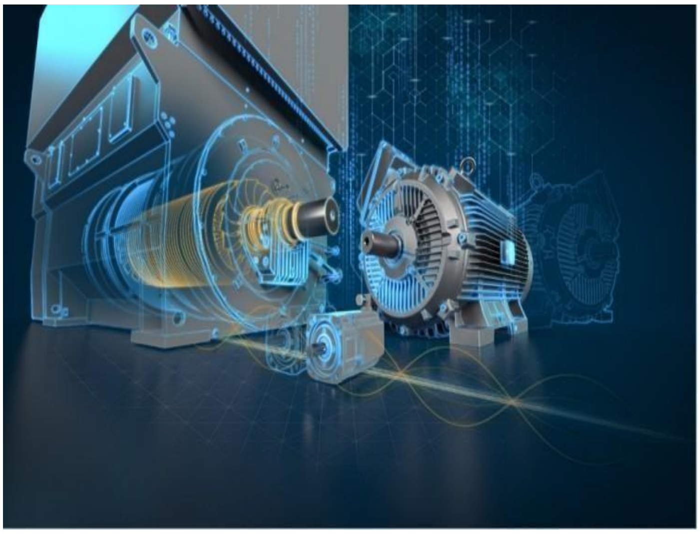

CONTROL SYSTEMS LAB REPORT

Group Number: 55

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Lab V2: Modelling and Identification of a DC Motor

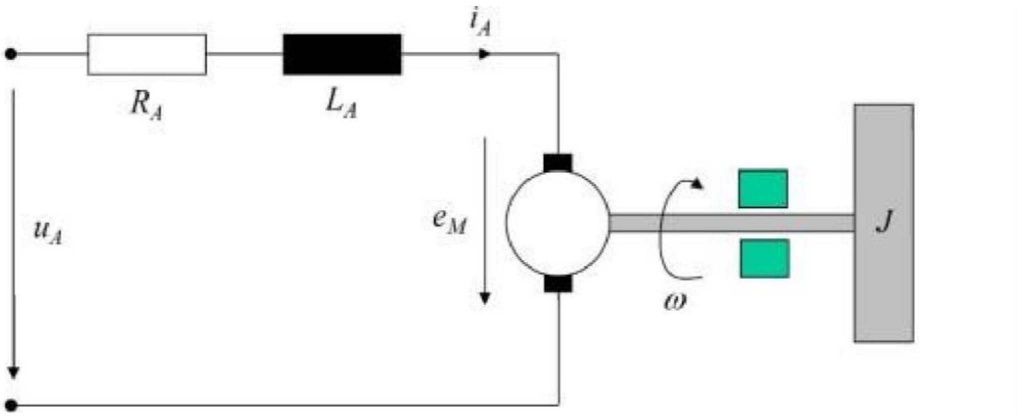
Experiment Performed on: 03.05.2022 :

Supervisor: **Prof. Dr. Tobias Kaupp**

Objective:

In this experiment we derive various parameters : Armature Resistance, Inductance Load, Generator Constant, Dry friction torque, Co-efficient of Viscous Friction and moment of Inertia of our model motor and then we ran simulation on MATLAB with same input signals in order to compare our real time Data with simulation model and find the reasons behind differences .

Model of the Motor:



Differential equation: according to kirchoff's voltage law

$$R_A \, . \, i_A + L_A \frac{di_A}{dt} = -U_A - e_M$$

Applying newton's second law on motor Dynamics we get

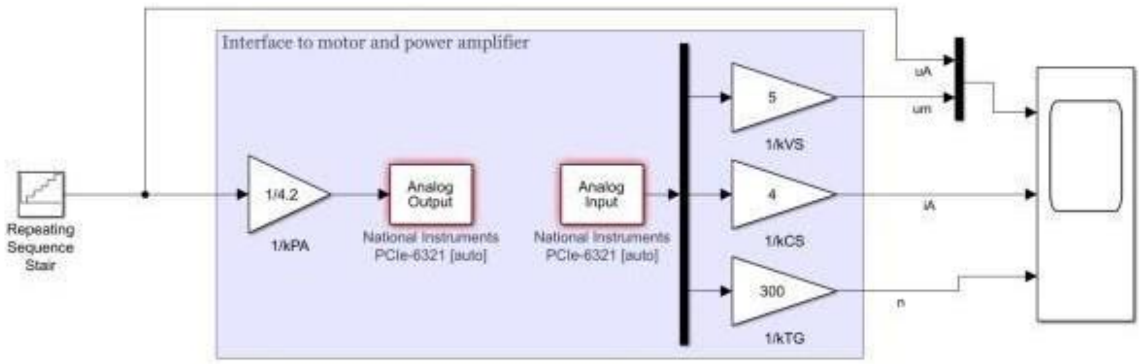
$$J \frac{dw(t)}{dt} = r_M - r_F - r_L$$

