Long Shunt DC Cumulative Compound Motor Speed Control

Date: 09-10-2020

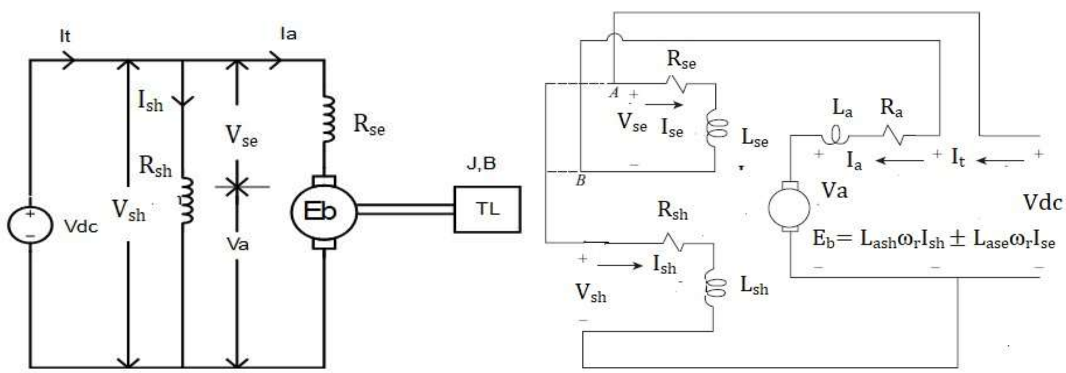
Aim:

To develop and simulate the mathematical dynamical model of a Long shunt DC cumulative compound motor and perform speed control and analyse characteristics.

Tools Used: MATLAB

and Simulink

Electrical Circuit:



Parameters Used for study:

Armature resistance R_a = 1.50 ohms

Armature winding self inductance L_a=0.12H

Mutual inductance between armature and main field L_{ash}=1.8H

Mutual inductance between armature and series field L_{ase}=0.0018H

Shunt field winding resistance R_{sh}=270 ohm

Shunt field winding Self inductance L_{sh}=0.03H

Mutual inductance between series and Shunt field L_{shse}= 0.001H

Self inductance of series field winding L_{se}=0.012 H

Series armature winding resistance R_{se}=0.7ohms

Back emf constant or torque constant K=0.0141

Moment of inertia J=0.02365

Friction coefficient B=0.0025

Theoretical Analysis:

$v_{dc} = v_a + v_{se}$

$v_{dc} = v_{sh}$

$T_e = T_L + J_{dw/dt} + B\omega$

$T_e = L_{ash} I_{se} I_{sh} + L_{ase} I_{se} I_a$

$\varepsilon_b = L_{ash} w I_{sh} + L_{ase} w I_{se}$

$V_{se} = R_{se} I_{se} + L_{se} *dise/dt + L_{shse} *dIsh/dt$

$V_a = R_a I_a + L_a * dI_a/dt + \varepsilon_b$

At steady state, $^{dIe/dt} = 0$, $^{dI_{sh/dt}} = 0$,

dw/dt= 0

$V_a = R_a I_a + \varepsilon_b$

$T_e = T_L + B\omega$

$V_{se} = R_{se} I_{se}$

$v_{dc} = v_a + v_{se}$

$T_e = L_{ash} I_{se} I_{sh} + L_{ase} I_{se} I_a$

$I_{se} = I_a$ $v_{dc} = v_a + v_{se}$

$v_{dc} = v_{sh} + v_{se}$

Solving for Ia, we get v_{dc}

$$v_{dc} = I_a(R_{se} + R_a) + \left(\frac{1}{B}\right) * (L_{ash}^2 I_{sh}^2 I_a) + \left(\frac{1}{B}\right) * (2L_{ash}^2 I_a^2 I_{ash}) + \left(\frac{1}{B}\right) * (L_{ash}^2 I_a^3) - \left(\frac{1}{B}\right) * (T_l \ I_{sh} I_{ash}) - \left(\frac{1}{B}\right) * (T_l \ I_a \ I_{ash})$$

Procedure for Simulation:

- Write the code to initialize the input parameters in the m file and save it.
- Open a new Simulink file and make mathematical modelling as per circuit diagram and save it.

- Run the m file first followed by the run Simulink file for various values of load torque.
- Note down the necessary values of parameters and make a plot.
- Make various plots and view the results.

