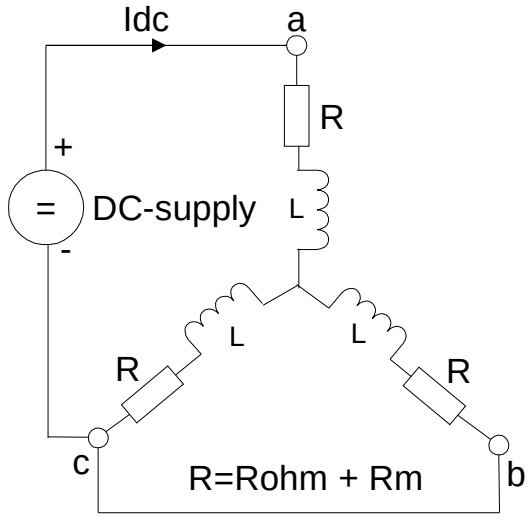
Step 3: Replace the DC-Supply by a variable frequency AC-Source. Apply current Iq.

Step 4: From the 108A display read frequency, |Z01|, Phi01, (use current synchronization).

Step 5: Calculate: $R = 0.5\ |Z01| \cos(Phi01)$
$Xq = 0.5\ |Z01| \sin(Phi01)$
$Lq = Xq / 2\pi f$

Step 6: Repeat step 5 at different current levels. Plot Lq versus current.

Measure Ohmic component of Loss resistance R = Rohm + Rm



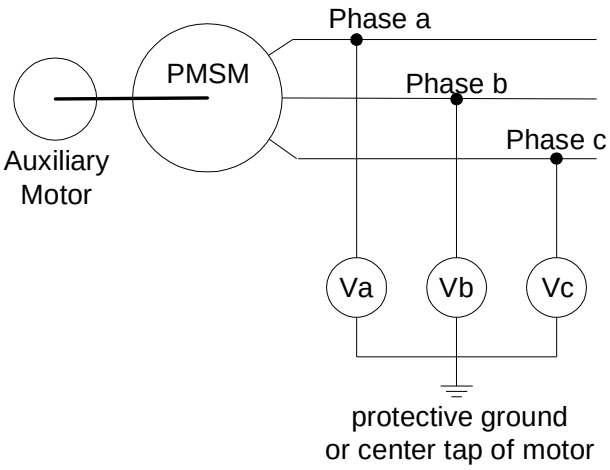
Step 1: Connect DC power supply.

Step 2: Measure Vdc, Idc, and Pdc using 108A.

Step 3: Calculate Rohm = Pdc / I^2dc

Back – EMF (BEMF)

To measure the BEMF the shaft of a PMSM / IPMSM is turned by an auxiliary motor at constant speed ω_{el}.



Step 1: Connect Va, Vb, Vc to phase 1, 2, 3 of the 108A. (use voltage synchronization).

Step 2: Display V01a, V01b, V01c the fundamental of voltage and frequency.

Step 3: Calculate the BEMF peak value.

$$Vapeak = 1.41 \cdot V01a$$
$$Vbpeak = 1.41 \cdot V01b$$
$$Vcpeak = 1.41 \cdot V01c$$

Calculate $k = Vpeak / 2\pi f$ [Vs / rad].
k is a constant used for motor control.