Symbol Abbreviation:

Symbol	Explanation	Unit
R_A	Armature resistance	Ω
L_A	Armature inductance	H
i_A	Armature current	A
u_A	Armature voltage	V
e_M	Electromotive force (emf)	V
ω	Angular velocity of the rotor	rad/s
J	Moment of inertia of the motor	kg m^2
τ_M	Motor torque	Nm
τ_F	Friction torque	Nm

τ_{F0}	Dry friction torque	Nm
a_F	Coefficient of viscous friction	Nm/(rad/s)
τ_L	Load torque	Nm
k_G	Motor constant	Vs/rad or Nm/A
n	Motor speed	min^{-1}

Simulink Block Diagram (Matlab):



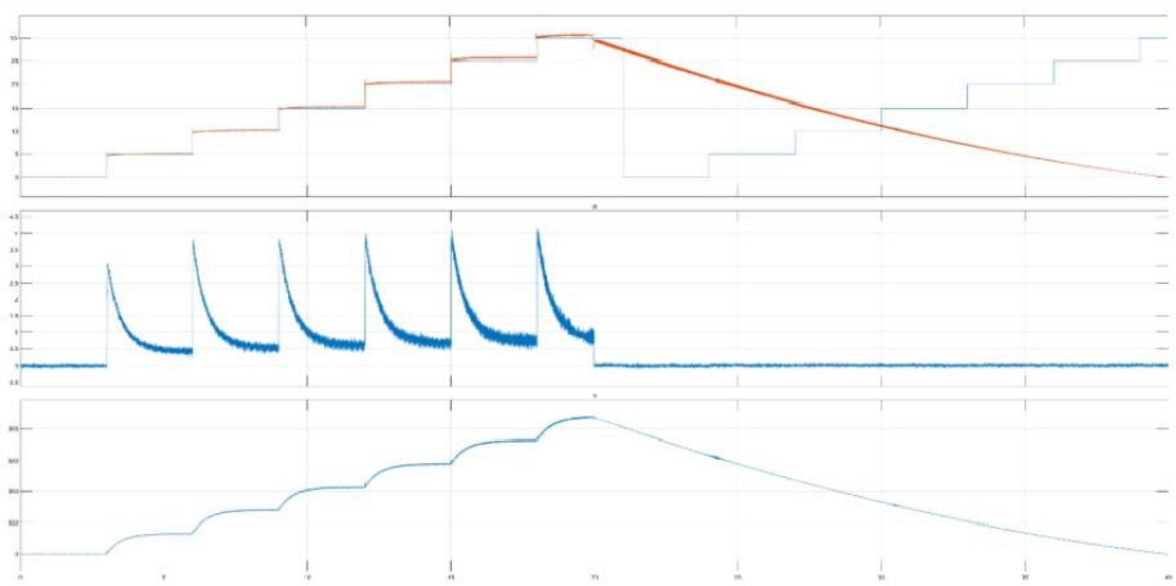
Here,

Power Amplifier (Kpa)=4.2

Speed Sensor (Ktg) $= 300\ \overline{\mathrm{m}}\mathrm{in}_{-1}$

Voltage Sensor (Kvs) $= \frac{1}{5}$

★ **Measurement:** The link between power amplifier and the DC motor is taken off after 20 seconds and the graph received is as follows



After running the model with the Simulink Diagram above we used the following code to extract data

```
 t=D.time;
u=D.signals(1).values(:,1);
e=D.signals(1).values(:,2);
i=D.signals(1).values(:,1);
n=D.signals(1).values(:,1);
Omega=pi*n/30;
```

⋆Determining model parameters :

- **Armature resistance R_A and inductance L_A :** Theoretically, the armature parameters LA and RA can be determined with the help of a blocked-rotor test. In that test, the rotor of the motor is blocked and a voltagestep is applied to the motor terminals and from the measured current, the values for inductance resistance are calculated. In the blocked-rotor mode, the angular velocity and the emf of the motor are zero.