M file code:

R_A Control:

```
a1 = [58.16 44.23 37.2 32.74
    5.145 10.11 15.09 20.08
1.5 1.5 1.5 1.5];
a2 = [58.32 44.43 37.41 32.95
    5.146 10.11 15.09 20.08
1 1 1 1];
a3 = [57.82 43.85 36.79 32.31
    5.145 10.11 15.09 20.08
2.5 2.5 2.5 2.5];
 a4 = [57.49 43.46 36.37
31.88
    5.145 10.11 15.09 20.08
3.5 3.5 3.5 3.5];
a5 = [58.49 44.62 37.61 33.17
    5.145 10.11 15.09 20.08
0.5 0.5 0.5 0.5];
 a6 = [57.99 44.04 35.99
32.52
    5.145 10.11 15.09 20.08
2 2 2 2];
a7 = [57.65 43.65 36.58 32.09
    5.145 10.11 15.09 20.08
3 3 3 3];
a8 = [57.32 43.27 36.17 31.66
    5.145 10.11 15.09 20.08
4 4 4 4];
subplot(2,1,1)
plot(a1(2,:),a1(1,:))
 hold on
plot(a2(2,:),a2(1,:))
 hold on
plot(a3(2,:),a3(1,:))
 hold on
plot(a4(2,:),a4(1,:))
 hold on
 plot(a5(2,:),a5(1,:))
 hold on
plot(a6(2,:),a6(1,:))
hold on
plot(a7(2,:),a7(1,:))
 hold on
plot(a8(2,:),a8(1,:))
xlabel('Electromagnetic Torque')
ylabel('Angular Speed')
```

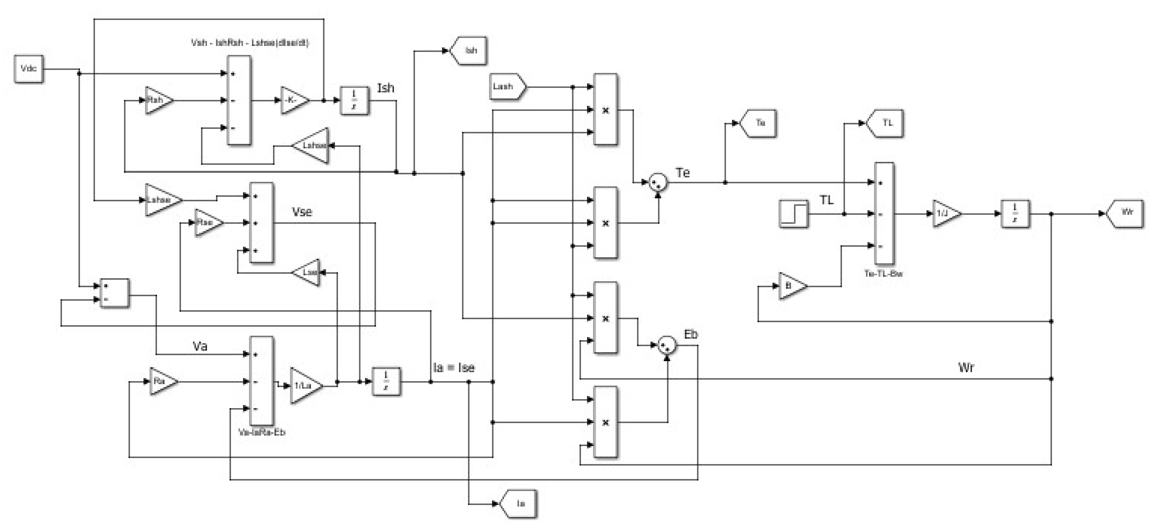
```
title('Angular Velocity Profile with Varying Load torque')
 subplot(2,1,2)
plot(a1(3,:),a1(1,:))
hold on
plot(a2(3,:),a2(1,:))
hold on
plot(a3(3,:),a3(1,:))
hold on
plot(a4(3,:),a4(1,:))
hold on
plot(a5(3,:),a5(1,:))
hold on
plot(a6(3,:),a6(1,:))
hold on
plot(a7(3,:),a7(1,:))
hold on
plot(a8(3,:),a8(1,:))
xlabel('Ra')
ylabel('Angular
velocity')
title('Angular Velocity Profile with Varying Load torque')
xlim([0 4.5]) ylim([25 65])
```

