DCMotor

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1 Developing a motor-signal (DC, BLDC, PMSM) model based on the operator transmittance

The mathematical equations describing the operation of DC Motor are presented below:

$$\frac{dw}{dt} = \frac{1}{J}(k_\varphi i - T_L)$$
$$\frac{di}{dt} = \frac{1}{L}(V_a - iR_a - k_\varphi w)$$

From that, we can derive transfer function:

$$\frac{V_A(s)}{\Omega(s)} = \frac{s^2 JLI(s) + JsRI(s) + Jsk_e\Omega(s)}{K_\varphi I(s) - T_L}$$

And the model looks in the following way:

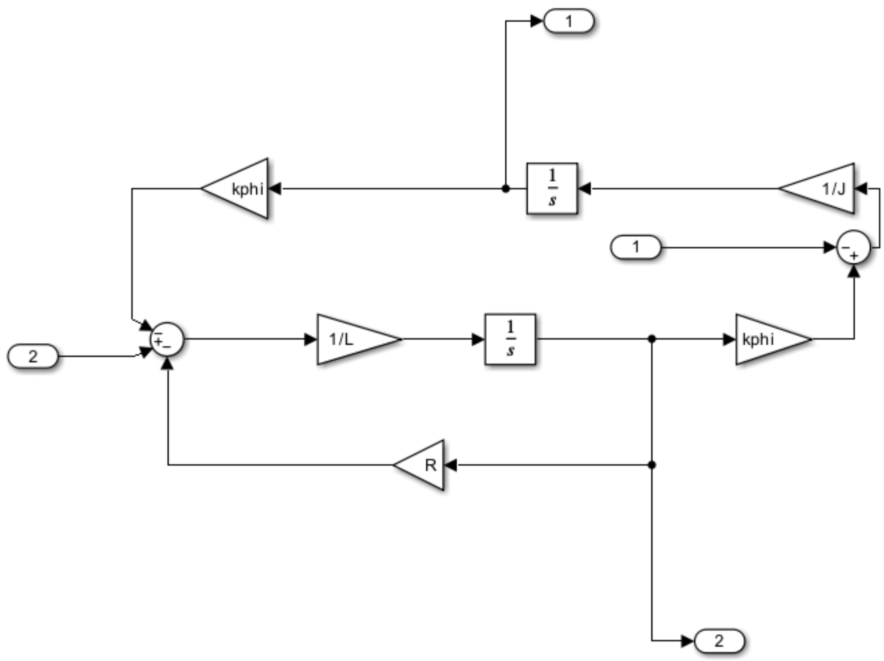