Differential equation: In time domain

$$R_A \cdot i_A(t) + L_A \frac{di_A(t)}{d(t)} = u_A(t)$$

In S domain:

$$\frac{I_A(s)}{U_A(s)} = \frac{1/R_A}{L_A/R_A\, s + 1}$$

Matlab Code:

```
stairs(t,u); hold on;plot (t,i);hold off;
grid on; xlim([2.995 3.04]); ylim([-0.1
5.1]); xlabel('Time (sec)')
legend({'u_A/V','i_A/A'})
```

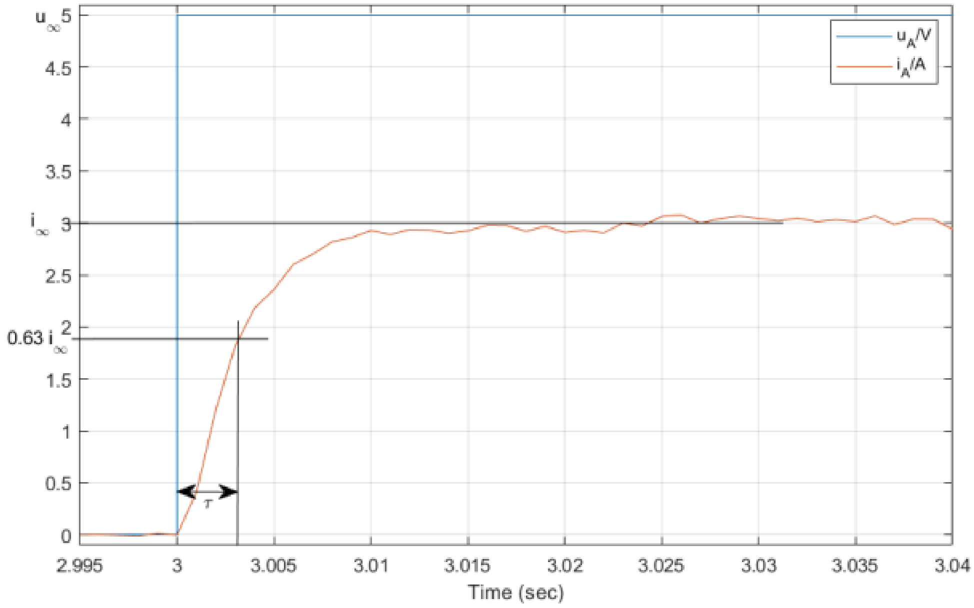


Fig: Armature Step response

From figure:

$$U_\infty = 5V$$

$$i_\infty = 3A$$

$$T = 0.005s$$

$$R_A = \frac{u_\infty}{i_\infty} = 1.67\ \Omega; \qquad L_A = \tau R_A = 5.01mH$$

- **Motor/Generator Constant** K_G: *kG could be determined by dividing the emf measured during the coast-down phase by the angular velocity of the motor. As both signals are noisy, a directdivision would not deliver satisfactory results. We can plot emf against angular velocity and then determine the slope of the graph*

  We use the following Matlab codes to determine K_G :

```
 ind_s = 20500; ind_e=40000;
plot(Omega(ind_s:ind_e),e(ind_s:ind_e));
xlabel('Angular velocity\omega(rad/s)');
ylabel('Induced emf e_M(V)');
```

We got the following figure with equation:

Fig: *Motor or Generator Constant k G*

The slope can be yielded from the equation:

Y = 0.1232*x + 0.02673 m $K_G = 0.1232$

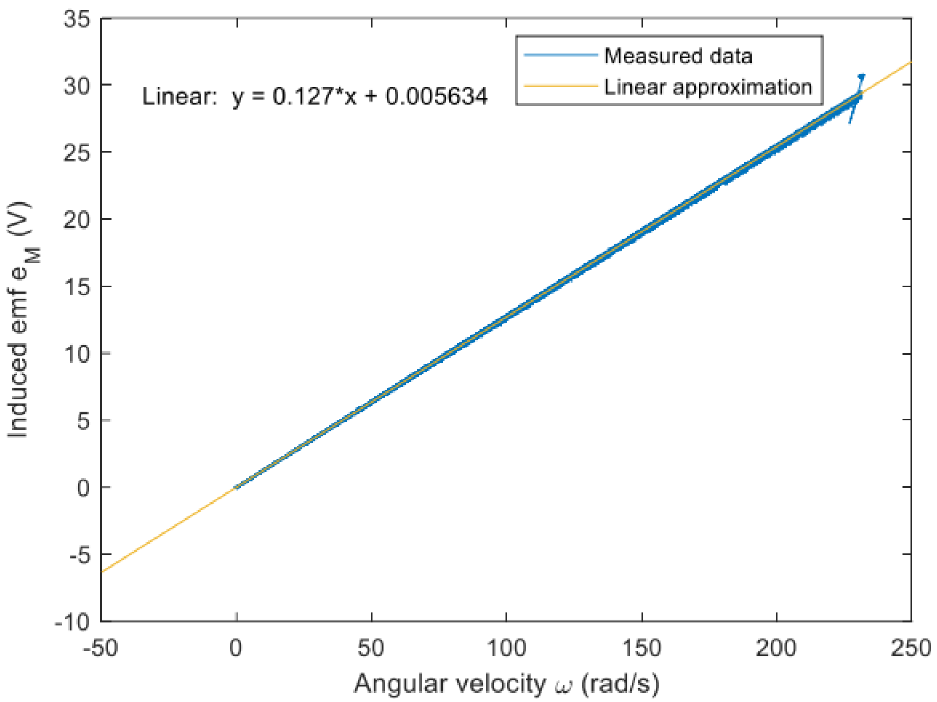
- **Parameters of the Friction model**:

According newtons law rotor mechanics the differential equation:

$$J \frac{dw(t)}{dt} = r_M - r_F - r_L$$

Considering $r_L = 0$

And $dw(t)/dt = 0$; $r_F = r_M$



we used the following code to determine motor torque and friction torque

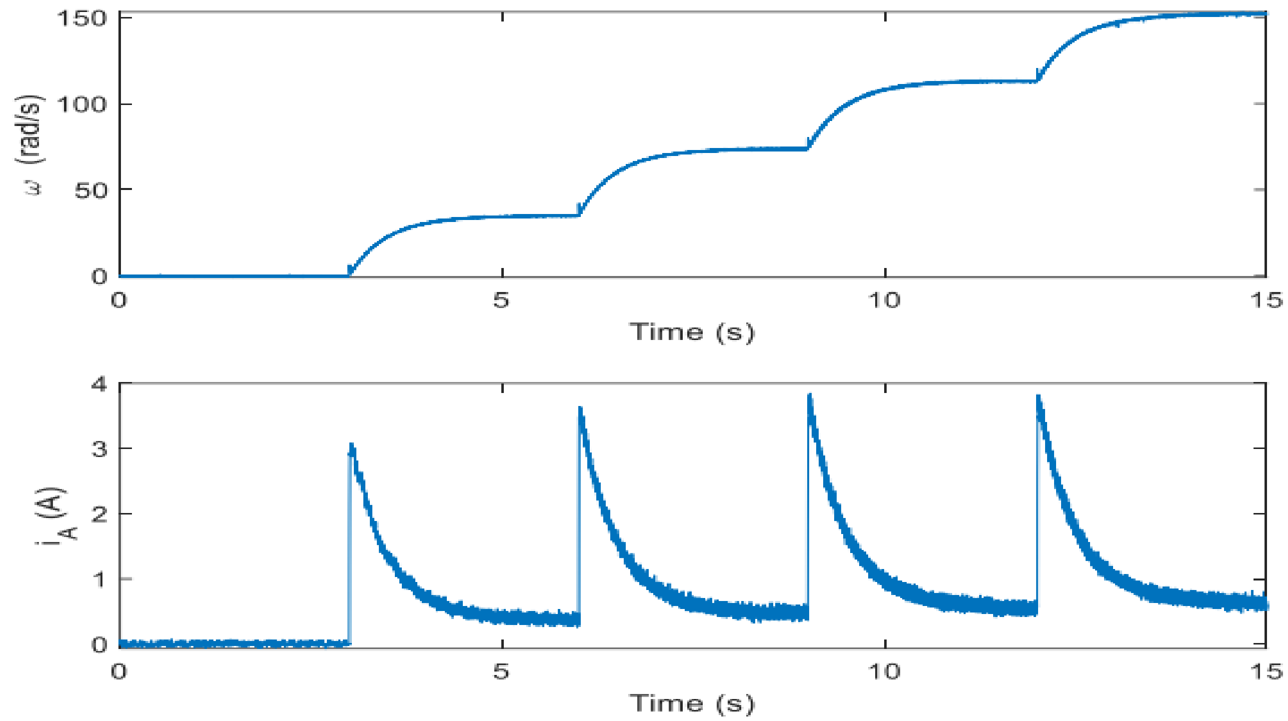
Code :

