
Practical Work No.3

Study of Speed Control: Case of a DC Motor

1. OBJECTIVE OF THE EXPERIMENT

Simulate the operation of a DC motor and study its speed control using MATLAB/SIMULINK software.

2. THEORETICAL BACKGROUND

The linear operation of a DC motor is characterized by the following electrical and mechanical equations:

- **Electrical equation of the motor:**

$$v(t) = R \cdot i(t) + L \cdot \frac{di(t)}{dt} + e(t)$$

where:

$v(t)$ = motor control voltage

$e(t)$ = induced back EMF

R = armature resistance

$i(t)$ = armature current

L = armature inductance

- **Mechanical equation of the motor:**

$$C_m(t) = J \frac{d\omega(t)}{dt} + f \omega(t) + C_r(t)$$

where: $C_m(t)$ = motor torque

$C_r(t)$ = load torque

J = motor moment of inertia

f = viscous friction coefficient

The Laplace transform of equations (1) and (2) gives:

$$V(s) = (R + Ls)I(s) + E(s)$$

$$C_m(s) = (Js + f)\Omega(s) + C_r(s)$$

The flux and torque constant, denoted K , relates electrical and mechanical parameters through:

$$E(s) = K\Omega(s)$$

$$C_m(s) = KI(s)$$

6.3 SIMULATION USING MATLAB/SIMULINK

6.3.1 Simulation

Create a schematic with the following characteristics:

- $R = 1.2 \, \Omega$
- $L = 0.18 \, \text{H}$
- $K = 0.284 \, \text{N.m/A}$
- $f = 6 \times 10^{-3} \, \text{N.m/rad/s}$
- $J = 24 \times 10^{-4} \, \text{kg.m}^2$

The schematic to simulate is as follows:

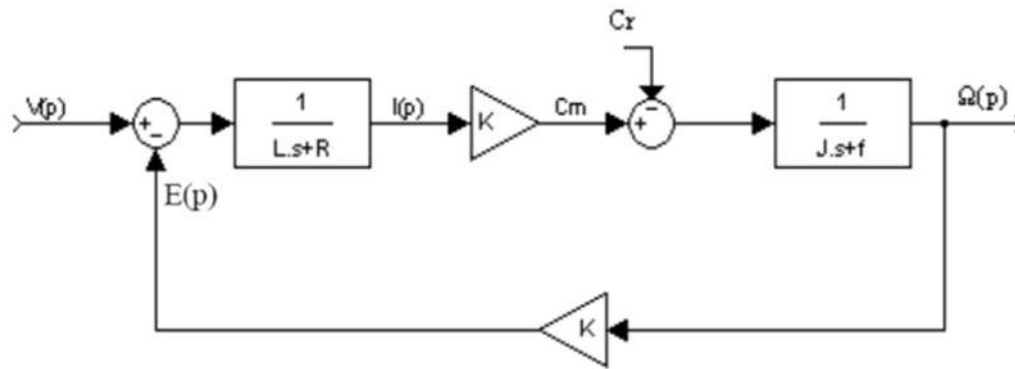


Fig. 1. Block diagram of a DC motor

In Simulink (MATLAB's graphical interface), the schematic takes the following form:

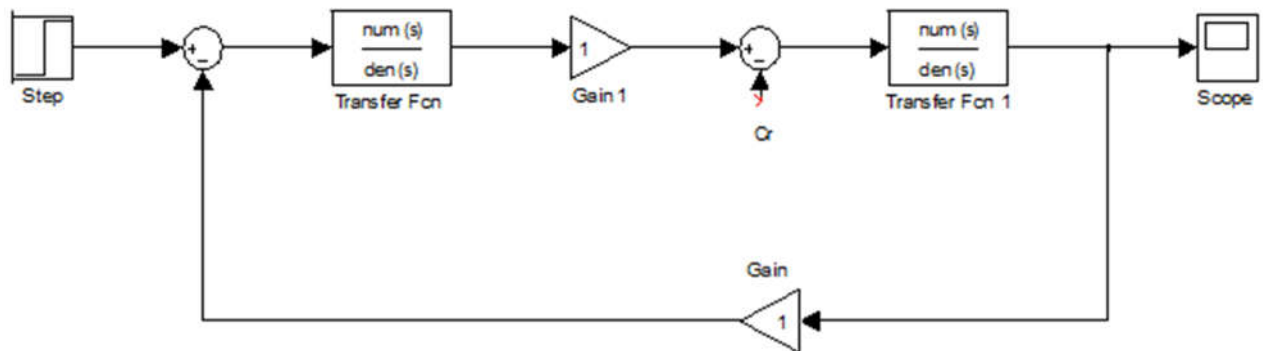


Fig. 2. Representation of Fig. 1 in Simulink

To execute the simulation, define the parameters of each block:

1. Click on input $V(s)$: Constant: 48
2. Click on the first transfer function and enter: Denominator: [0.18 1.2]
3. Click on the gains and enter: Gain: 0.284
4. Click on input $C_r(s)$: Constant: 0
5. Click on the differentiator and enter: [-1 1]
6. Click on the second transfer function and enter: Denominator: [0.0024 0.006]

Required Work:

- Write the relationship linking speed $\Omega(s)$ to control voltage $V(s)$ and load torque $C_r(s)$

- Based on the obtained step response, what is the motor speed in steady state? Specify the unit. Compare this result with the theoretical value
- Modify your schematic to display speed in rpm on the oscilloscope. Provide the obtained speed in this unit
- Determine the overshoot value and 90% rise time
- Set a load torque of 5Nm and rerun the simulation. Adjust oscilloscope parameters if necessary to properly observe the motor speed evolution in response to a 48V control voltage step
- Analyze the obtained graph to determine the steady-state motor speed, overshoot, and 90% rise time
- Compare the obtained values with those calculated theoretically (for $C_r=0$ Nm)

6.3.2 CLOSED-LOOP MOTOR OPERATION SIMULATION

Required Work:

- Modify the previous schematic to implement the following diagram:

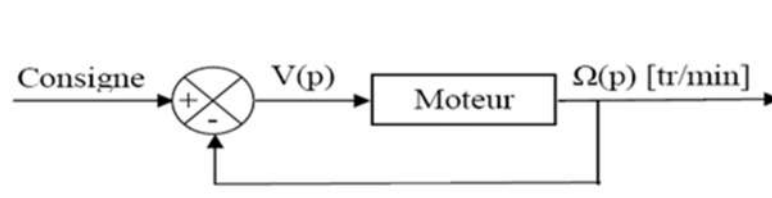
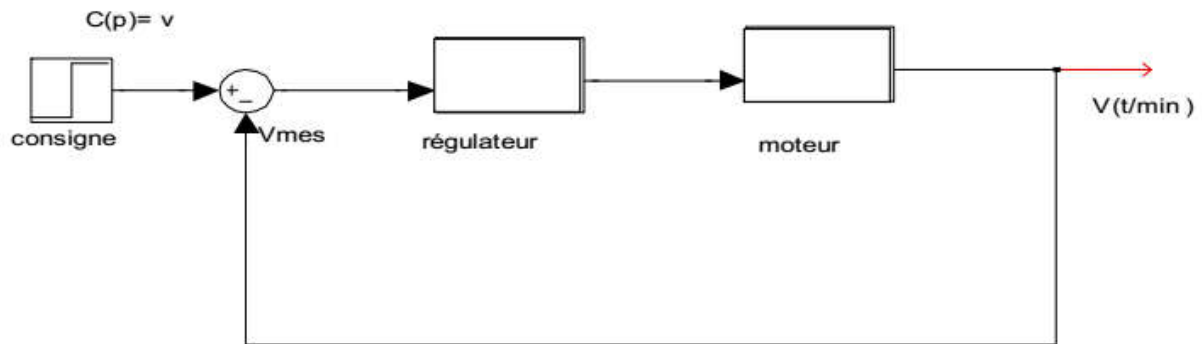


Fig. 3. Closed-loop speed control system

- Determine the relationship linking speed $\Omega(s)$ (in rpm) to reference $C(s)$ and load torque $C_r(s)$
- What reference value should be applied to obtain a steady-state motor speed equal to that previously obtained without load torque? Apply this value for the step reference and verify that the output speed converges to the desired value
- From this new step response, determine the overshoot value and 95% rise time. Compare these results with those previously obtained without load torque

- Set a load torque of 5 Nm and analyze the new step response to obtain the steady-state speed, overshoot, and 95% rise time. Compare your results with those obtained in open loop
- Introduce a proportional controller P in the previous schematic (Fig. 3)



Find the value of P to achieve responses satisfying:

1. 10%, 20%, and 30% overshoot for $C_p=1500$ and $C_r=0$ Nm
 2. Final values of 100, 500, and 1000 rpm for $C_p=1500$ and $C_r=5$ Nm
- **Conclusion:** Explain the advantages of operating the motor in closed loop