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ABC Tunned FOPID Controller For BLDC Motor Drive System Performance Analysis.

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INTRODUCTION

Studied the current field demands on drive system and its application.

Studied and model a BLDCM.

Generate mathematical expression and corresponding cs for the BLDCM drive system.

Create a software approach to implement this BLDC drive system.

For controller side used FOPID.

Tunning of FOPID.

Objective

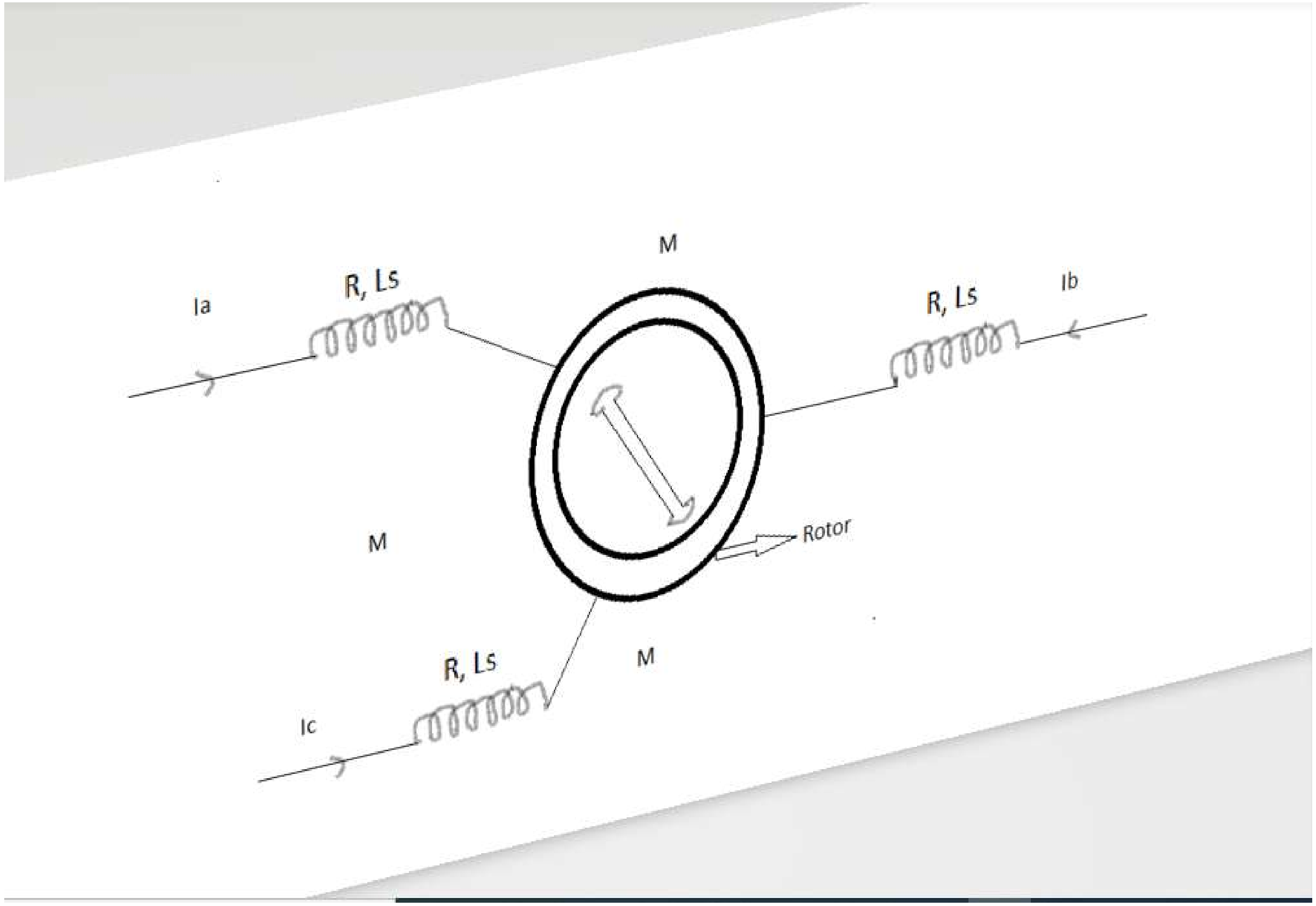
- Develop a BLDCM drive system.
- Made sensors commutation logic.
- Controller implementation.
- Tunning of controller.
- Study and introduce ABC algorithm.
- Test and implement the system.
- Analyse the performance using IAE, ITAE.

Problem Definition

- Implementation of FOPID.
- Sectoral information hacking.
- Implementing inverter as well as buck converter.
- Tunning of FOPID.
- Improved settling time.
- Less steady state error.
- Better performance indices.

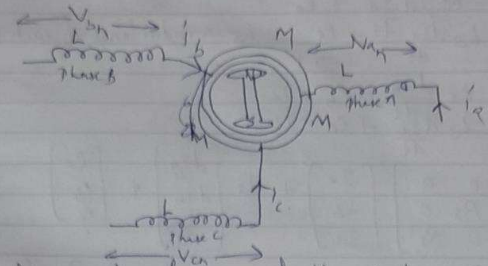
Glance Via the Work

Circuit Diagram and Mathematical Modelling



Contd

Dynamic Modelling of a BLDC Mtr



Induced emf : rate of change of flux linkages. V_{an} it consists of resistance voltage drop, rate of flux linkage & induced emf produced in phase a winding & similar for V_{bn} & V_{cn}.

$$V_{an} = R_s \times I_a + L\frac{dI_a}{dt} + M\frac{dI_b}{dt} + M\frac{dI_c}{dt} + e_a$$

$$V_{bn} = R_s \times I_b + L\frac{dI_b}{dt} + M\frac{dI_c}{dt} + M\frac{dI_a}{dt} + e_b$$

$$V_{cn} = R_s \times I_c + L\frac{dI_c}{dt} + M\frac{dI_a}{dt} + M\frac{dI_b}{dt} + e_c$$

where e_a, e_b, e_c are induced emfs in each phase

applied voltage

derivative

$$\begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} = \begin{pmatrix} R_s & 0 & 0 \\ 0 & R_s & 0 \\ 0 & 0 & R_s \end{pmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} + \begin{bmatrix} L & M & M \\ M & L & M \\ M & M & L \end{bmatrix} p \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} + \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix}$$

$e_a, e_b, e_c \propto \omega_r$ (speed of the mtr), bldc stator are star connected

$e_a = k_a \omega_r$. for a star connected $i_a + i_b + i_c = 0$.