Figure 1: DC motor Matlab model

2 Recording setpoint voltage, speed, current signals for: unit voltage step, load step

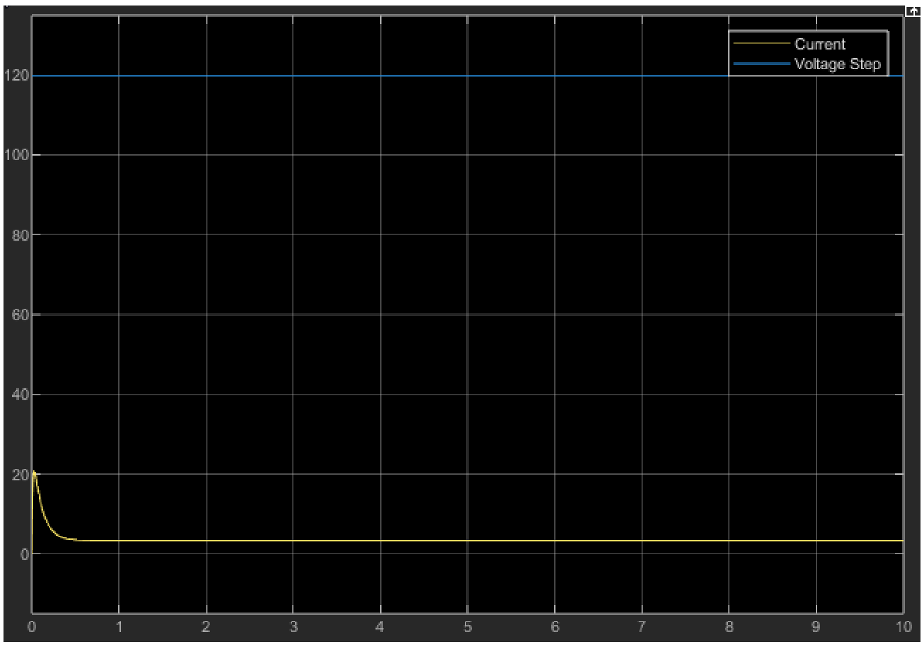

Figure 2: Current reaction to VOltage Step

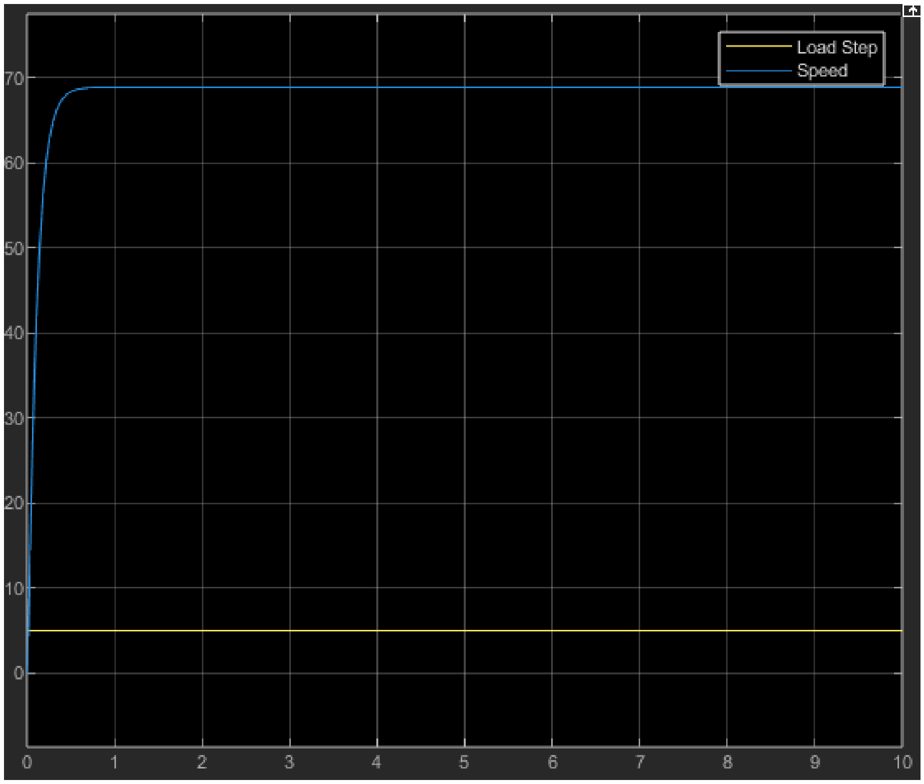

Figure 3: Speed reaction to Load Step

3 Recording set speed signals for a given load: elevator, electric vehicle or drone drive. Apply the load at the beginning when the speed is zero rad/s

Based on EV performance, the following values were selected: 400 V of supply voltage and 500 Nm of torque load.

