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Report for Laboratory No. 4

Analysis of Nonlinear Electromechanical Plant Using Simulink Model
Course: Mathematical Modeling and Simulation

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Introduction

Lab 4 is about the Analysis of a Nonlinear Electromechanical Plant. A power controller and motor are selected randomly, providing required design constant values. Using these design constants, the system is analyzed for two different input types: step and sinusoidal. From these results, various plots for angular velocity and amperage are produced. Finally, using these plots and any critical values, a summary of the system's trends is produced.

The analysis software for this lab is Matlab and Simulink. All system models are produced in a graphical style, rather than producing transfer functions and writing code. These models are then used as a template and adjusted using Matlab code to test different scenarios. All code used for this analysis can be seen in Appendix 1.

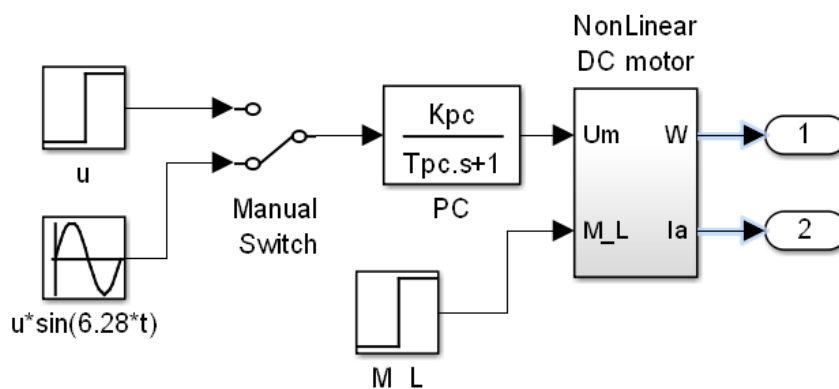
Background

Non-Linear Plant

For testing, a non-linear plant is set up with a switch. This switch allows both step input and sinusoidal input objects in the model, allowing one or the other to be enabled. It is used to test the DC motor under both conditions.

Power Controller Constants/Inputs

- K_{pc} = Power controller gain constant
- T_{pc} = Power controller inductance/resistance ratio
- u = Applied Voltage

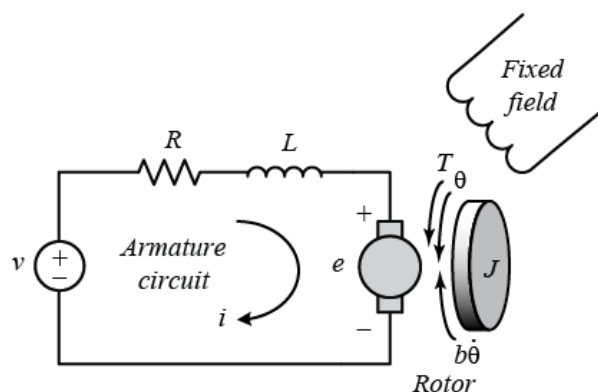


Non-Linear DC Motor

For testing a non-linear DC motor is utilized. This motor behavior is changed using the previously described power controller.

Motor Constants

- R_a = Electrical Resistance
- L = Electrical Inductance
- K_e = Electromotive force constant
- K_m = Motor torque constant
- J = Moment of inertia of the rotor
- W_{DCM} = Angular motor speed



Results

Motor Details

A random motor was chosen with the following characteristics. This motor is combined into the previously mentioned plant and is the main component being tested.

Chosen Motor Design Constants

R _a	= 10	Ohms	= Electrical Resistance
L	= 0.1	Henrys	= Electrical Inductance
K _e	= 0.05	V/(rad/sec)	= Electromotive force constant
K _m	= K _e	Nm / P ²	= Motor torque constant
J	= 0.5E-5	Kg/m ²	= Moment of inertia of the rotor
W _{DCM}	= (output)	rad/sec	= Angular motor speed

Power Controller Details

The control system consists of the power regulator with the following default configuration.

