VOLTAGE MODE CONTROL FOR BUCK BOOST CONVERTER

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OBJECTIVE:---

- 1. Simulate a closed loop buck-boost converter with voltage mode control
- 2. Obtain the bode plot before and after the controller design and show that a phase margin of 50 degrees is achieved.
- 3. Draw the nyqist plot of open loop gain and confirm the same as in 2
- 4. Draw the root-locus of the output capacitor series resistance variation and show the limits of the capacitor series resistance variation for stable operation.

Parameters used:----

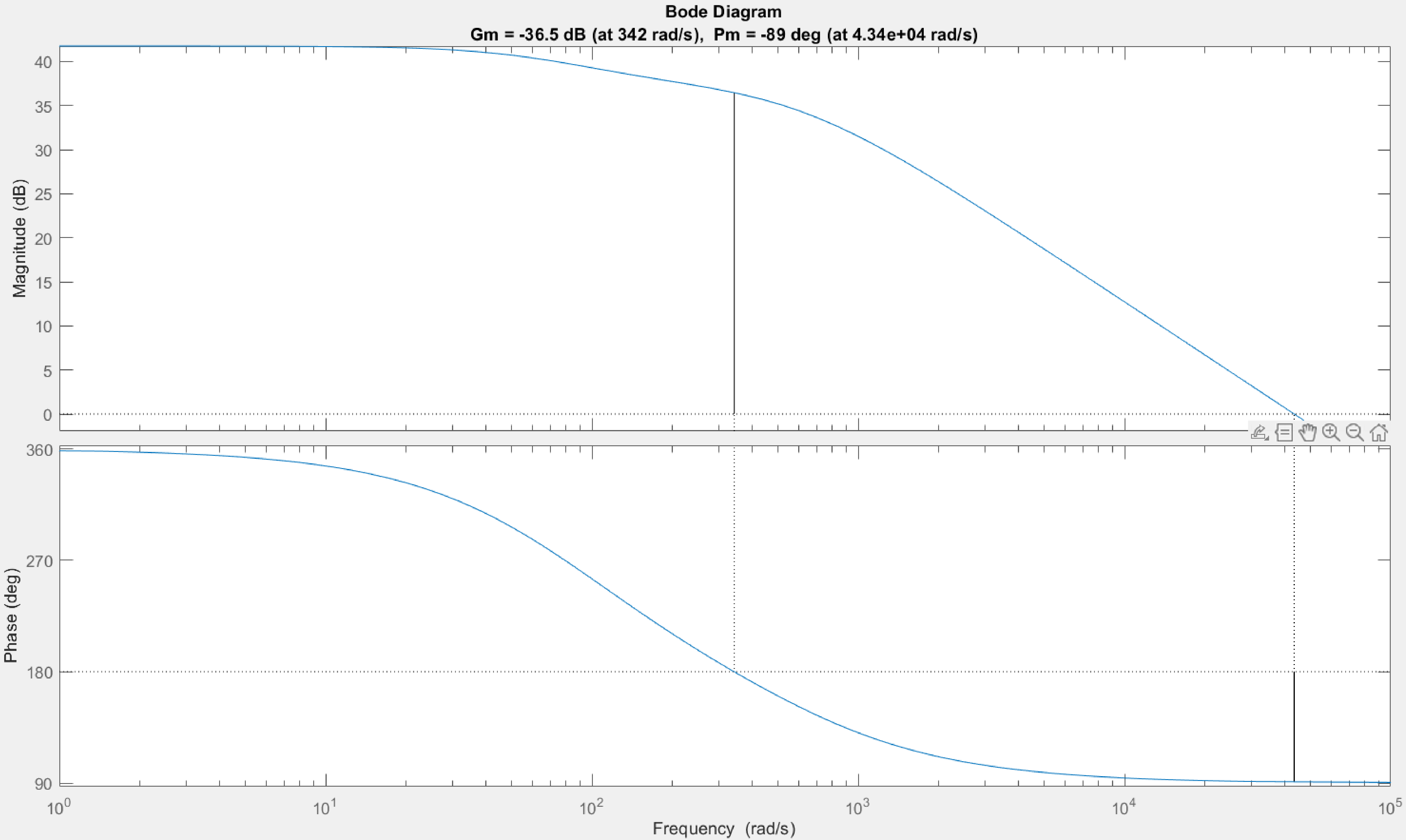
- Vin=14 Volts
- Vo= 30 Volts
- Lin=10 mH
- C=480 μF
- R=3.2Ω
- f=40 KHZ
- ΔI=2%