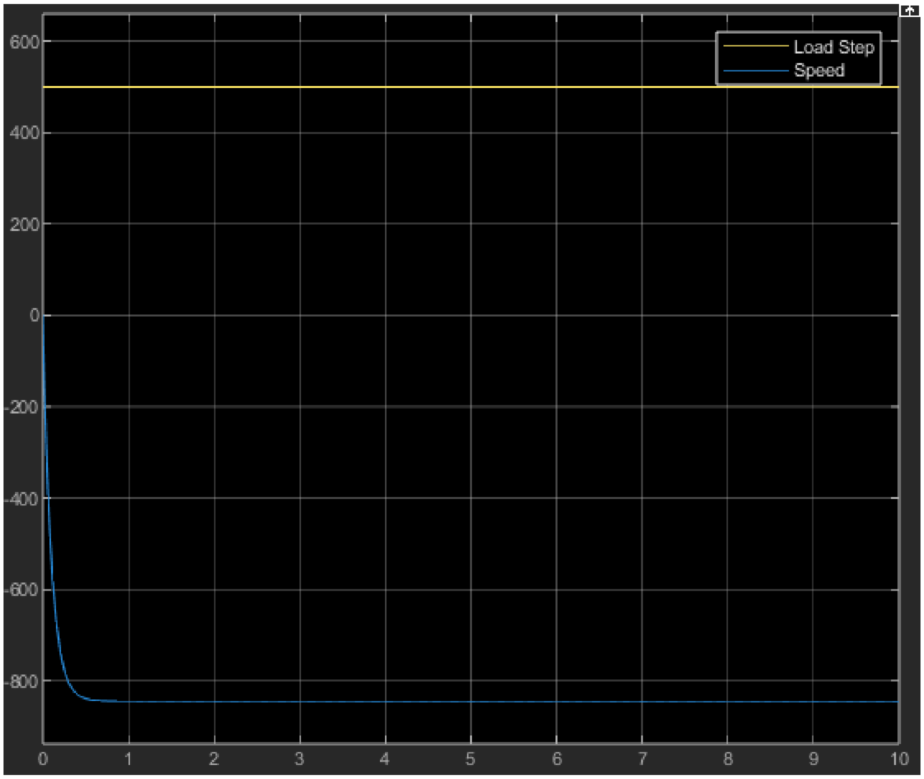

Figure 4: Speed graph with applied load

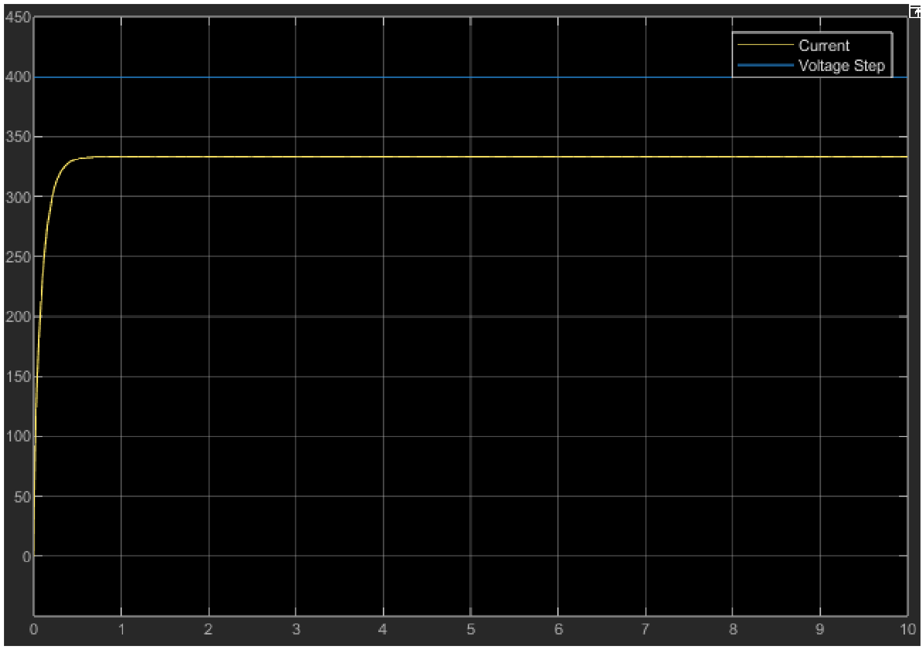

Figure 5: Current graph with applied voltage step

4 Development of a signal model of a power electronic converter

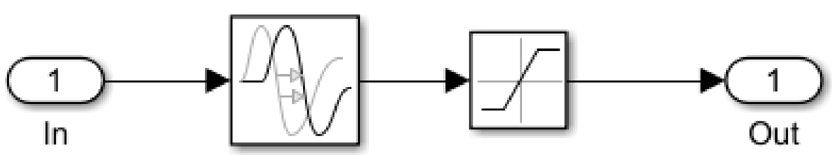

Figure 6: Power Converter Model

5 Designing a current controller by module criterion

Below are presented parameters of PI controller which are designed according to symmetry criterion.

```
kphi=1.5;
OM=50;

L=0.05;
J=0.05;

T_p = 0.01

Kb = 18
Tii= L/R
Kpi = Tii/(2*(1/R)*T_p)
Kii = Kpi/Tii
```