Power Controller Constants

K _{pc}	= 3	= Power controller gain constant
T _{pc}	= 0.001	= Power controller Inductance/resistance ratio
u	= 5	= Applied Voltage

Influence of Parameters

Each parameter M_L, dU, K_vf, and M_df was adjusted separately. By doing this, the effect of each parameter on the system can be shown. Each individual parameter is tested and the charts are analyzed to discuss trends. The interaction of these parameters is not investigated.

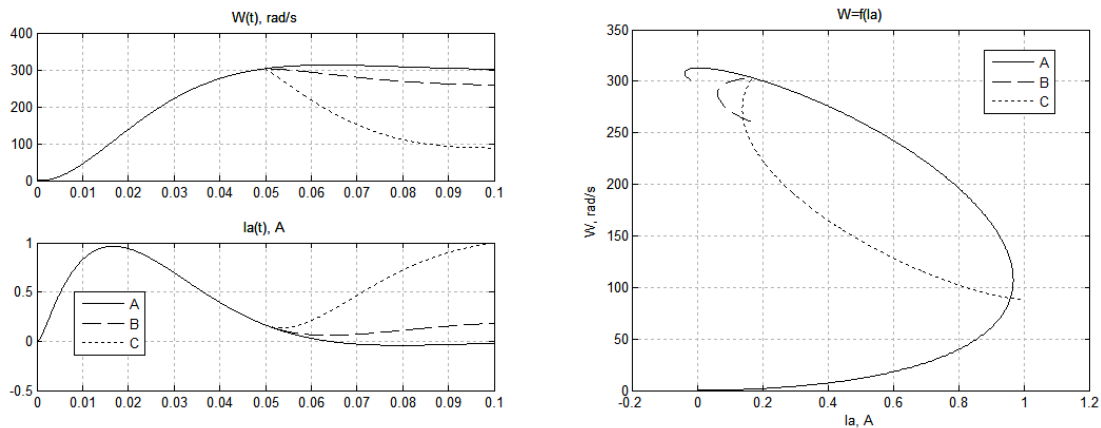
Effect of M_L

The charts below show that as the parameter “ M_L ” is increased, the following trends occur.
 Note: The effect of “ M_L ” is only introduced at the halfway point.

Legend	M_L	dU	Kvf	Mdf
A	0.00	0	0.00000	0.000
B	0.01	0	0.00000	0.000
C	0.05	0	0.00000	0.000

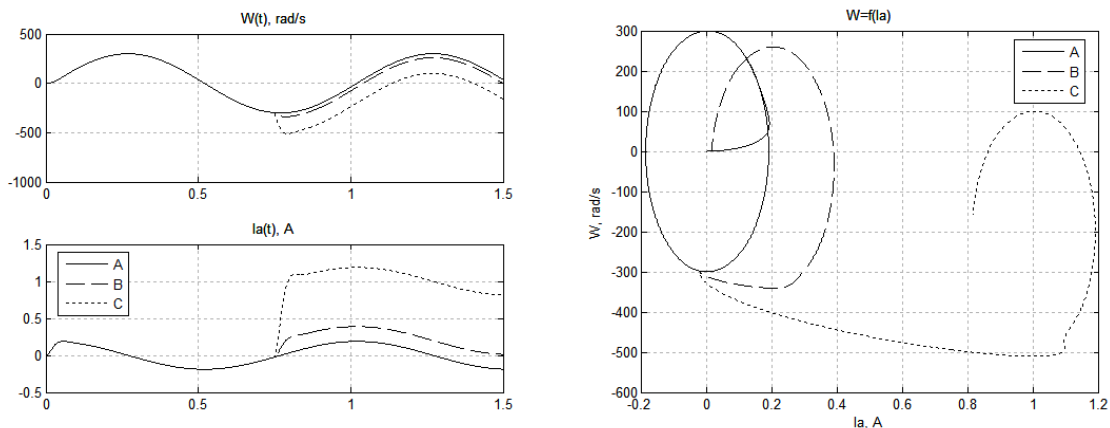
Step Input

1. $W(t)$ – The slope drastically decreases. The steady state value drastically decreases.
2. $I_a(t)$ – The slope drastically increases. The steady state value drastically increases.
3. $W(I_a)$ – The shape of the curve is drastically different, and not easily compared.