$||^{ly}$ $e_b = k_b \omega_r$, $e_c = k_c \omega_r$ & $i_b + i_c = -i_a$

So,

$$V_{an} = R_s I_a + L\frac{dI_a}{dt} + M\frac{d}{dt}(i_b + i_c) + e_a$$

$$= R_s I_a + L\frac{dI_a}{dt} + M\frac{d}{dt}(-I_a) + R_a \Rightarrow R_s I_a + L\frac{dI_a}{dt} - M\frac{dI_a}{dt} + R_a$$

$$V_{an} = R_s i_a + (L - M)\frac{dI_a}{dt} + e_a$$

$$V_{an} = R_s I_a + L_s \frac{dI_a}{dt} + e_a \rightarrow 1$$; $L_s \rightarrow$ inductance of each phase

$$V_{bn} = R_s I_b + L_s \frac{dI_b}{dt} + e_b \rightarrow 2$$

$$V_{cn} = R_s I_c + L_s \frac{dI_c}{dt} + e_c \rightarrow 3$$

$$\begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} = \begin{bmatrix} R_s & 0 & 0 \\ 0 & R_s & 0 \\ 0 & 0 & R_s \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} + L_s \begin{bmatrix} \frac{dI_a}{dt} \\ \frac{dI_b}{dt} \\ \frac{dI_c}{dt} \end{bmatrix} + \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix}$$

$$\begin{bmatrix} \frac{dI_a}{dt} \\ \frac{dI_b}{dt} \\ \frac{dI_c}{dt} \end{bmatrix} = \left\{ \begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} - \begin{bmatrix} R_s & 0 & 0 \\ 0 & R_s & 0 \\ 0 & 0 & R_s \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} - \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix} \right\} \times \frac{1}{L_s} \rightarrow (a)$$

Simplify this R-K 4th order method.

$e_a \propto \overset{\text{speed}}{\omega_r} \Rightarrow e_a = k_a \cdot \omega_r$. (speed can be obtained from torque eq)

Mechanical Power P_m = (Induced emf in each phase wind · current in) $= (e_a i_a + e_b i_b + e_c i_c)$

$$T = \frac{P_m}{\underset{\text{mech speed}}{\omega_{rm}}} = \frac{P}{2}\frac{P_m}{\omega_r} = \frac{(e_a i_a + e_b \cdot i_b + e_c \cdot i_c)}{\omega_r}$$

$$e_a = k_a \cdot \omega_r \Rightarrow \omega_r = \frac{e_a}{k_a}$$

$$\frac{P}{2}\cdot\frac{P_m}{\omega_r} \Rightarrow \frac{(k_a \cdot i_a + k_b i_b + k_c \cdot i_c)\,\omega_r}{\omega_r} \; P/2$$

$$T = f(k_a \cdot i_a + k_b \cdot i_b + k_c \cdot i_c) \quad \text{— (b)}$$

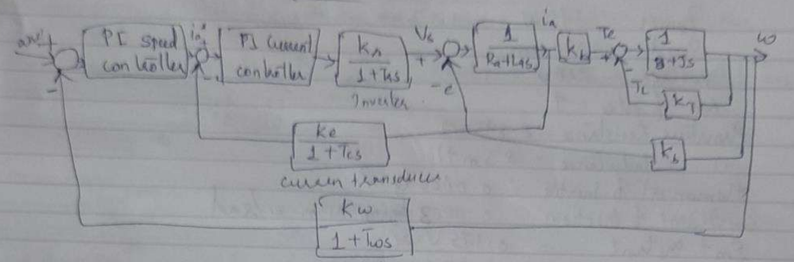
k_a, k_b, k_c are function of position of 'θ'.

electro mechanical energy can represent the frictional coefficient 'J'

$$\frac{J}{P/2}\left(d\omega_r/dt\right) + \frac{B}{P/2}\cdot\omega_r + T_L = T \text{ (motor torque)}$$

$$\frac{d\omega_r}{dt} = \frac{\left(T - T_L - \frac{B}{P/2}\cdot\omega_r\right)}{J}\cdot P/2 \quad \text{— (c)}$$

BLDC Mtr Drive Sym



$$\frac{1}{Js+B} = \frac{1}{0.0167s+0.01}$$

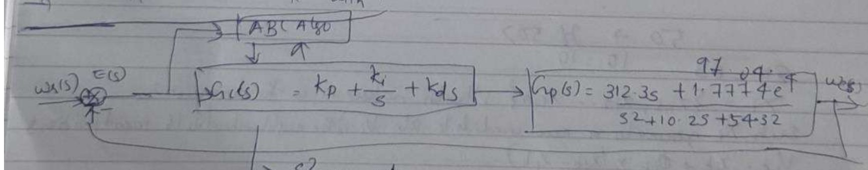
$$\frac{1}{L_a s+R_a} = \frac{1}{0.003s+0.5}$$