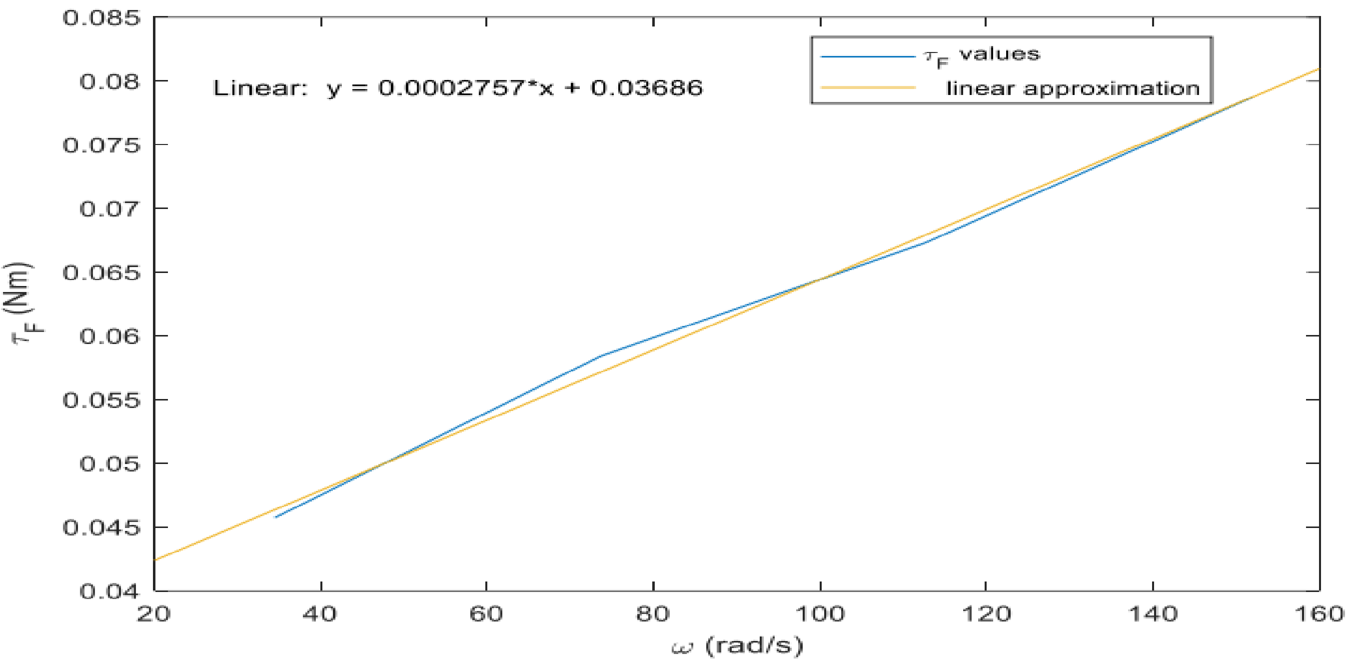
```
figure(3) subplot(2,1,1);
plot (t(1:15000), Omega(1:15000));
xlabel('Time(s)') ylabel('\omega
(rad\s)') subplot(2,1,2);
plot(t(1:15000), i(1:15000));
```

```
xlabel('Time(s)')
ylabel('i_A(A)')

VecOmega=[37.2,78.06,119.337,160];
VecTau=[0.345,0.373,0.52,0.6]*0.1232;
figure(4); plot(VecOmega,VecTau);
xlabel('Time(s)')
ylabel('i_A(A)')
```