Sinusoidal Input

1. $W(t)$ – The entire curve shifts downward.
2. $I_a(t)$ – The entire curve shifts drastically upward.
3. $W(I_a)$ – The range of velocity decreases. The required amperage drastically increases.



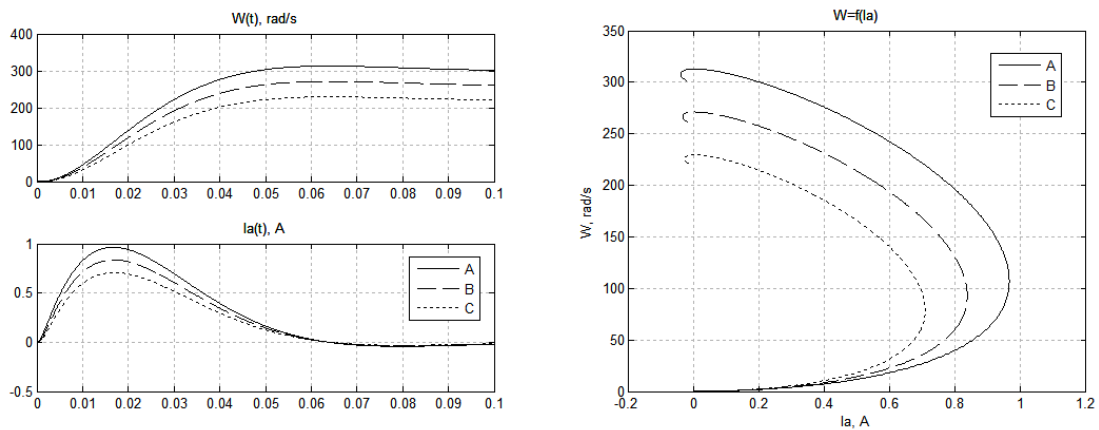
Effect of dU

The charts below show that as the parameter “dU” is increased, the following trends occur.

Legend	M_L	dU	Kvf	Mdf
A	0.00	0	0.00000	0.000
B	0.00	2	0.00000	0.000
C	0.00	4	0.00000	0.000

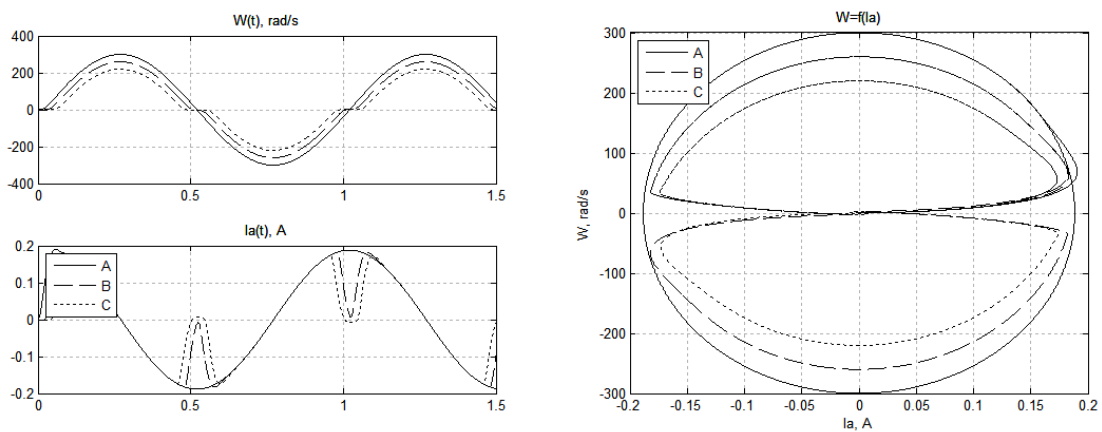
Step Input

4. $W(t)$ – The slope decreases. The steady state value decreases.
5. $ia(t)$ – The peak decreases. The steady state value is not affected.
6. $W(ia)$ – The curve scales down and to the left.