6 Recording the current response to a unit current step. The motor must be stopped (SEM = 0)

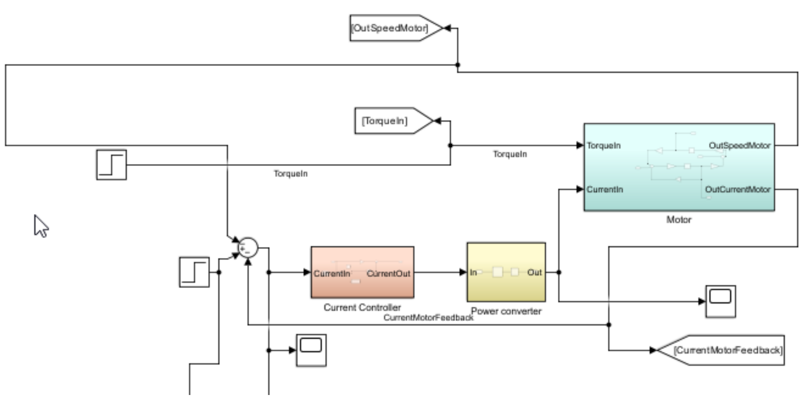

Figure 7: Block Diagram with Current Controller

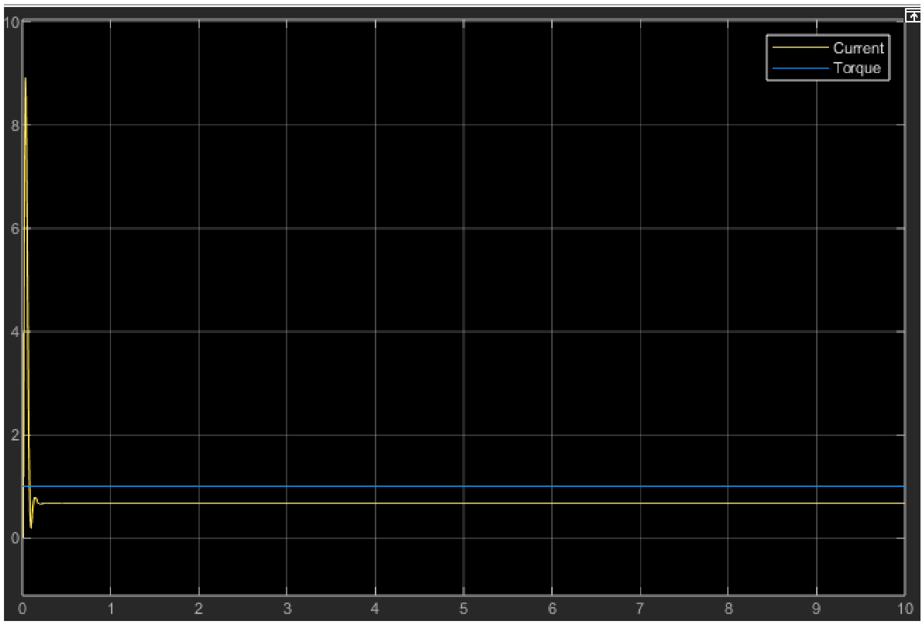

Figure 8: Current response for a current unit step set to 10

7 Designing a speed controller by symmetry criterion

The calculation of parameters according to symmetry criterion is presented below.

```
kphi=1.5;
OM=50;

L=0.05;
J=0.05;

T_p = 0.01

Tiw = 4*2*T_p
Kpw = J/(2*kphi*2*T_p)
Kiw = Kpw/Tiw
```

