ELECTRICAL ENGINEERING

IDENTIFYING THE PARAMETERS OF A DC MACHINE

1. Preamble :

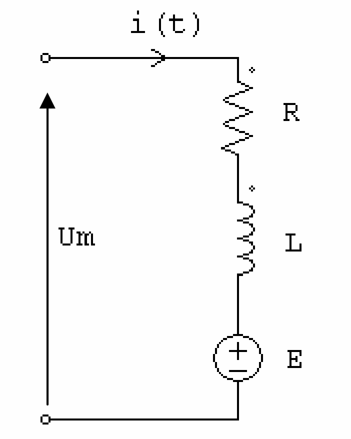
Identification consists in obtaining a dynamic (or static) model of a system. We can proceed in two ways:

- By elaborating the model using knowledge of the system and differential equations. It is then necessary to determine through measurements the values of the coefficients.
- By using an identification algorithm that uses experimental data obtained with an acquisition system.

We propose here a measurement procedure associated with the first method.

2. Fundamental relations :

We present on the right the equivalent circuit of the armature of the machine.



We can deduce the electrical equation in any given state:

$$U_m(t) = Ri(t) + L\frac{di(t)}{dt} + E(t) \qquad (2.1)$$

We are reminded of the electromechanical equations linked to the motor:

$$E(t) = k\Phi\Omega(t) \text{ et } C_{em}(t) = k\Phi i(t)$$

The equality 2.1 can therefore be written:

$$\boxed{U_m(t) = Ri(t) + L\frac{di(t)}{dt} + k\Phi\Omega(t)} \qquad (2.2)$$

K is a constant that depends on the geometry of the motor (number of conductors, pairs of poles and windings)

Φ is the effective flux (in Wb) and Ω the rotation speed (in rad/s).

For a constant flux machine, we can write :

$$E(t) = k_e\Omega(t) \text{ and } C_{em}(t) = k_i i(t) \text{ with } k_e = k_i$$

In general (separately excited or series machine) the flux depends on the excitation current in the inductor. For a given speed we have E = f(I)

Mechanical equations:

C_{em} : electromagnetic torque supplied by the motor.
J : moment of inertia of the rotating unit.
C_{ch} : load torque. It is made up of the load torque C_r and the friction C_f.

with $\boxed{C_f = f\Omega + C_{s0} \times \mathrm{sgn}(\Omega)}$

f : viscous friction coefficient.
C_{s0} : kinetic friction torque.
The fundamental principle of dynamics allows us to write:

$$J\frac{d\Omega(t)}{dt} = C_m(t) - C_{ch}(t) \qquad (2.3)$$

By specifying $C_{ch} = C_r + C_f$, the equation (2.3) can be written :

$$\boxed{C_m(t) = J\frac{d\Omega(t)}{dt} + f\Omega + C_{s0}\mathrm{sgn}(\Omega) + C_r(t)} \qquad (2.4)$$

3. <u>Measuring resistance and armature inductance</u> :

- For permanent magnet motors:
  We block the shaft of the DCM, we have therefore $\Omega(t) = E(t) = 0$
  The equation (2.2) becomes :

$$\boxed{U_m(t) = Ri(t) + L\frac{di(t)}{dt}} \qquad (3.1)$$

In these conditions, the armature current is the equivalent of a RL series circuit.
It is then possible to measure the resistance using a constant voltage method, but we can also feed the armature current with a voltage U, which is rectangular (produced by a chopper).
We can thus visualize the current with an oscilloscope.

The asymptote I_{max} is equal to U/R and the time constant τ_e is equal to L/R.
Observations : We will be careful to ***limit the current*** *in the armature current (risk of deterioration of the brushes and collectors).*
We can take several measurements for different positions of the rotor (for example three measurements at 120 °) and calculate an average.

- For separately excited motors:

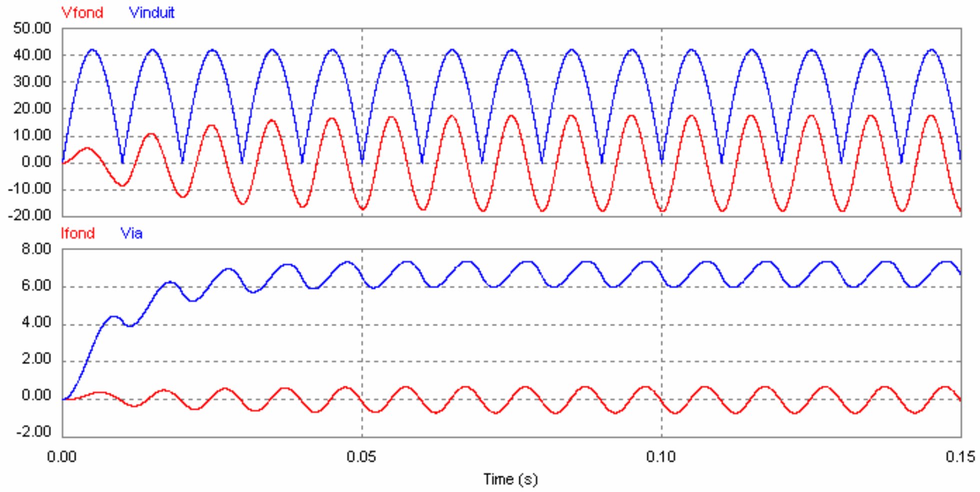
The inductor is not supplied and the relation 3.1 is applied.
We note the value of the resistance with the constant voltage method taking into account the pervious observations. We can make a correction according to the temperature:
$R_{60} = 1{,}15R_{20}$

We measure the value of the armature inductance for a nominal value of the current (taking into account its eventual saturation). We will use the method of the first order harmonic.
We feed the armature current by using a single phase (or three phase) bridge rectifier while calculating the RMS value of the sinusoidal voltage in such a way as to obtain an average value of the armature current equal to its nominal value (see redress_nc.doc).