Sinusoidal Input

4. $W(t)$ – The magnitude of the peak decreases. A flat area appears near zero.
5. $ia(t)$ – A strong counter response appears near the peaks.
6. $W(ia)$ – The range of velocity options decreases.



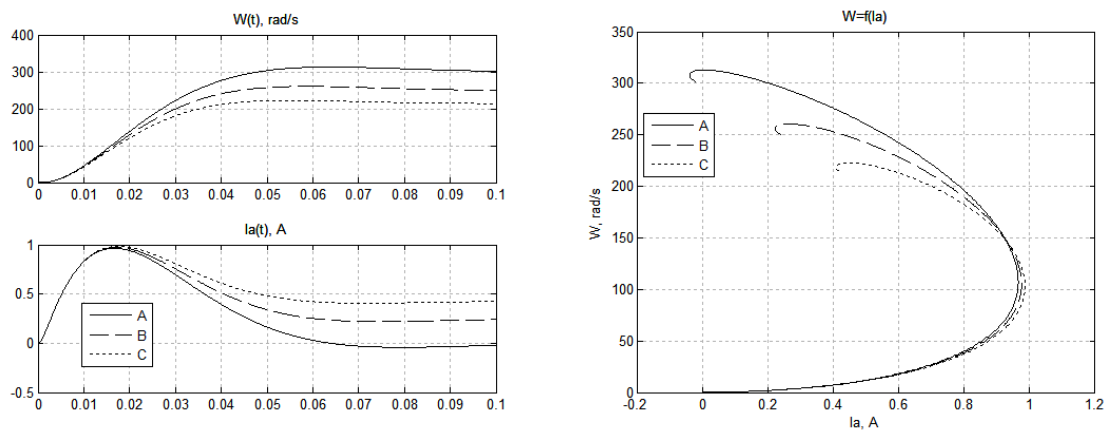
Effect of Kv_f

The charts below show that as the parameter “Kv_f” is increased, the following trends occur.

Legend	M_L	dU	Kv _f	Mdf
A	0.00	0	0.00000	0.000
B	0.00	0	0.00005	0.000
C	0.00	0	0.00010	0.000

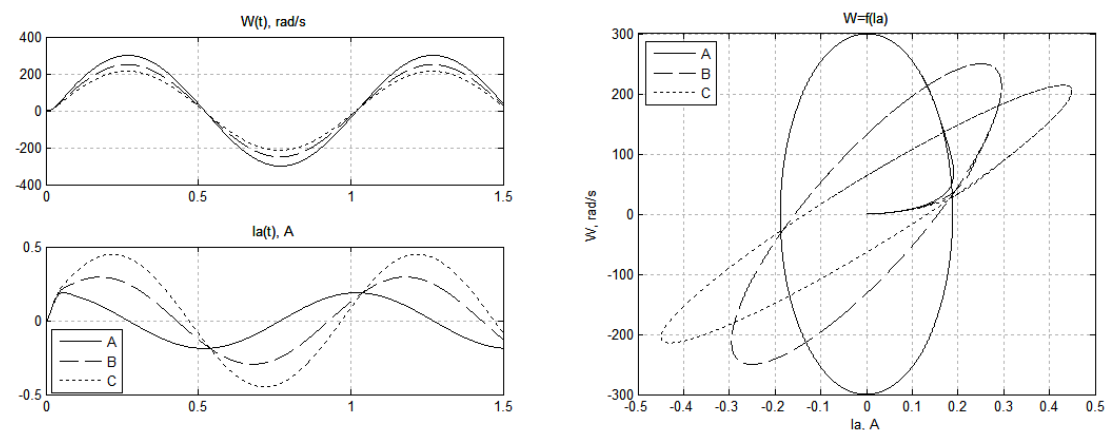
Step Input

1. $W(t)$ – The slope decreases. The steady state value decreases.
2. $I_a(t)$ – The slope increases. The steady state value increase.
3. $W(I_a)$ – The curve shape very similar. However the max velocity decreases.