Trasfer function for voltage mode control

- Open loop transfer function without controller

$$GH(s)\ \frac{V_c}{d} = \frac{\dfrac{(1-D)(Vdc+Vc)}{LC} - \dfrac{sI_l}{C}}{s^2 + \dfrac{s}{RC} + \dfrac{(1-D)2}{LC}}$$

```
Gp =

  -4.34e04 s + 5.062e06
  ----------------------
  s^2 + 651 s + 4.126e04
```


Bode Diagram
Gm = -36.5 dB (at 342 rad/s), Pm = -89 deg (at 4.34e+04 rad/s)
Magnitude (dB)
40
35
30
25
20
15
10
5
0
Phase (deg)
360
270
180
90
Frequency (rad/s)
10^0
10^1
10^2
10^3
10^4
10^5

Open loop trasfer function with controller

- $$GH(s) = \frac{\frac{(1-D)(Vdc+Vc)}{LC} - \frac{sI_l}{C}}{s^2 + \frac{s}{RC} + \frac{(1-D)2}{LC}}\left(K_p + \frac{K_i}{s}\right)$$

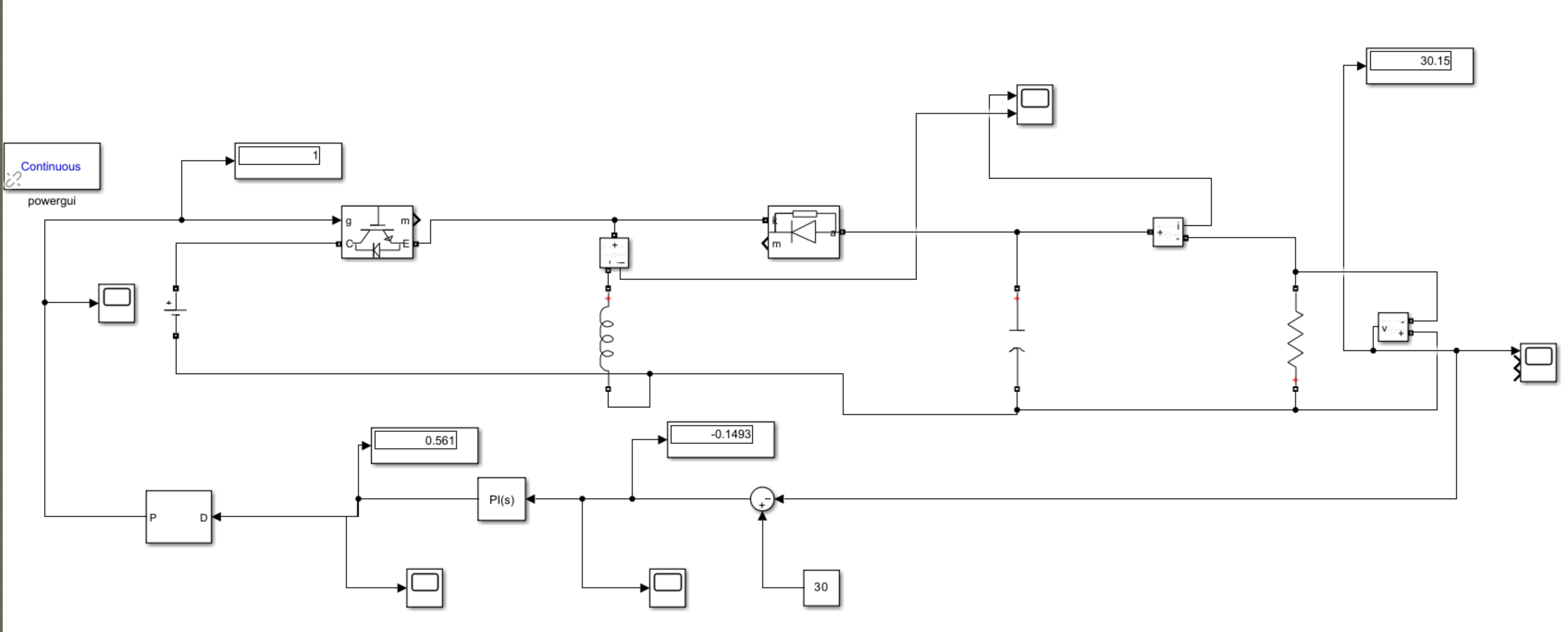
- $$G(s)H(s) = \frac{(Kp*43402.833)*(116.64-s)(s+Kp/Ki)}{s(s+71.147)(s+579.85)}$$