V_A Control:

```
a1 = [50.55 38.38 32.24 28.35
    5.126 10.11 15.09 20.08
200 200 200 200];
a2 = [51.82 39.35 33.07 29.08
    5.146 10.11 15.09 20.08
205 205 205 205];
a3 = [53.08 40.33 33.89 29.81
    5.145 10.11 15.09 20.08
210 210 210 210];
 a4 = [54.35 41.31 34.72 30.5
    5.145 10.11 15.09 20.08
215 215 215 215];
a5 = [55.62 42.28 35.55 31.28
    5.145 10.11 15.09 20.08
220 220 220 220];
a6 = [56.89 43.26 36.37 32.01
    5.145 10.11 15.09 20.08
225 225 225 225];
 a7 = [58.16 44.23 37.2 32.7
    5.145 10.11 15.09 20.08
230 230 230 230];
a8 = [59.42 45.21 38.03 33.47
    5.145 10.11 15.09 20.08
235 235 235 235];
subplot(2,1,1)
plot(a1(2,:),a1(1,:))
hold on
 plot(a2(2,:),a2(1,:))
hold on
 plot(a3(2,:),a3(1,:))
hold on
 plot(a4(2,:),a4(1,:))
hold on
plot(a5(2,:),a5(1,:))
```

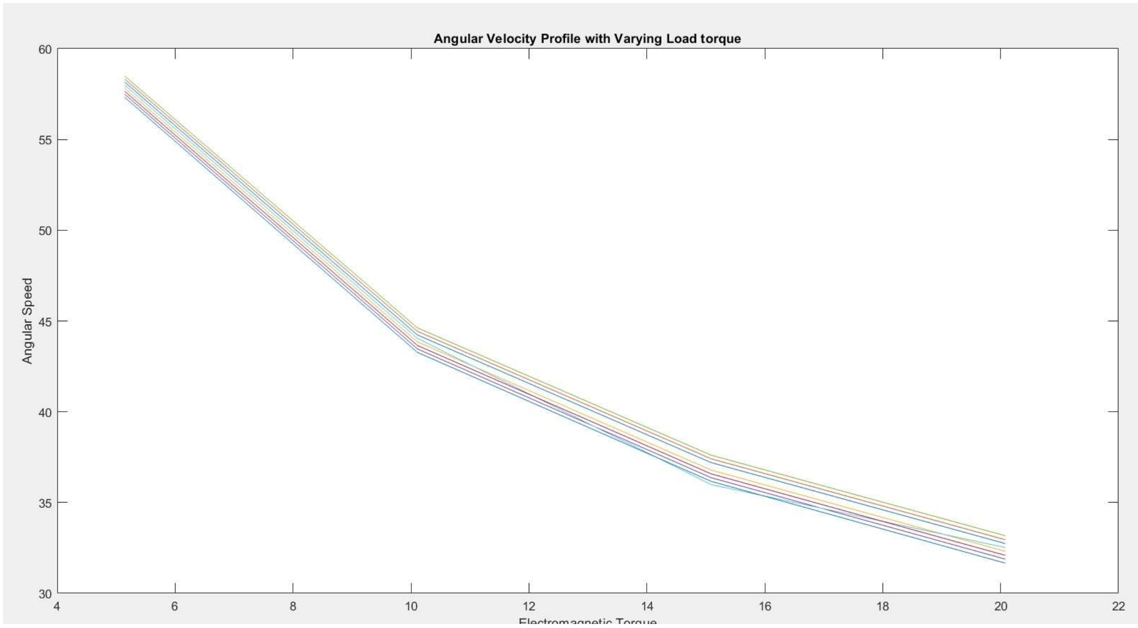
```
hold on plot
(a6(2,:),a6(1,:))
 hold on
plot(a7(2,:),a7(1,:))
 hold on
plot(a8(2,:),a8(1,:))
 xlabel('Electromagnetic Torque')
ylabel('Angular Speed')
 title('Angular Velocity Profile with Varying Load
torque')
 subplot(2,1,2)
plot(a1(3,:),a1(1,:))
hold on
plot(a2(3,:),a2(1,:))
hold on
plot(a3(3,:),a3(1,:))
hold on
plot(a4(3,:),a4(1,:)) hold
on
plot(a5(3,:),a5(1,:)) hold
on plot(a6(3,:),a6(1,:))
hold on
plot(a7(3,:),a7(1,:)) hold
on
plot(a8(3,:),a8(1,:))
xlabel('Vdc')
ylabel('Angular velocity')
title('Angular Velocity Profile with Varying Load
torque')
xlim([195 240])
ylim([25 65])
```