Sinusoidal Input

1. $W(t)$ – The magnitude of the peak value decreases.
2. $I_a(t)$ – There is a phase shift. The magnitude of the peak value increases.
3. $W(I_a)$ – More amperage is used but less velocity is available.



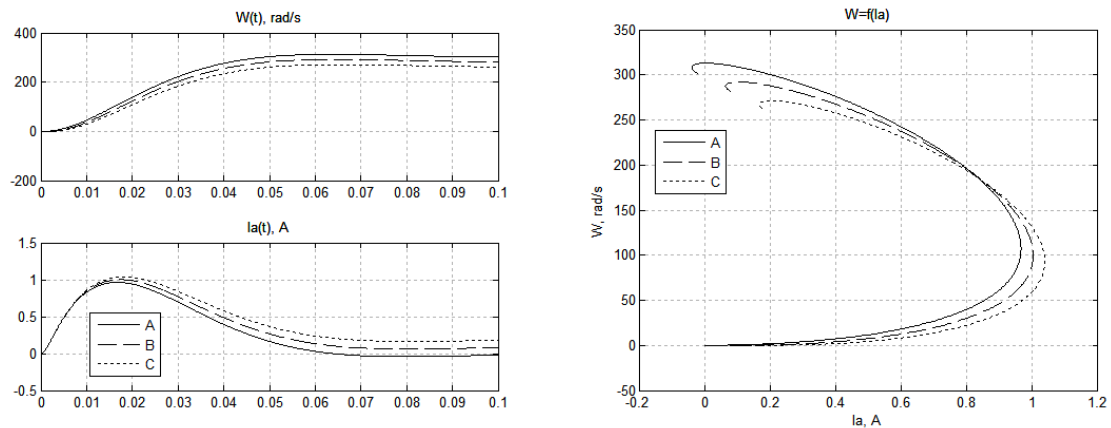
Effect of Mdf

The charts below show that as the parameter “Mdf” is increased, the following trends occur.

Legend	M_L	dU	Kvf	Mdf
A	0.00	0	0.00000	0.000
B	0.00	0	0.00000	0.005
C	0.00	0	0.00000	0.010

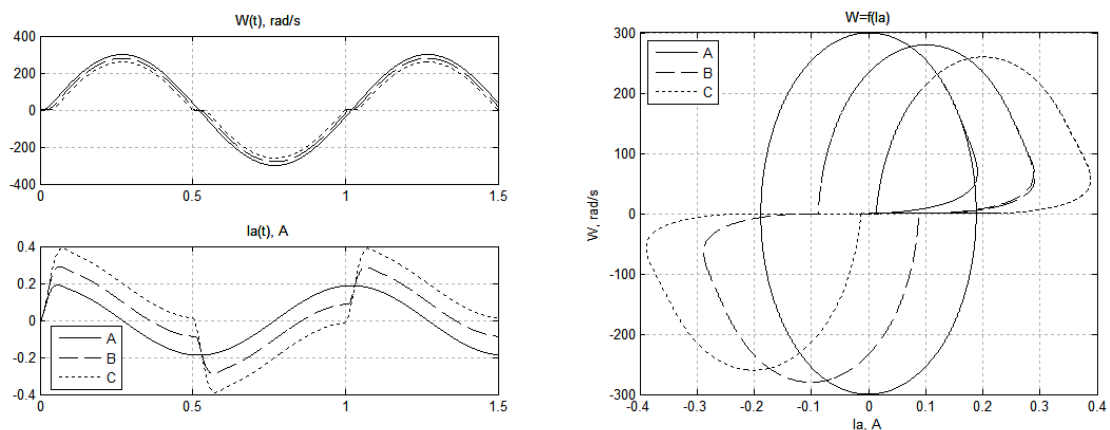
Step Input

1. $W(t)$ – The slope decreases slightly. The steady state value decreases slightly.
2. $I_a(t)$ – The peak increases slightly. The slope increases slightly. The settling value increases slightly.
3. $W(I_a)$ – The curve vertically shortens and horizontally expands to the right.



