**Ministry of Higher Education and Scientific Research**
**Med Boudiaf University - M'sila**
**Department: Electrical Engineering**
**Module: Control Systems**
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**3rd Year _electrical engineering**

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:**

$v(t) = R*i(t) + L*di(t)/dt + e(t)$

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:**

$Cm(t) = J*d\omega(t)/dt + f*\omega(t) + Cr(t)$

where: $Cm(t)$ = motor torque

$Cr(t)$ = load torque

J = motor moment of inertia

f = viscous friction coefficient

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

$V(s) = (R + L*s)*I(s) + E(s)$

$Cm(s) = (J*s + f)*\Omega(s) + Cr(s)$

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

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

$Cm(s) = K*I(s)$

## 6.3 SIMULATION USING MATLAB/SIMULINK

### 6.3.1 Simulation

Create a schematic with the following characteristics:

- $R = 1.2\ \Omega$
- $L = 0.18$ H
- $K = 0.284$ N.m/A
- $f = 6\times10^{-3}$ N.m/rad/s
- $J = 24\times10^{-4}$ kg.m²

The schematic to simulate is as follows:

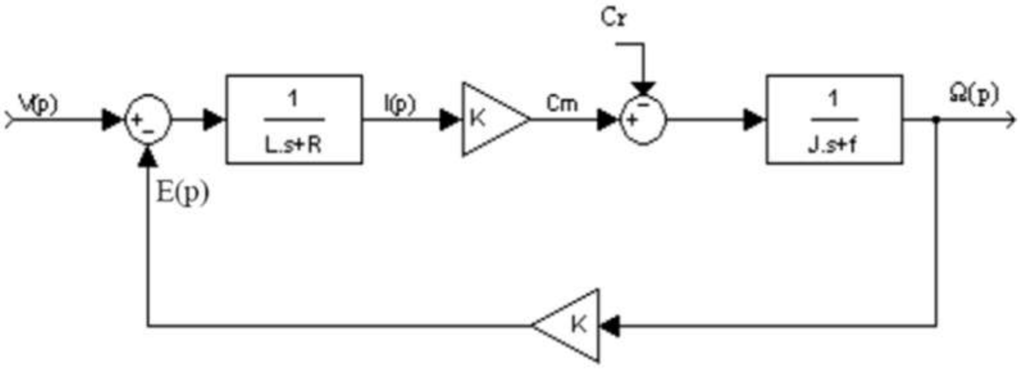



**Fig. 1. Block diagram of a DC motor**

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

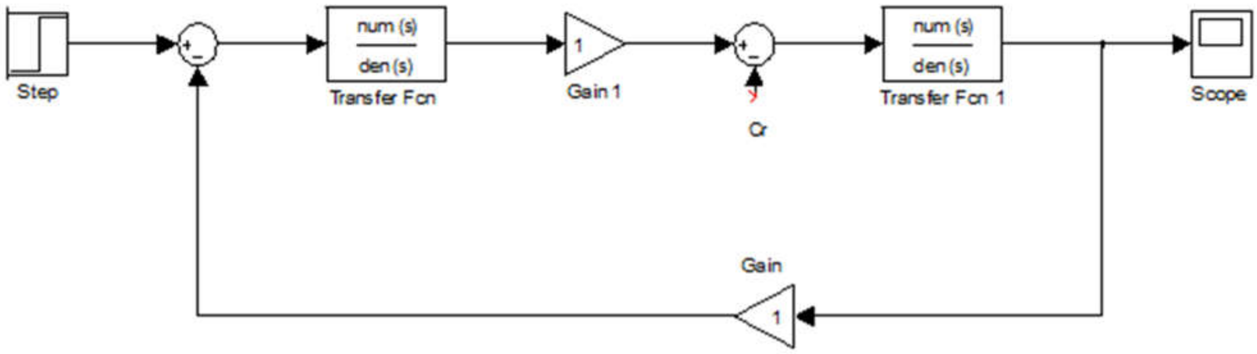



**Fig. 2. Representation of Fig. 1 in Simulink**

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 Cr(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 Ω(s) to control voltage V(s) and load torque Cr(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 Cr=0 Nm)

### 6.3.2 CLOSED-LOOP MOTOR OPERATION SIMULATION

**Required Work:**

- Modify the previous schematic to implement the following diagram:

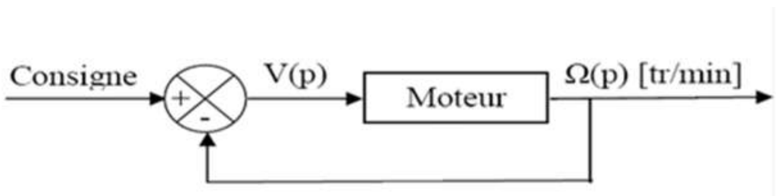
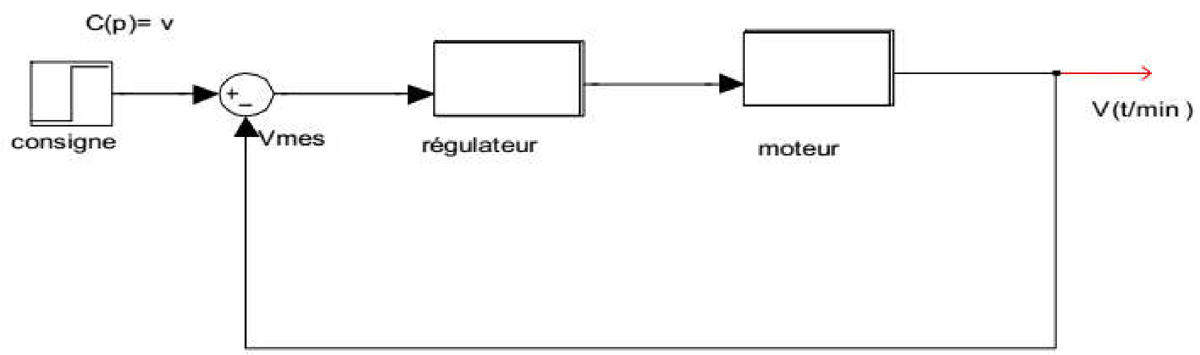



**Fig. 3. Closed-loop speed control system**

- Determine the relationship linking speed Ω(s) (in rpm) to reference C(s) and load torque Cr(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 Cp=1500 and Cr=0 Nm
2. Final values of 100, 500, and 1000 rpm for Cp=1500 and Cr=5 Nm

- **Conclusion:** Explain the advantages of operating the motor in closed loop