3.99 → Kp
1.18 → Ki
2.80 – Kd
0.98 – λ
1.25 – μ

$$FOPID = K_p + KI/s^{\lambda} + Kd \cdot s^{\mu}$$

$$\left(\frac{z}{z-1}\right)^{-1} = \frac{z-1}{z}$$

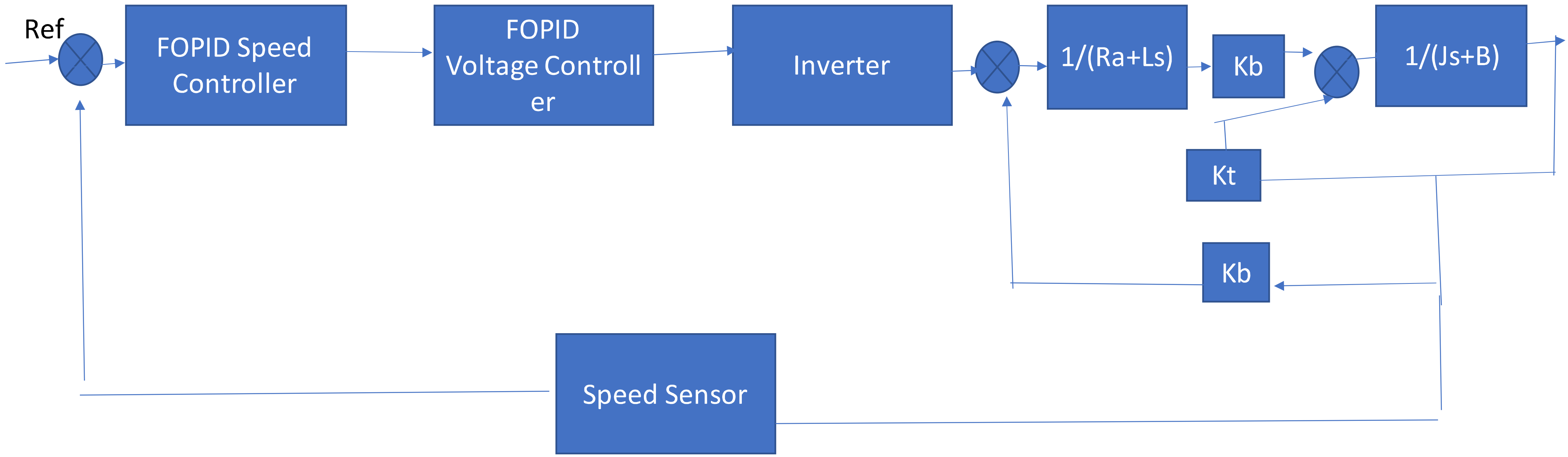
→ BLDC Mtr PID
→ " " with Drive Sym
→ " FOPID
→ " " with "



$$\frac{s^2+s+1}{s}$$

Provided $K_p = K_i = K_d = 1$

Block Diagram



Motor Parameters

Power : 240w

Speed : 2000rpm

Voltage : 220v

No. Of Poles : 4

Stator resistance : 2.8750 ohm

Stator inductance : 8.5 mH

Inertia : 0.0008kg.m^2

Emf Constant = 0.175 v.sec

Pseudo Code of ABC Algorithm

- 1: Initialize the population of solutions x_{ij}
- 2: Evaluate the population
- 3: cycle=1
- 4: repeat
- 5: Produce new solutions (food source positions) $\upsilon_{i,j}$ in the neighbourhood of $x_{i,j}$ for the employed bees using the formula $\upsilon_{i,j} = x_{i,j} + \Phi_{ij}(x_{i,j} - x_{k,j})$ (k is a solution in the neighbourhood of i, Φ is a random number in the range [-1,1])and evaluate them.
- 6: Apply the greedy selection process between x_i and υ_i.
- 7: Calculate the probability values P_i for the solutions x_i by means of their fitness values using the equation

$$P_i = \frac{fit_i}{\sum_{i=1}^{SN} fit_i}$$

- In order to calculate the fitness values of solutions we employed the following equation

$$fit_i = \begin{cases} \frac{1}{1+f_i} & if\ f_i \geq 0 \\ 1 + abs(f_i) & if\ f_i < 0 \end{cases}$$

Normalize Pi values into [0,1]

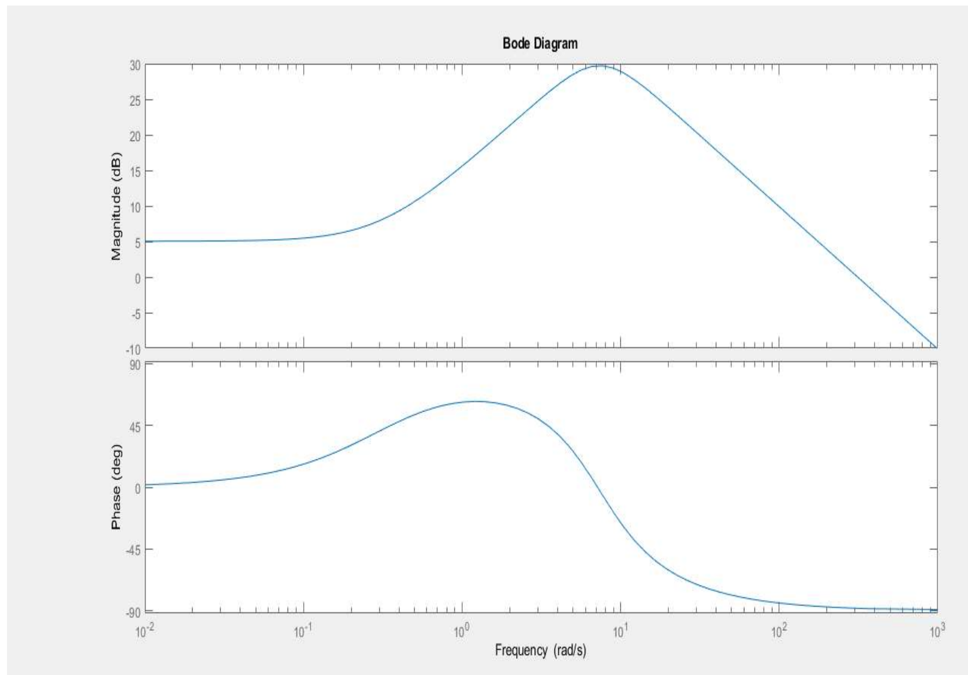
8: Produce the new solutions (new positions) υi for the onlookers from the solutions xi, selected depending on Pi, and evaluate them.

9: Apply the greedy selection process for the onlookers between xi and υi.