It yielded the following figure:





The following equation **y = 0.0002757x + 0.03686**

Comparing it with equation

$$r_F = r_{F0} + \alpha_0 w$$

$$r_{F0} = 0.03868\ Nm$$

$$\alpha_F = 0.0002757\ Nm/rads_{-1}$$

- **Moment of Inertia J:**

In order to determine the moment of inertia of the motor an experiment with a measurement of the angular acceleration and torque of the motor is needed. If the armature current of the machine rotating at some certain speed is set to zero then the motor torque will become ZERO. The motor will decelerate due to friction torque.During this deceleration phase, the following expression describes the rotational dynamics.

$$J\frac{d\omega(t)}{dt} = r_F(t)$$

The moment of inertia can be calculated as

$$J = -\frac{r_F(t)}{\frac{dw(t)}{dt}}$$

Code:

```
plot(t(ind_s:ind_e),Omega(ind_s:ind_e));
xlabel('Time(s)')
ylabel('\omega (rad\s)')
```

We extracted the following figure:

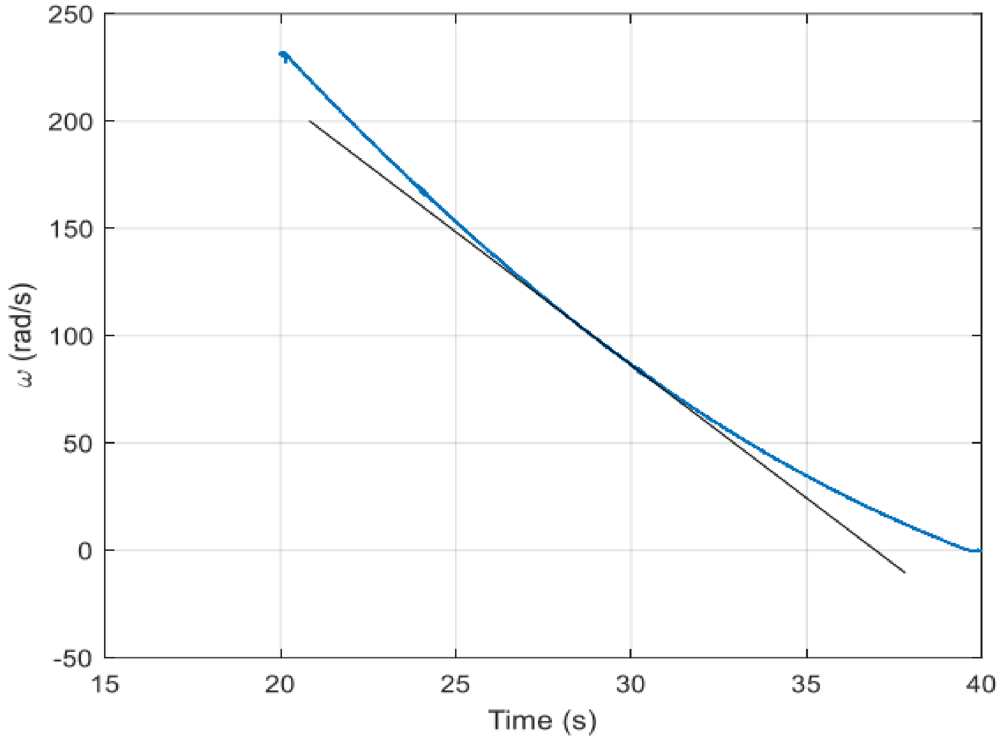


Fig: Validation of moment of inertia J

Slope of the curve at specific angular velocity ω_p(by drawing tangent line on the curve):

$$\mathrm{dw}/_{dt}(t)\,\Big|_{\omega p} = \frac{rad}{s^2}\ 5.57$$

Friction torque at ω_p using friction curve of the motor.