A filter system and an oscilloscope allow us to see the phase displacement between the fundamental of the voltage and fundamental of the current.

The equality $\tan\varphi = L\omega/R$ allows us to obtain L for the chosen operating point.

Note : It is necessary to know the value of the frequency of the fundamental.



4. Measuring the no-load characteristic:

The no-load characteristic is measured as a generator. It consists in noting the curve that shows the evolution of the electromagnetic force (no-load) in function of the excitation current, the rotation speed of the machine being maintained constant. We therefore note that $E = f(I_{exc})$ at nominal N.
This measurement allows us to evaluate the product $k\Phi$ for the nominal operating point.

Note : In a real situation, we would proceed by changing Iexc by applying increasing and then decreasing values in order to show the hysteresis and the residual flux of the magnetic material.

5. Measuring friction :

This measurement is carried out no-load. It is used to determine experimentally the coefficients of f and C_{s0}.
Since the motor is not loaded, load torque, C_{ch} is equal to the friction C_f (because $C_r = 0$)
If the speed is positive, the equality (2.4) is written :

$$\boxed{C_m(t) = J\frac{d\Omega(t)}{dt} + f\Omega + C_{s0}} \quad (5.1)$$

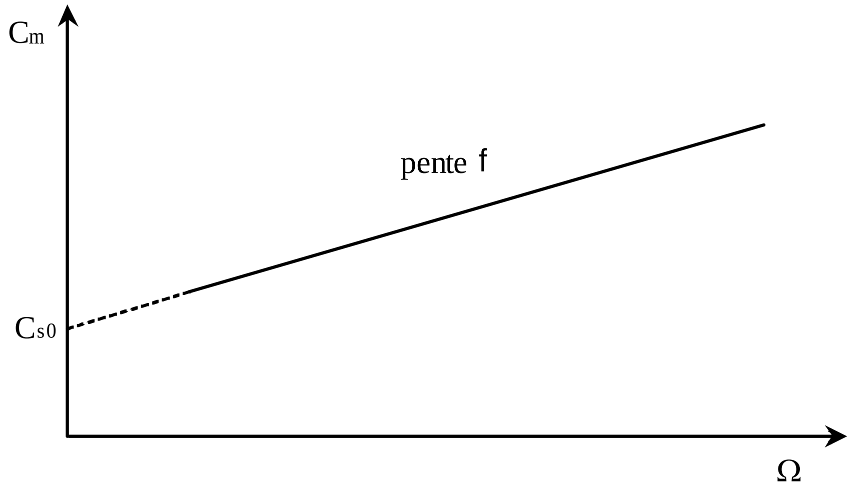
In steady state (stabilized speed), the previous equation becomes :

$$\boxed{C_m(t) = f\Omega + C_{s0}} \quad (5.2)$$

For different values of the rotation frequency (we vary U_m), we note the value of the current I.
We deduce the value of $C_m \approx C_{em}$ because $k\Phi$ is known for the nominal excitation:

The equality (5.2) becomes : $\boxed{k\Phi I = f\Omega + C_{s0}}$

We obtain an equation like y = ax + b that we are going to plot in order to find a (f) and b (C_{s0})
The term $\mathbf{C_{s0}}$ represents the **kinetic friction torque** whereas the term $\mathbf{f\Omega}$ represents the **viscous friction**.



We therefore have $f = \frac{\Delta C_m}{\Delta\Omega}$ and by linear extrapolation the value of C_{s0}.

6. Measuring the value of the moment of inertia:

The motor is running at a constant speed Ω_0 (no-load). We cut off the power supply for the armature current and the field and we can visualize with the oscilloscope the decrease in speed until the motor stops. We carry out a no-load test.

The motor, which is only subject to the friction slows down and stops. The slowing down is subject to the equation (5.1) with $C_m = 0$ as long as $\Omega(t) \neq 0$.

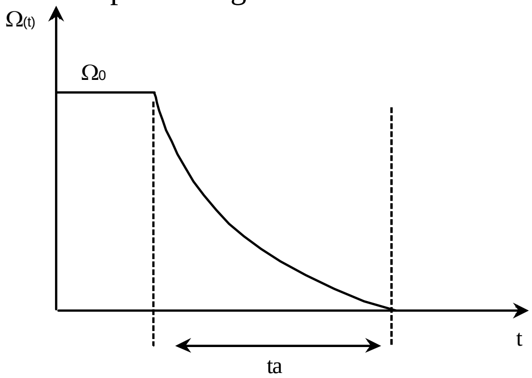
The equation (5.1) can be expressed in the form :

$$\tau_m \frac{d\Omega(t)}{dt} + \Omega(t) = -\frac{C_{s0}}{f} \quad (6.1) \text{ with } \tau_m = \frac{J}{f}$$

We recognize the differential equation of the first order where the typical solution is :

$$\Omega(t) = \Omega_0 e^{-\frac{t}{\tau_m}} - \frac{C_{s0}}{f}(1 - e^{-\frac{t}{\tau_m}}) \quad (6.1)$$

The limit of the previous solution corresponds to the interval [0, t_a], the instant t_a when the shaft stops rotating.



The equation $\Omega(t_a) = 0$ allows us to express t_a in function of Ω_0, C_{S0}, f and J (n.b. J is the moment of inertia of the entire rotation group). From (6.1) we get :

$$J = f \frac{t_a}{\ln(f \frac{\Omega_0}{C_{s0}} + 1)} \quad (6.2)$$

The knowledge of f and of C_{S0} allows us to calculate J while carrying out a no-load test based on the speed Ω_0.