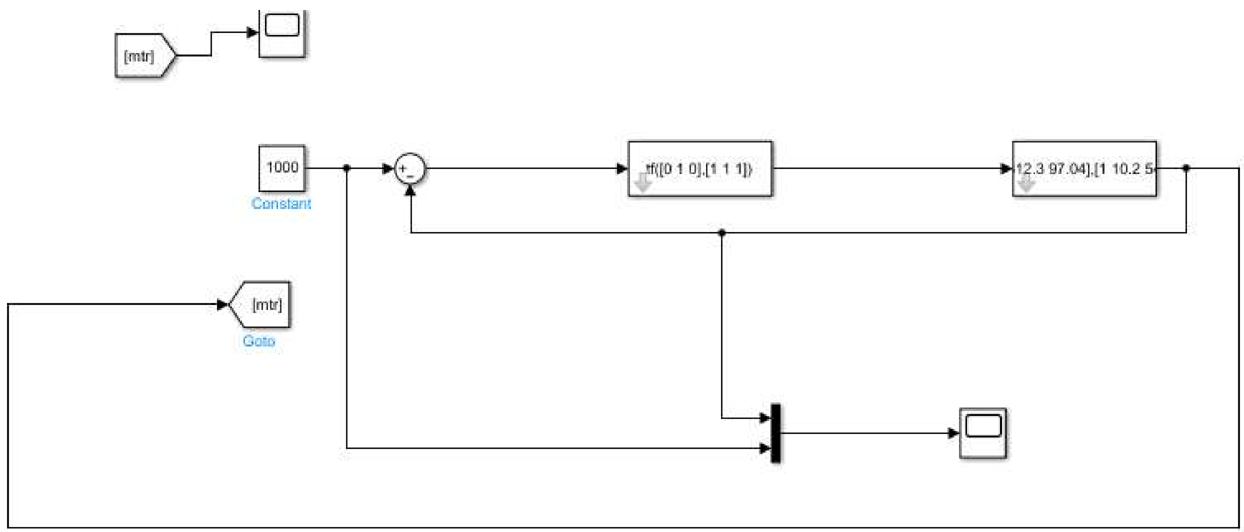
- 10: Determine the abandoned solution (source), if exists, and replace it with a new randomly produced solution xi for the scout using the equation xij=minj+rand(0,1)*(maxj-minj)
- 11: Memorize the best food source position (solution) achieved so far 12: cycle=cycle+1
- 13: until cycle= Maximum Cycle Number (MCN)

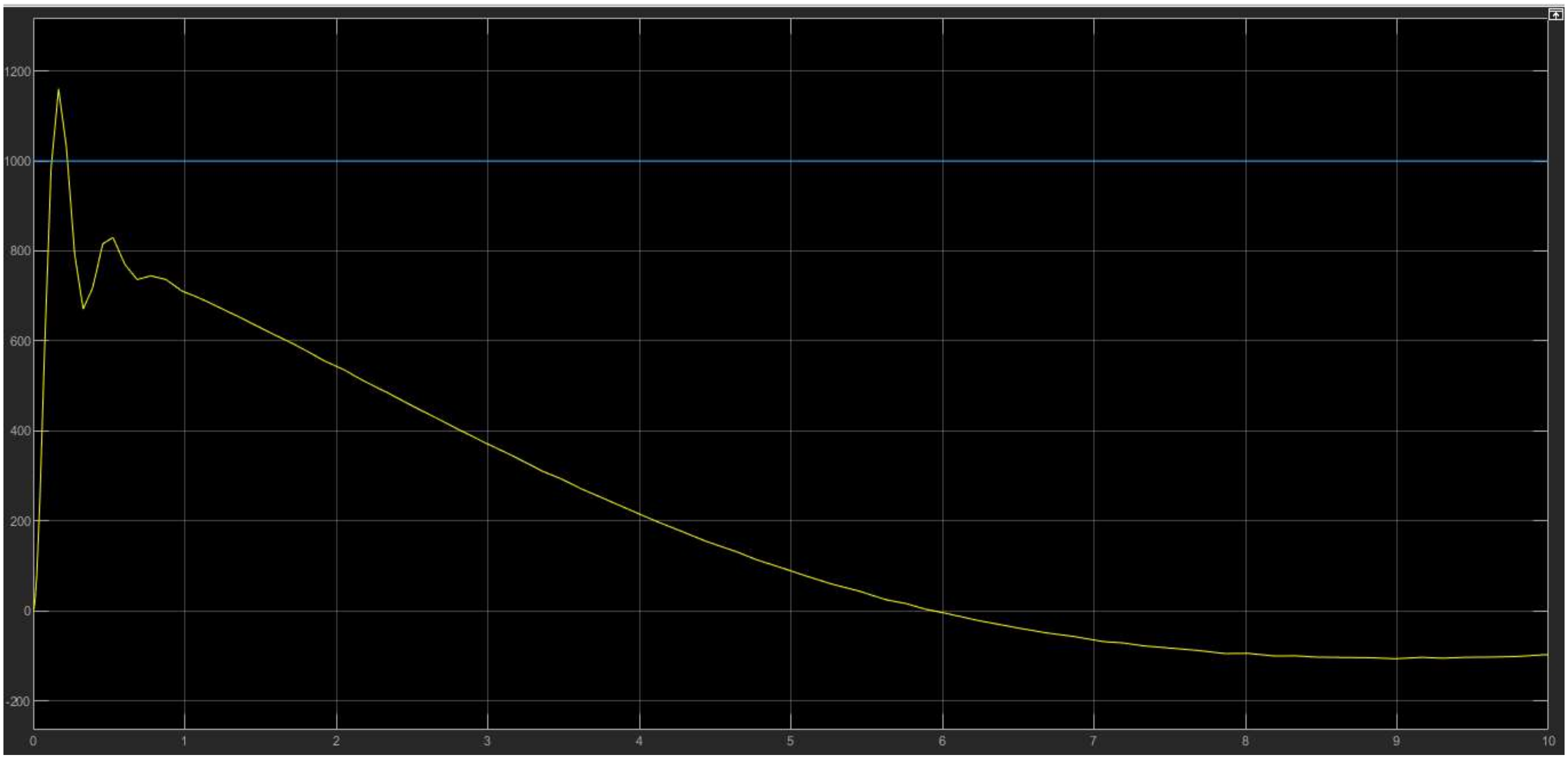
Stability Analysis

```
>> G=tf([0 312.3 97.04],[1 10.2 54.32])

G =

    312.3 s + 97.04
  --------------------
  s^2 + 10.2 s + 54.32

Continuous-time transfer function.

>> bode(G)
```