$$\langle r_F|\omega_p\rangle = r_{F0} + \alpha_F = 0.6632\ Nm$$ Moment of inertia:

$$J = -\langle r_{F(t|)}\omega_p\rangle/(\mathrm{dw(t)/dt})\,\Big|\mathrm{wp} = 0.00555\ \mathrm{kg}m^2$$

⋆Simulation and Validation:

In this section we created a virtual DC motor in order to compare the theoretical data with the real data that we got in our experiment. For that we will insert a **Motor Model** (gi below).

We used the following diagram:

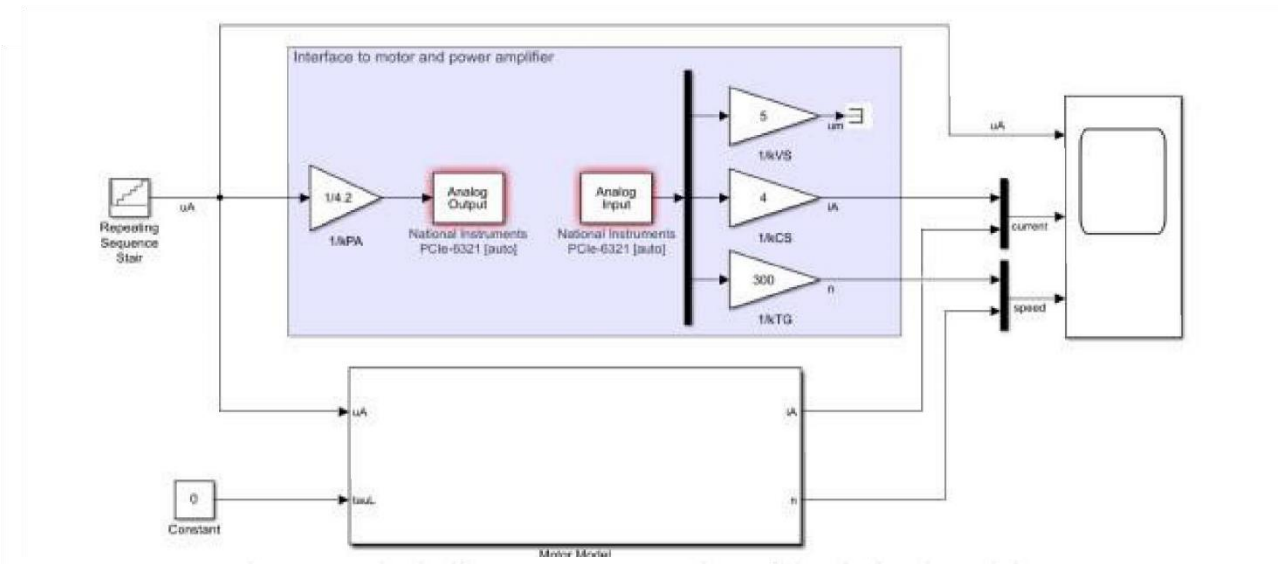


Fig. **Motor Model***

Code:

```
J=0.00555;
Tau_f0=0.02954; alpha_F
=0.0002744;
tC=t(ind_s:ind_e);
wC=Omega(ind_s:ind_e);
wSim=zeros(size(wC));
dT=0.001; wSim(1)=wC(1);
for k=1:length(wC)-1;
    Tf= tau_F0 + alpha_F*wSim(k);
    wSim(k+1)= wSim(k)-dT*Tf/J;
end
```

```
plot(tC,wC,`b´,tC, wSim,`k´);
xlabel(`Time(s)´)
ylabel(`Angular velocity \omega(rad/s)´ )
legend({`Measured´,`Simulated´}) title
(`validation of moment of inertia J´)
```

We got the following output:

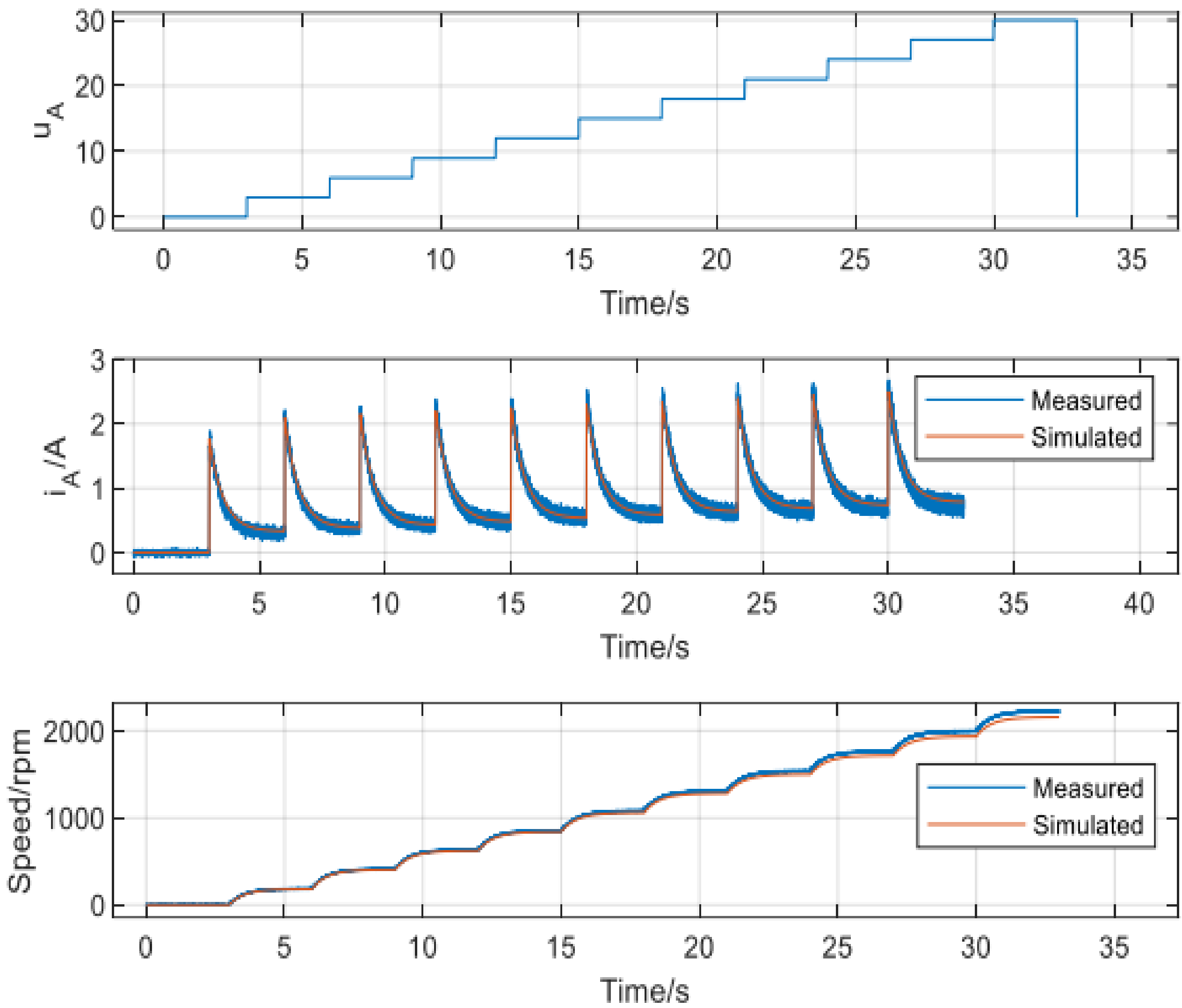


Fig: Simulation and Validation of system

In this stage , the model is implemented on a simulation systems. The simulation model and the real system are actuated with same inputs. The response of the simulation model is compared to system response. In case of large deviations, the parameters are adjusted accordingly. In this way the system can be validated.

Conclusion:

The simulation model and the real system are actuated with same inputs. The response of the simulation model is compared to the system response.

In case of large deviations, the parameters are adjusted accordingly. In this way the system can be validated