# Compensator design for a typical electromechanical engine gimbal control (EGC) system and Linear system performance assessment using MATLAB/SIMULINK

**Abstract:** Design of (proportional + rate feedback), (Proportional + rate feedback + Integral) and (Proportional + Integral + Derivative) type of compensators for a typical electromechanical engine gimbal control system of launch vehicles and linear system performance assessment using SIMULINK model and SIMULINK LTI Viewer.

# Literature Survey:

The block diagram representation of a typical electromechanical engine gimbal control system using proportional plus rate feedback controller is shown in Fig.1.



+

+

K

1

Kp

K1

-

J.s+B

s

-

K

Controller gains

KTG

input

Output

Fig.1 Block diagram representation of a typical electromechanical EGC system with proportional + rate feedback controller

# The parameter values are given below:

J=Jm + (Nm/NL)2.JL , B = Bm + KT.Kb/Ra + (Nm/NL)2.BL K=KT/Ra

KT – Motor torque constant = 0.181 N-m/A

Kb- Motor back emf constant = 0.181 V/(rad/sec)

Jm – MI of motor rotating assembly =1.1694 x 10-4 Kg-m2

JL-MI of Engine Gimbal=12.753 Kgm2

Ball screw gear ratio=1/398

Bm – Viscous damping coefficient of motor shaft = 2.943 x 10-4 N-m/(rad/sec) BL – Viscous Damping coefficient of the Engine gimbal = 58.86 N-m/(rad/sec) Ra – Armature resistance = 8.6 ohms

Kp – Position sensor scale factor = 0.36 V/rad ( 10V corresponds to 4 \*398 deg deflection of motor shaft)

KTG – Tacho generator scale factor = 0.1 V/ (rad/sec)

***Controller design and Simulation***

The values of undamped natural frequency (wn), proportional controller gain (K1) and rate feedback controller gain (K2) were calculated and are given below:

wn = 27.3600, K1= 19.5077, K2 = 0.9538

Matlab Code:

kt=0.181;

kb=0.181;

jm=1.1694e-4;

jl=12.753;

bsgr=(1/398);

bm=2.943e-4;

bl=58.86;

ra=8.6;

kp=0.36;

ktg=0.1;

wb=5;

shi=0.6;

k=kt/ra;

wn=wb/(sqrt((1-2\*(shi).^2)+sqrt(4\*(shi).^4 - 4\*(shi).^2 + 2)));

j=jm+((bsgr).^2)\*jl;

b=bm+(kt\*kb/ra)+((bsgr).^2)\*bl;

k1=((wn.^2)\*j)/(kp\*k);

k2=(2\*shi\*wn\*j-b)/(k\*ktg);

From the Simulink model for the closed loop system, these parameters were determined:

* 1. – 3 dB bandwidth=31.3 rad/s.
  2. M–peak=0.354dB
  3. Peak Overshoot for step response=9.48%
  4. Rise time=0.0678s
  5. Settling time=0.217s

Diagram

Description automatically generated

Chart, line chart

Description automatically generated

Chart

Description automatically generated

Adding an integral controller `G(s)=Ki/s ‘ in parallel with the proportional controller gain ‘K1’ with a gain Ki= K1/10 and repeating the above measurements:

Diagram

Description automatically generated

Chart, line chart

Description automatically generated

Diagram

Description automatically generated with medium confidence

Adding a derivative controller `G(s) = Kd.s/(1+s/300)’ where Kd = K2\*KTG/Kp in parallel with the PI controller and removing the rate feedback controller:

In simulink, using kd\*s will give error like improper transfer function. So I add a pole far away from the original poles and zeros so that the TF will be proper and the root locus and hence the performance of the closed loop system won’t be affected much.

Diagram

Description automatically generated

Chart, line chart

Description automatically generated

Chart

Description automatically generated

**Performance Comparison Table**

|  |  |  |  |
| --- | --- | --- | --- |
| Performance Parameter | P + Rate feedback | P + I + Rate feedback | P+I+D |
| -3 dB Bandwidth (Hz) | 4.98 | 4.98 | 5.55 |
| M peak (dB) | 0.354 | 0.388 | 0.592 |
| Peak Overshoot (%) | 9.48 | 9.99 | 10.7 |
| Rise time (m.sec) | 67.8 | 67.5 | 58.3 |
| Settling time (m.sec) | 217 | 222 | 202 |

**Conclusions**

* PR controller increases the rate of the response. PI controller makes SS error 0. PID controller improves SS error and transient response.
* -3dB BW: Greater for PID. Almost same for PR and PI.
* M peak varies. Its minimum for PR and maximum for PID.
* %OS is also varying . Its minimum for PR and maximum for PID.
* Rise time is almost constant for PR and PI. Its minimum for PID and maximum for PR.
* Settling time is almost constant for PR and PI. Its minimum for PID.
* It appears as if PID controller performs very differently in almost all aspects when compared to other controllers. As expected PID controller reduces SS error at the same time improves transient response. (Lower ts value).