8 Recording speed and current per unit step of speed and load

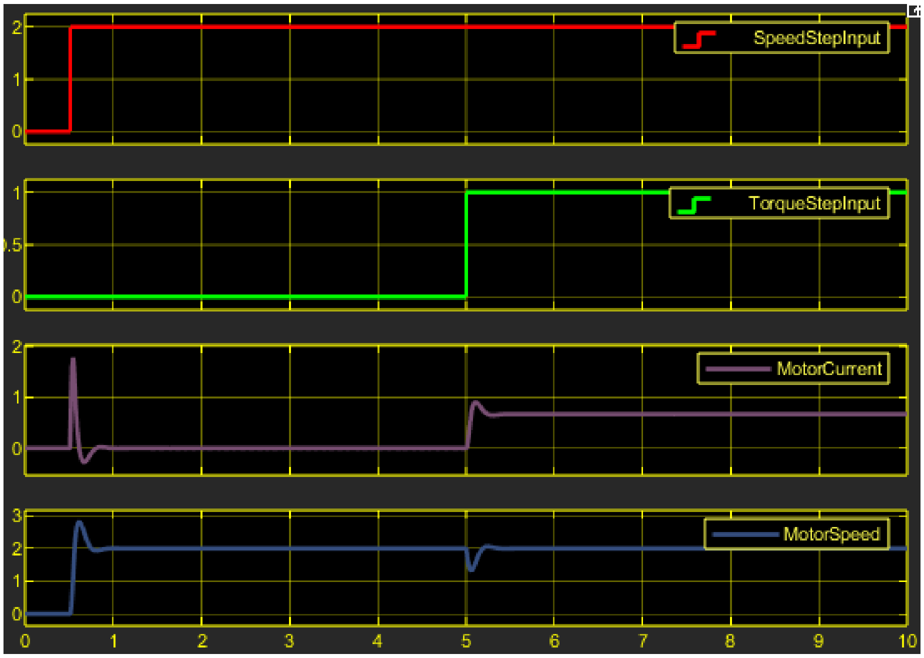

Figure 9: Matlab Scope with parameters and unit steps

9 Recording speed and current for a given load : elevator, electric vehicle or drone drive. Apply the load at the beginning when the speed is zero rad/s

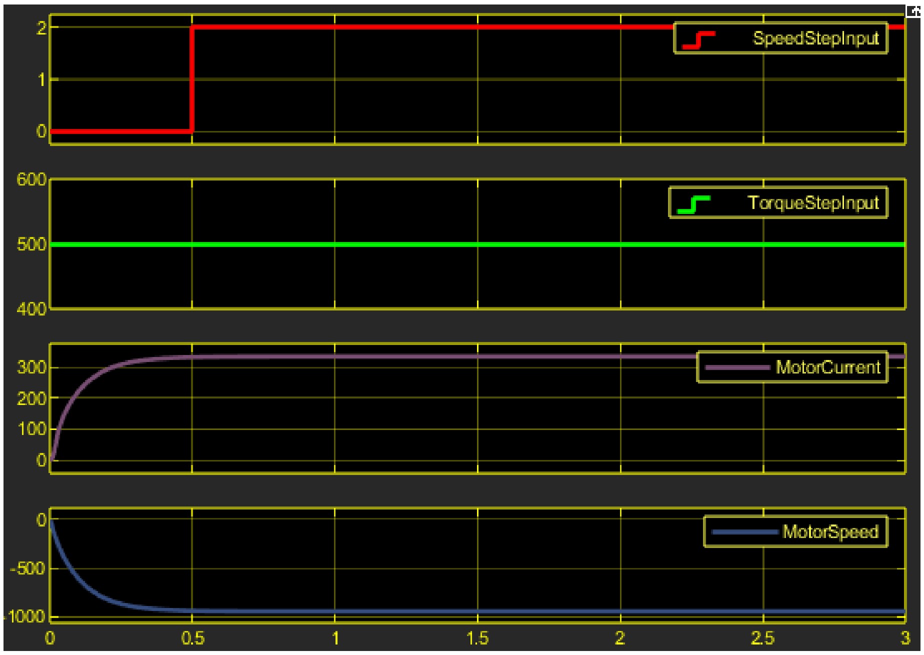

Figure 10: Matlab Scope after application of load of 500 Nm

10 Apply current and speed limits. Perform item 8 and 9

10.1 With load

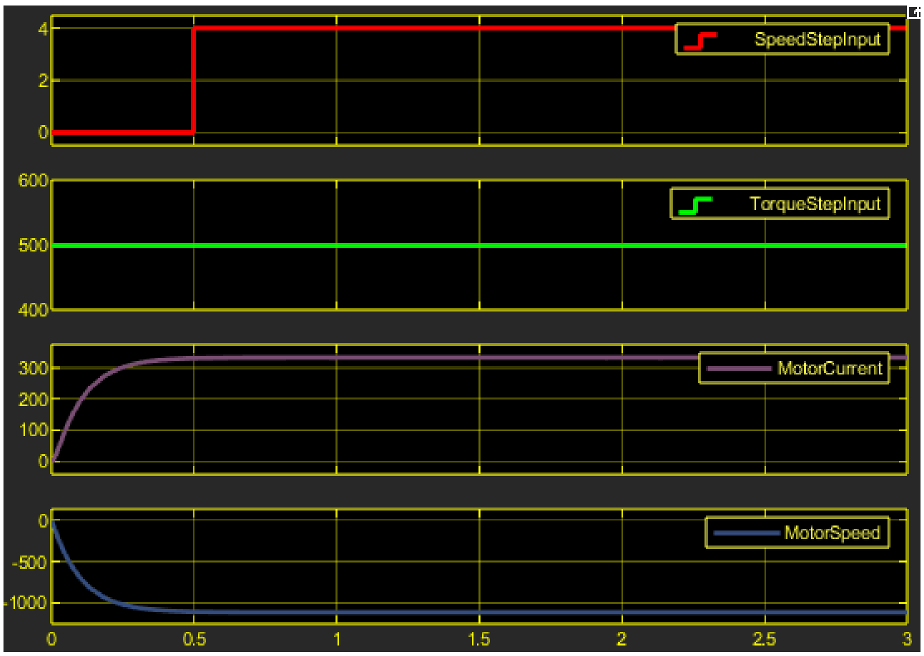

Figure 11: Matlab Scope after application of signal limits and load of 500 Nm

Application of saturation block with connected load gave no results, regardless of value