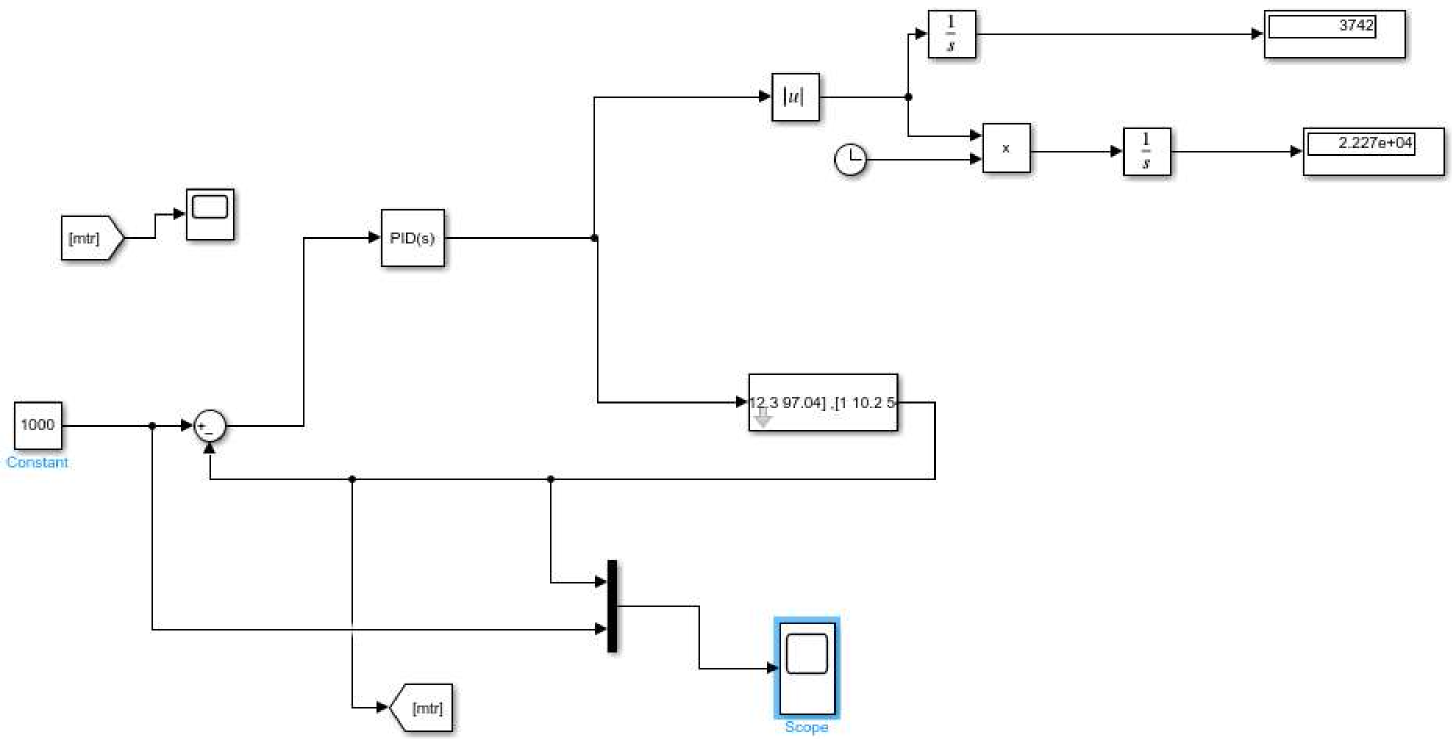


BLDC motor modelling without tunning

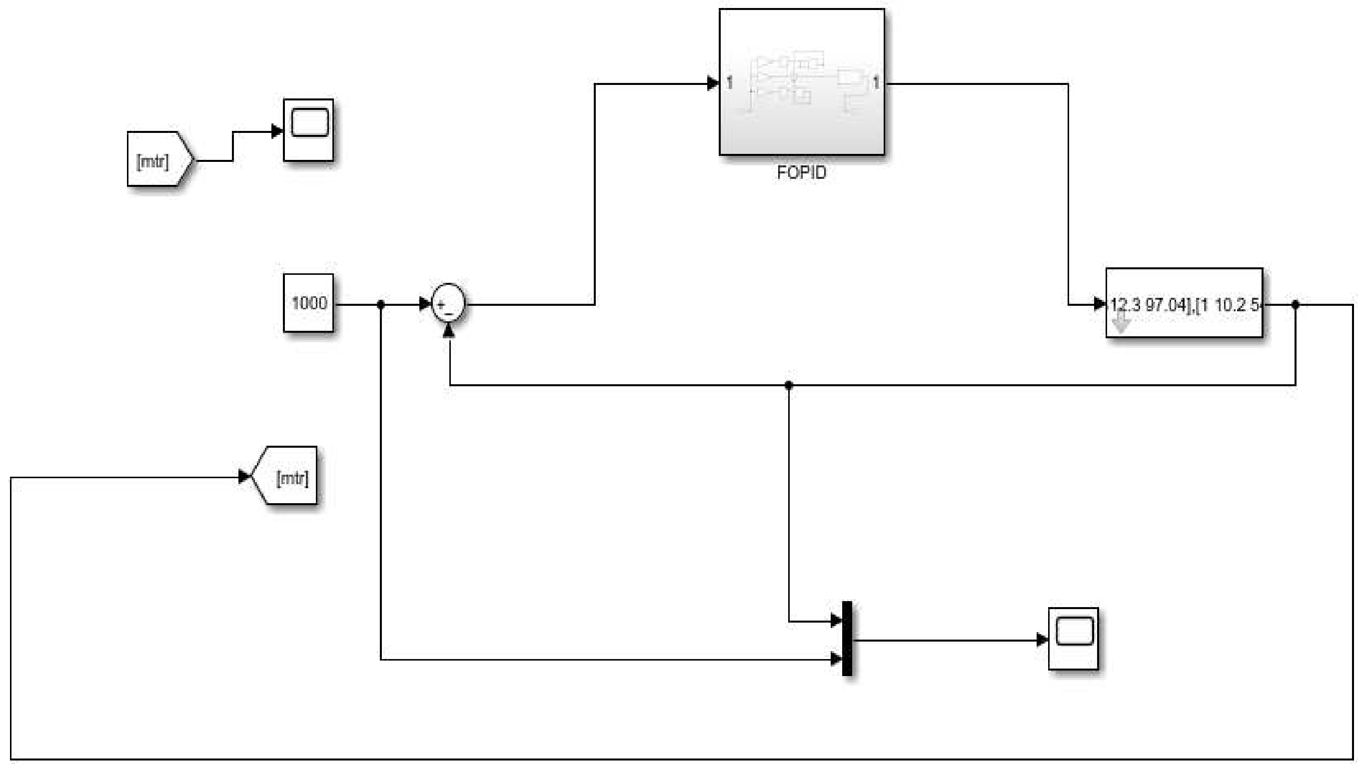


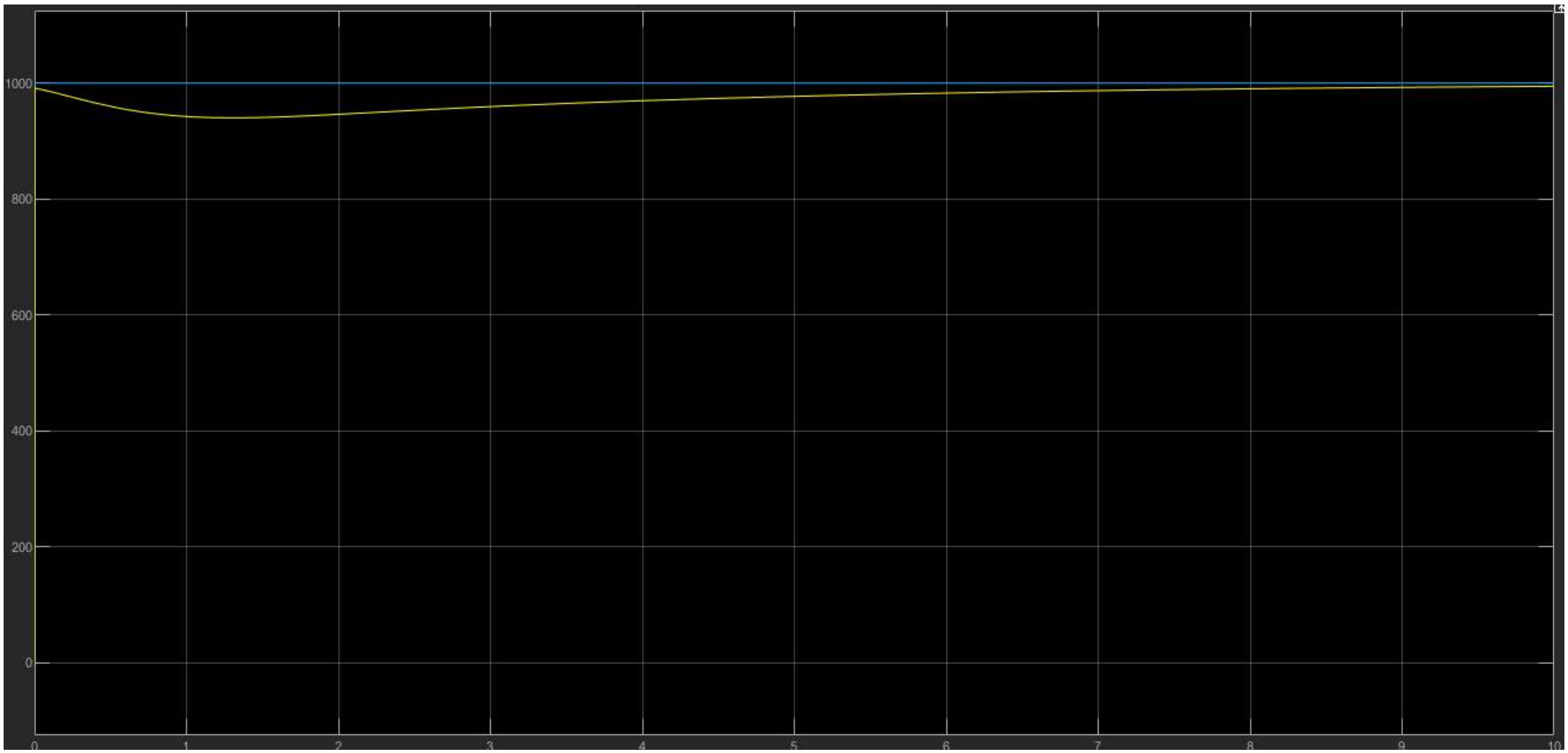

1200
1000
800
600
400
200
0
-200
0
1
2
3
4
5
6
7
8
9
10

Performance Indices



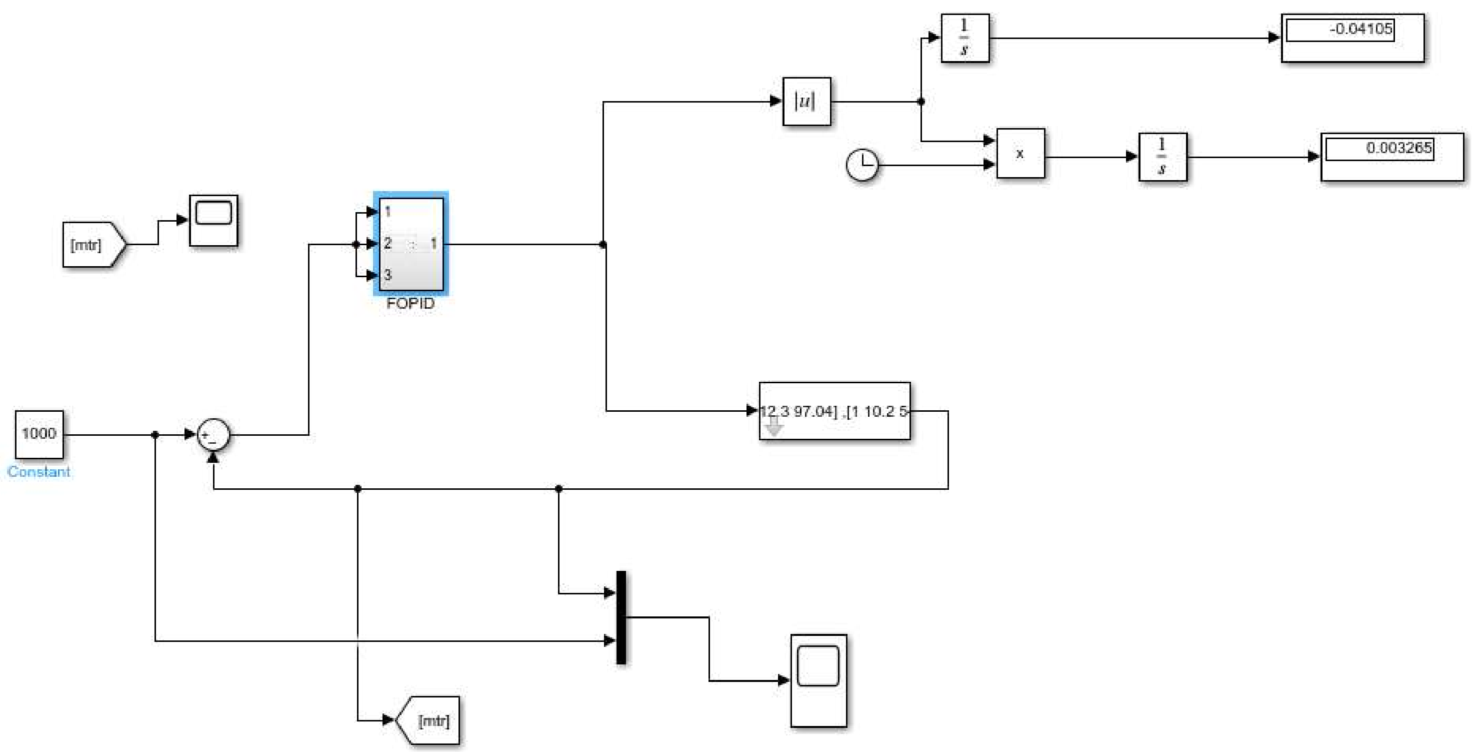
BLDC motor modelling with tunning