Simulation diagram:

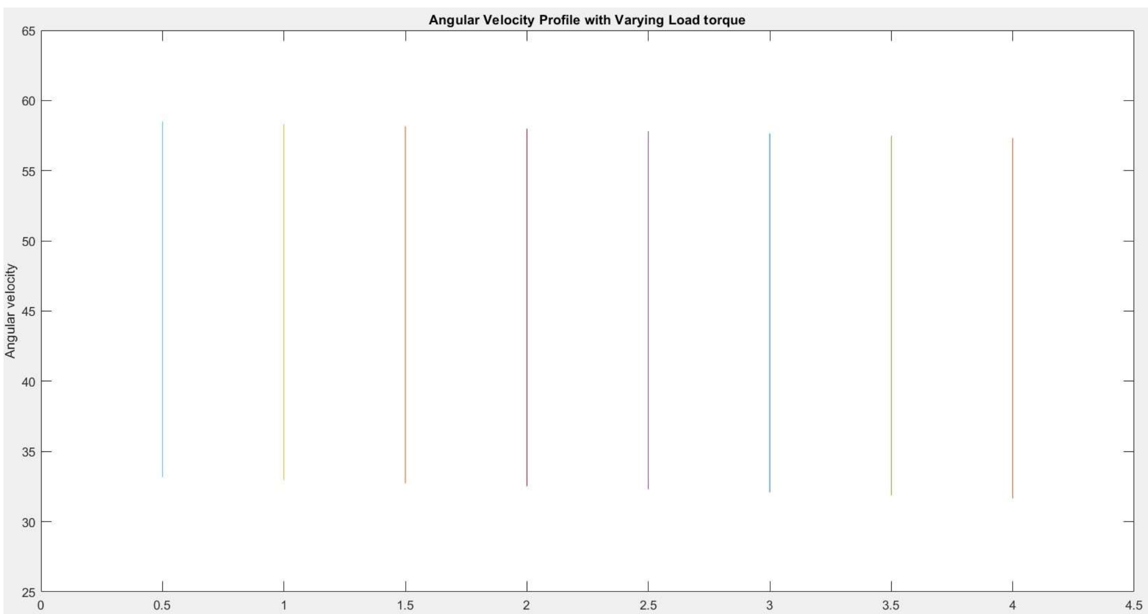


Output:

R_A Control:

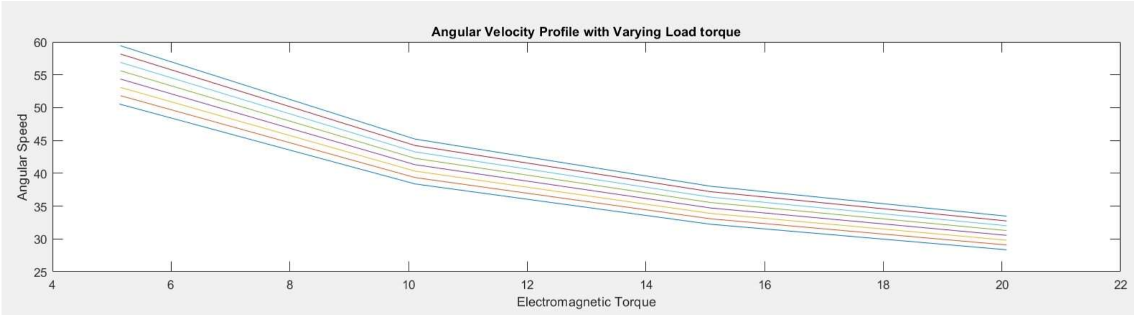


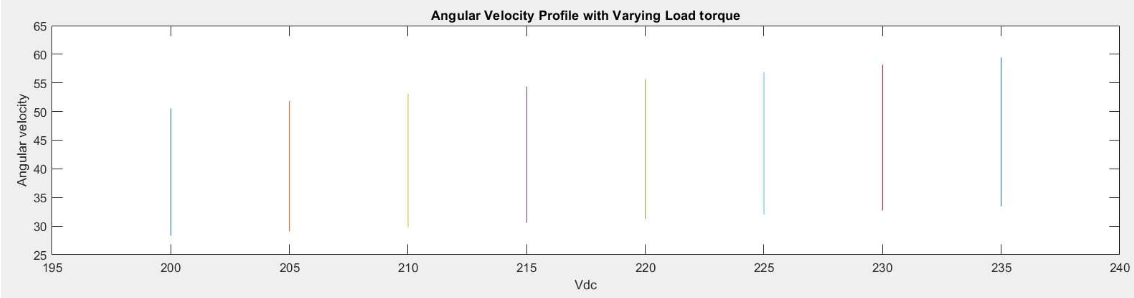
Angular Velocity Profile with Varying Load torque
Angular Speed
60
55
50
45
40
35
30
4
6
8
10
12
14
16
18
20
22



Angular Velocity Profile with Varying Load torque
Angular velocity
65
60
55
50
45
40
35
30
25
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5

V_A Control:





Observations: R_A

Control:

R_A = 1.5 Ohms

T_L (Nm)	T_E (Nm)	W (rad/s)
5	5.145	58.16
10	10.11	44.23
15	15.09	37.2
20	20.02	32.74

R_A = 1 Ohms

T_L (Nm)	T_E (Nm)	W (rad/s)
5	5.145	58.32
10	10.11	44.43
15	15.09	37.41
20	20.02	32.95

R_A = 3.5 Ohms

T_L (Nm)	T_E (Nm)	W (rad/s)
5	5.145	57.49
10	10.11	43.46
15	15.09	36.37
20	20.02	31.88

R_A = 0.5 Ohms

T_L (Nm)	T_E (Nm)	W (rad/s)
5	5.145	58.49
10	10.11	44.62
15	15.09	37.61
20	20.02	33.17

R_A = 2 Ohms

T_L (Nm)	T_E (Nm)	W (rad/s)
5	5.145	57.99
10	10.11	44.04
15	15.09	35.99
20	20.02	32.52

R_A = 2.5 Ohms

T_L (Nm)	T_E (Nm)	W (rad/s)
5	5.145	57.82
10	10.11	43.85
15	15.09	36.79
20	20.02	32.31

R_A = 3 Ohms

T_L (Nm)	T_E (Nm)	W (rad/s)
5	5.145	57.65
10	10.11	43.65
15	15.09	37.61
20	20.02	33.17

R_A = 4 Ohms

T_L (Nm)	T_E (Nm)	W (rad/s)
5	5.145	57.32
10	10.11	43.27
15	15.09	36.17
20	20.02	31.66

V_{DC} Control:

V_{DC} = 200 Volts

T_L (Nm)	T_E (Nm)	W (rad/s)
5	5.145	50.55
10	10.11	38.38
15	15.09	32.24
20	20.08	28.35

V_{DC} = 205 Volts

T_L (Nm)	T_E (Nm)	W (rad/s)
5	5.145	51.82
10	10.11	39.35
15	15.09	33.07
20	20.07	29.08

V_{DC} = 210 Volts

T_L (Nm)	T_E (Nm)	W (rad/s)
5	5.145	53.08
10	10.11	40.33
15	15.09	33.89
20	20.12	39.81

V_{DC} = 215 Volts

T_L (Nm)	T_E (Nm)	W (rad/s)
5	5.145	54.35
10	10.11	41.31
15	15.09	34.72
20	20.02	30.55

V_{DC} = 220 Volts

T_L (Nm)	T_E (Nm)	W (rad/s)
5	5.145	55.62
10	10.11	42.28
15	15.09	35.55
20	20.02	31.28

V_{DC} = 225 Volts

T_L (Nm)	T_E (Nm)	W (rad/s)
5	5.145	56.89
10	10.11	43.26

15	15.09	36.37
20	20.02	32.01

V_{DC} = 230 Volts

T_L (Nm)	T_E (Nm)	W (rad/s)
5	5.145	58.16
10	10.11	42.28
15	15.09	35.55
20	20.02	31.28

V_{DC} = 235 Volts

T_L (Nm)	T_E (Nm)	W (rad/s)
5	5.149	59.42
10	10.11	45.21
15	15.09	58.04
20	20.02	33.47

Results:

Hence, the speed control characteristics of a Long shunt DC motor for various values of load torque have been obtained.

Inference:

The simulation matches with the theoretical analysis.