Sinusoidal Input

1. $W(t)$ – The magnitude of the peak decreases slightly. A flat area near zero appears.
2. $I_a(t)$ – The normal sinusoidal curve significantly jumps at the zero amperage point.
3. $W(I_a)$ – The curve expands in both the left and right direction. The max speed decreases slightly.



Conclusion

Utilizing a step input and a sinusoidal input, a non-linear system with DC motor shows the following changes in response as the parameters M_L , dU , K_vf , and M_{df} are adjusted independently. However, there may be additional interactions between these parameters, which are not investigated.

- As the parameter " M_L " is increased, the overall achievable range of angular velocities drastically decreased. The same velocity also requires a drastically higher amperage.
- As the parameter " dU " is increased, the overall achievable range of angular velocities significantly decreased. The achieved velocity occurs at lower amperage.
- As the parameter " K_vf " is increased, the overall achievable range of angular velocities decreased. The descriptive curves however nearly overlap.
- As the parameter " M_{df} " is increased, the overall achievable range of angular velocities slightly decreased.

Appendix 1 – Matlab Code

```
%Lab 4
%Analysis of Nonlinear Electromechanical Plant Using Simulink Model
clear all;close all;clc;

%% Model Properties
NonLinearPlant % Simulink-model

%DC Motor
Ra=10;          % Electrical resistance          Units: ohms
La=0.1;        % Electrical inductance          Units: henry
Ta=La/Ra;      % Inductance Resistance Ratio
Ke=0.05;       % Torque constant                Units: Nm / (Work)^2
Km = Ke;       % Torque constant                Units: Nm / (Work)^2
J=0.5e-5;     % Inertia                        Units: Kg*m^2

%Power Controller
Kpc = 3;
Tpc = 0.001;

%Simulink Model
Tend = 1.5; % For sine
%Tend = 0.1; % For step
h = Tpc/10;
M_L=0.0;
t_L=Tend/2;
u = 5;

%% Simulation A
%Model Properties
dU=0;
Kvf=0;
Mdf=0;
LINE = 'k-'; %Display style
Legend1 = 'A';

%Generate Data
[t,x,W,Ia]=sim('NonLinearPlant',Tend);

%Plot Charts
figure(1);
    subplot(2,1,1);
        plot(t,W,LINE);
        title('W(t), rad/s');
        grid on; hold on;
    subplot(2,1,2);
        plot(t,Ia,LINE);
        title('Ia(t), A');
        grid on; hold on;

figure(2);
    plot(Ia,W,LINE);
    title('W=f(Ia)'); xlabel('Ia,A');ylabel('W, rad/s');
    grid on; hold on;

%% Simulation B
%Model Properties
dU=0;
Kvf=0.00000;
```

```

Mdf=0.000;
LINE = 'k--'; %Display style
Legend2 = 'B';

%Generate Data
[t,x,W,Ia]=sim('NonLinearPlant',Tend);

%Plot Charts
figure(1);
    subplot(2,1,1);
        plot(t,W,LINE);
        title('W(t), rad/s');
        grid on; hold on;
    subplot(2,1,2);
        plot(t,Ia,LINE);
        title('Ia(t), A');
        grid on; hold on;

figure(2);
    plot(Ia,W,LINE);
    title('W=f(Ia)'); xlabel('Ia, A');ylabel('W, rad/s');
    grid on; hold on;

%% Simulation C
%Model Properties
dU=0;
Kvf=0.00000;
Mdf=0.000;
LINE = 'k:'; %Display style
Legend3 = 'C';

%Generate Data
[t,x,W,Ia]=sim('NonLinearPlant',Tend);

%Plot Charts
figure(1);
    subplot(2,1,1);
        plot(t,W,LINE);
        title('W(t), rad/s');
        grid on; hold on;
    subplot(2,1,2);
        plot(t,Ia,LINE);
        title('Ia(t), A');
        grid on; hold on;

figure(2);
    plot(Ia,W,LINE);
    title('W=f(Ia)'); xlabel('Ia, A');ylabel('W, rad/s');
    grid on; hold on;

```