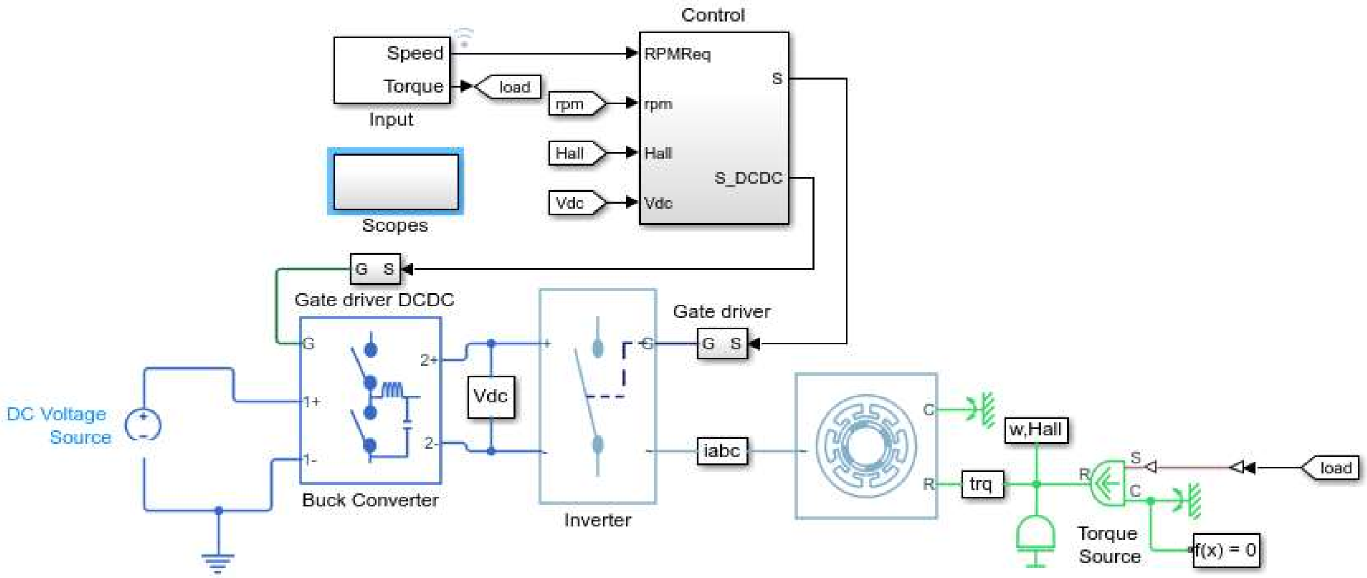


1000
800
600
400
200
0
0
1
2
3
4
5
6
7
8
9
10

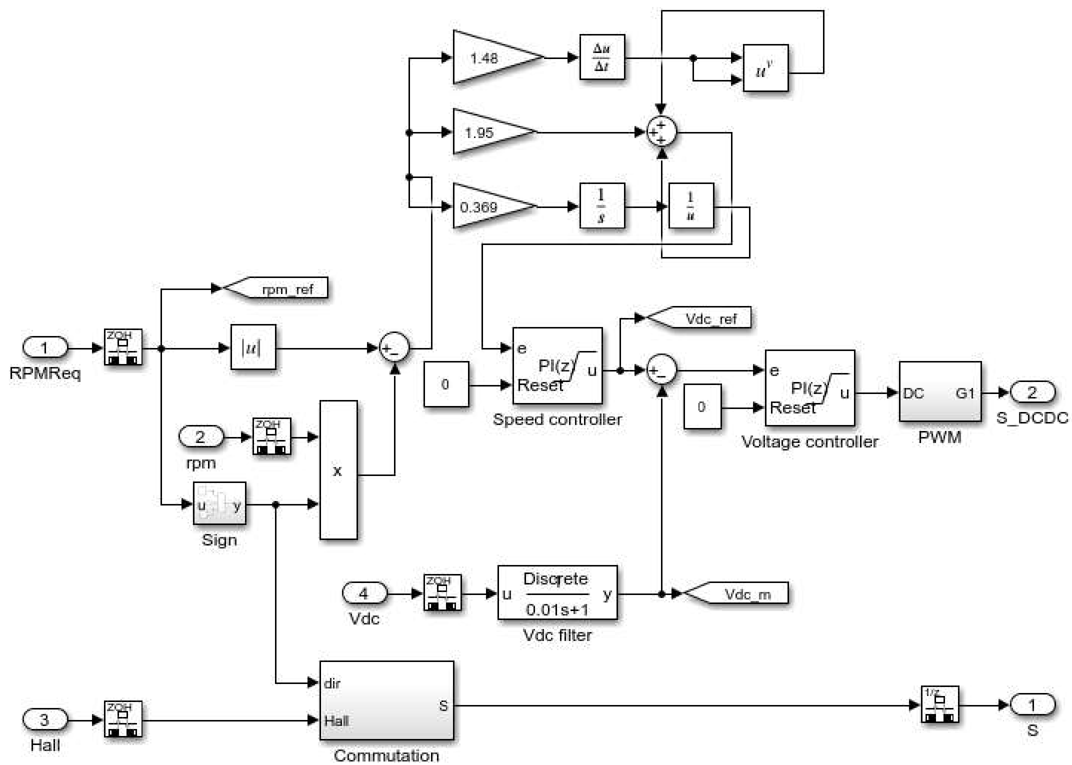
Performance Indices



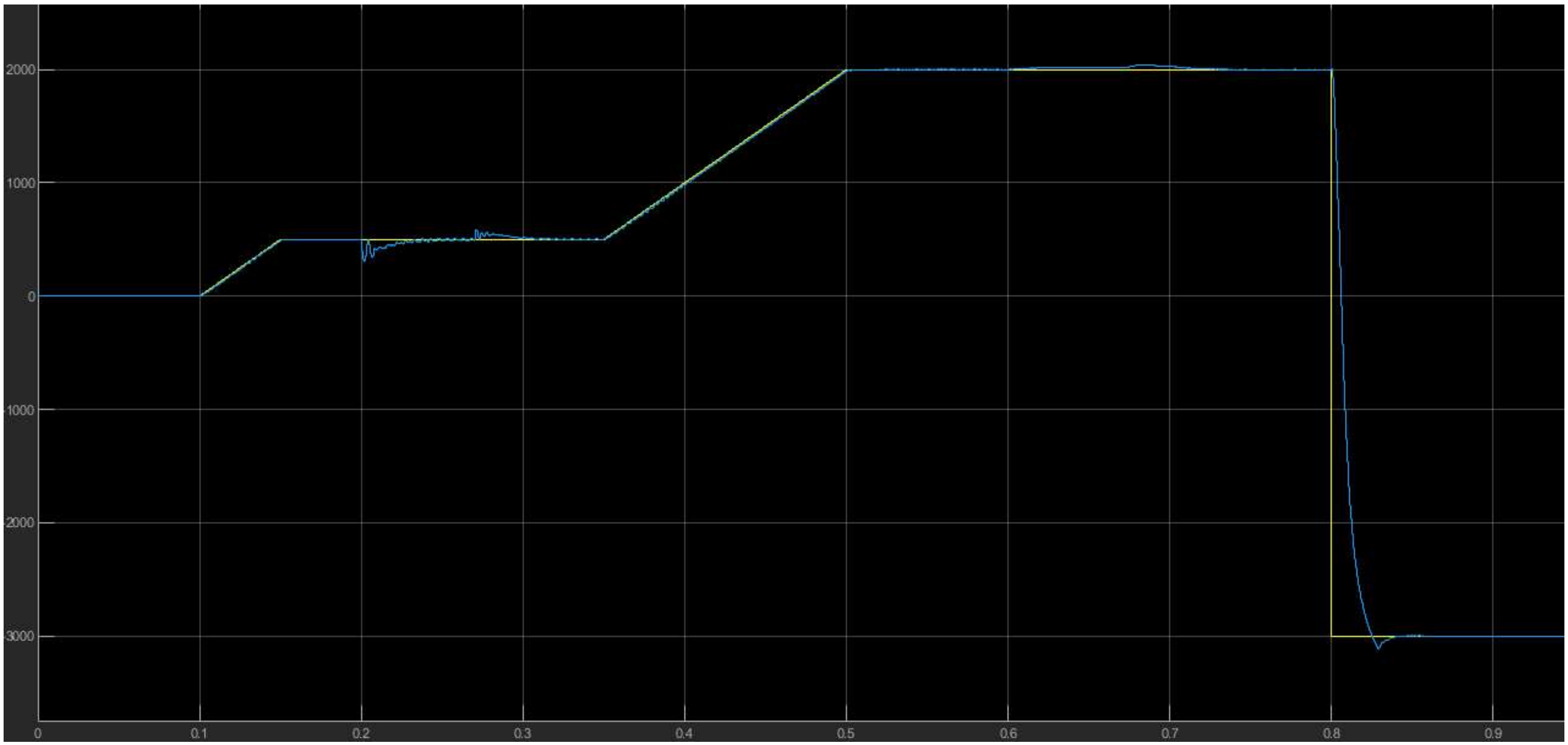
Simulation



Control
Speed
Torque
Input
load
rpm
Hall
Vdc
RPMReq
S
S_DCDC
Scopes
G S
Gate driver DCDC
Gate driver
DC Voltage
Source
Buck Converter
Vdc
Inverter
iabc
w,Hall
trq
Torque
Source
load
f(x) = 0



1.48
1.95
0.369
rpm_ref
1
RPMReq
|u|
2
rpm
x
Sign
Vdc_ref
0
e
PI(z)
Reset
u
Speed controller
0
e
PI(z)
Reset
u
Voltage controller
DC
G1
PWM
2
S_DCDC
4
Vdc
Discrete
0.01s+1
Vdc filter
Vdc_m
3
Hall
dir
Hall
S
Commutation
1
S


2000
1000
0
-1000
-2000
-3000
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

Results

- Obtained a control strategy for BLDCM drive system.
- Reduced settling time.
- Reduced steady state error.
- Good tracking.
- Robust performance.
- Improved characteristics than conventional bldcm.

Future Scope

- Make the system sensor lessly.
- Add weigheted as well as movable load.
- Different motor parameters.

- **THANK YOU**