10.2 No load

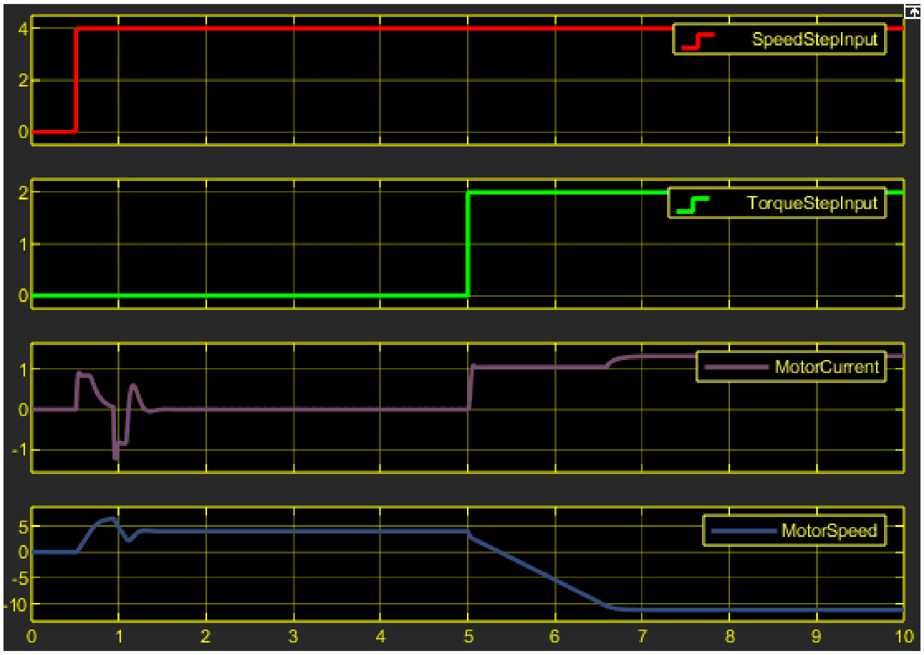

Figure 12: Matlab scope after application of signal limits without load

As we can see, application of saturation when load is not connected changes behavior of the system dramatically. The following parameters were applied:

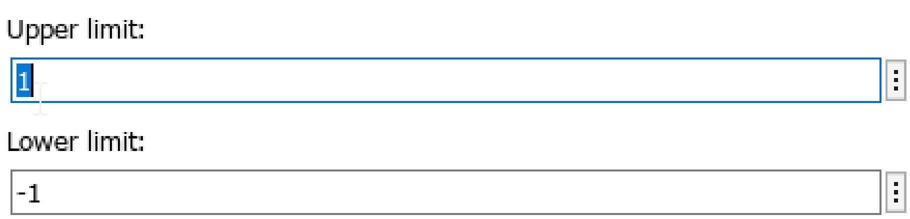

Figure 13: Speed Controller

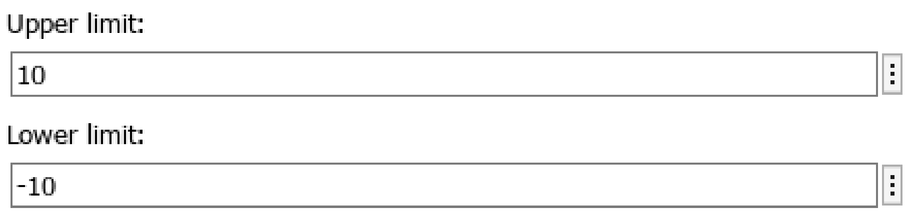

Figure 14: Current Controller

11 Explain the operation without signal limiting, with limiting without and with anti-wind-up system

Due to signal limiting the signal dynamics will be "cut off" and operation of the system might be different; due to integrator's effect, the system will enter into windup and its behavior will be unstable.
We will increase the saturation limits to the range -3:3 and get the following graph:

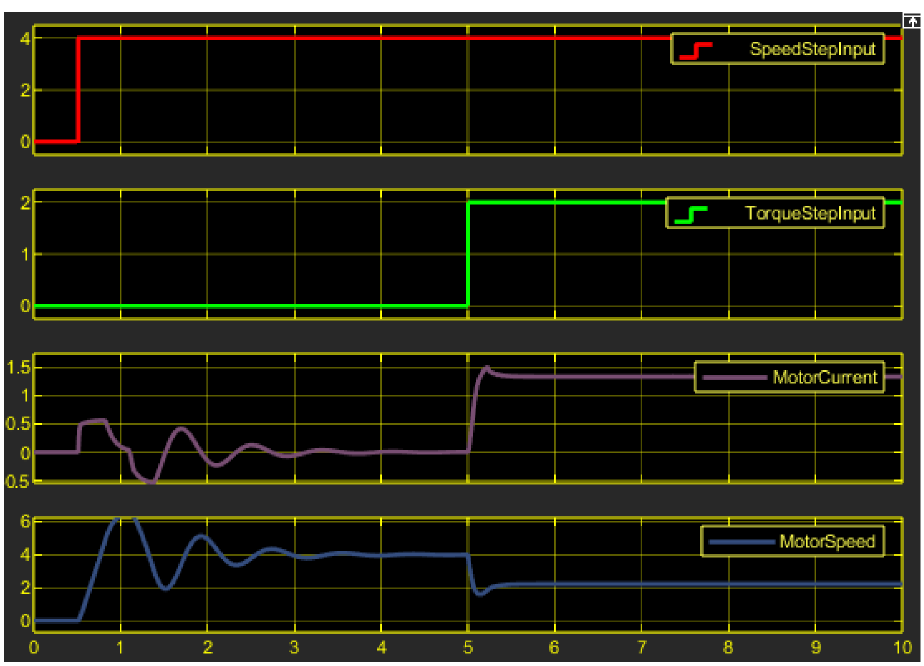

Figure 15: Matlab scope after application of signal limits without load

We can observe oscillations as we apply Speed Step. But after introduction of back-calculation method(kb = 18) we get something like this:

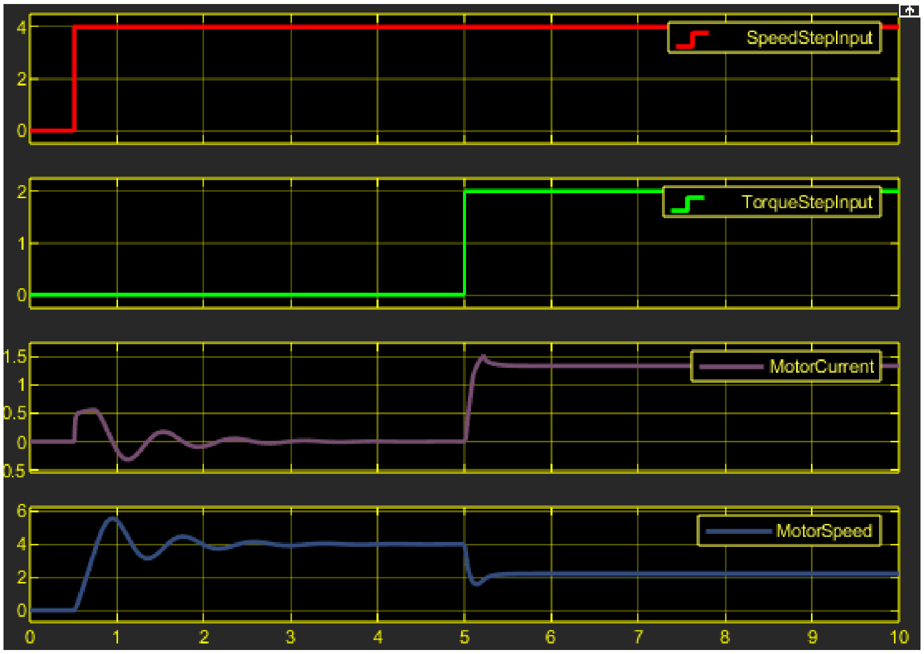

Figure 16: The previous scope after application of back-calculation

We can increase current limits to the range -100:100 to have even better example:

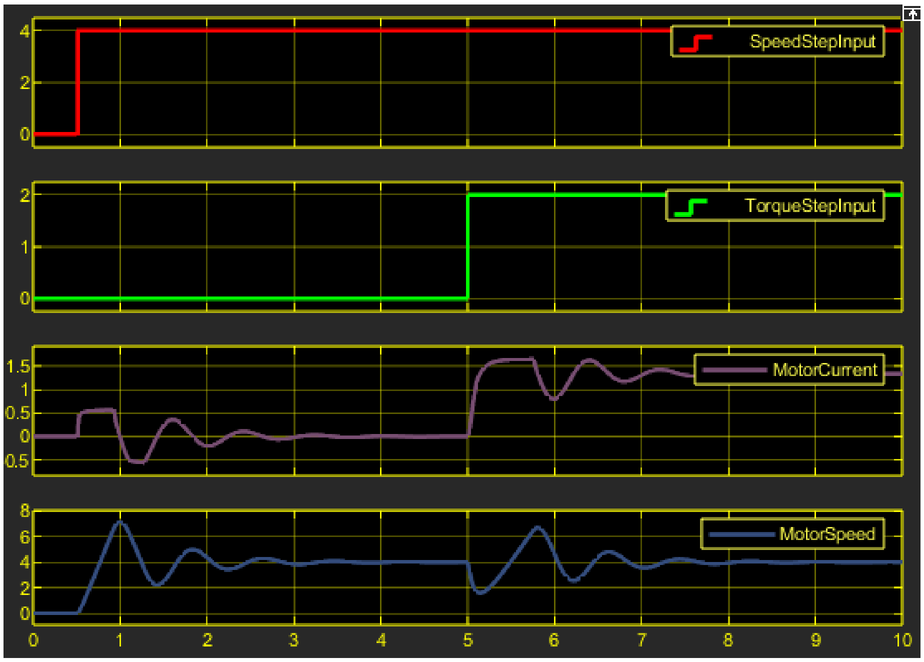

Figure 17: Matlab scope after application of signal limits without load

Applying back-calculation:

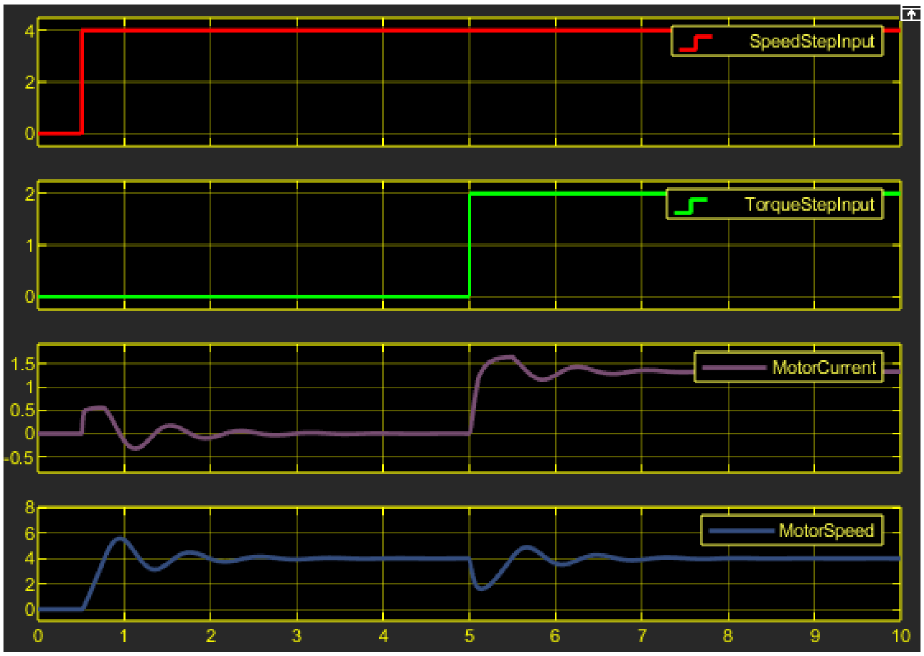

Figure 18: The previous scope after application of back-calculation

So, we can see that back-calculation is really useful at reducing oscillations.

12 Conclusions

In order to design robust and stable system we must test it with different conditions(with load, without load,etc) and then find the best solution for stable operation and proper control. Introduction of controllers with their criteria is crucial for achievement of desired performance of the system as they are virtually based on the parameters our system build upon. In our case, we see that our system expresses oscillatory behavior when we apply saturation, though back-calculation helps effectively reducing it.