- By using dominant pole concept ,we take Kp/Ki=71.147

PI cofficient used in controller

- We take Kp value such such that our DC gain will be small.
- K_p= 0.005
- Ki=0.471

Simulation model:-

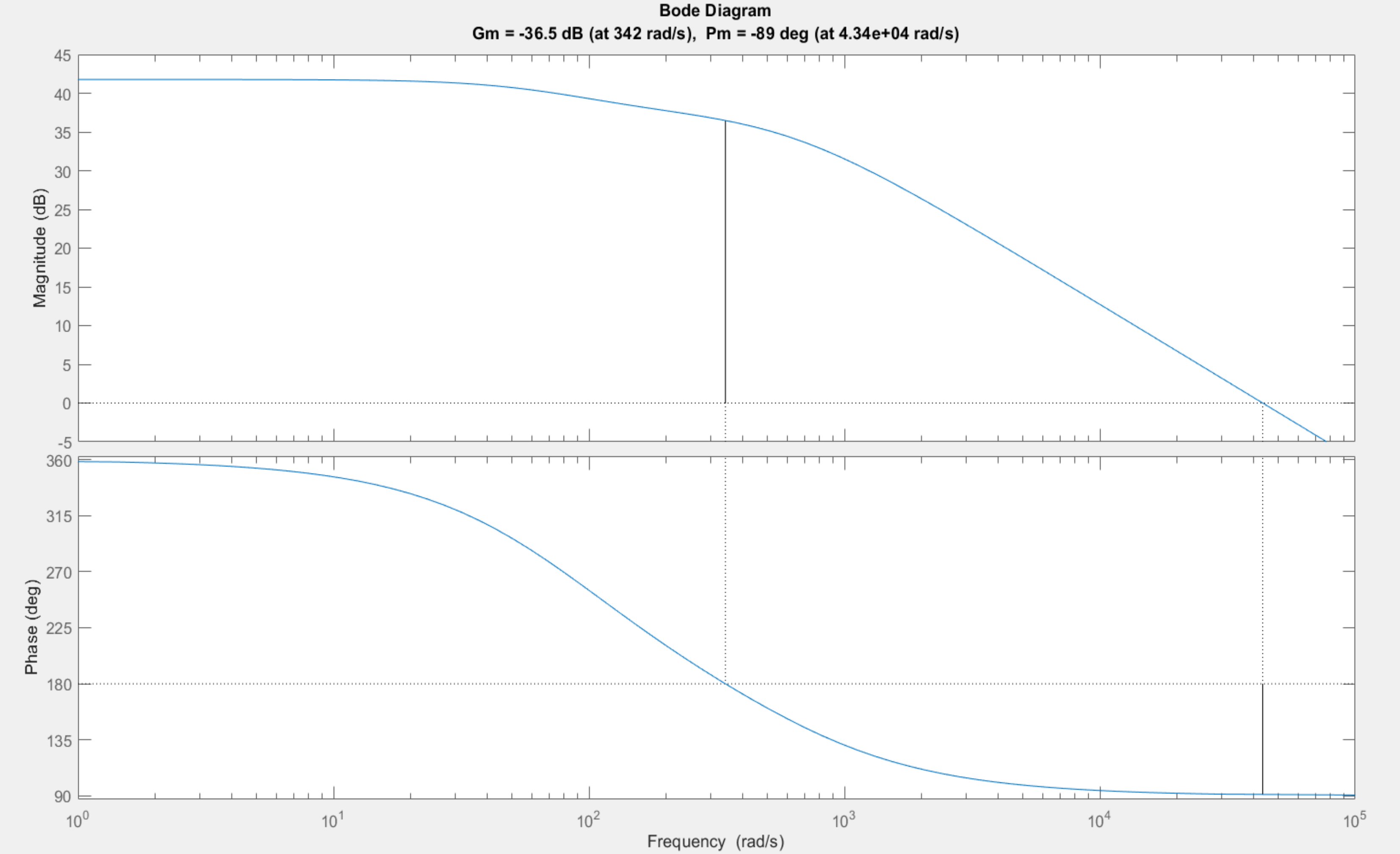


Vout waveform:-

overshoot(for k=0.009):-

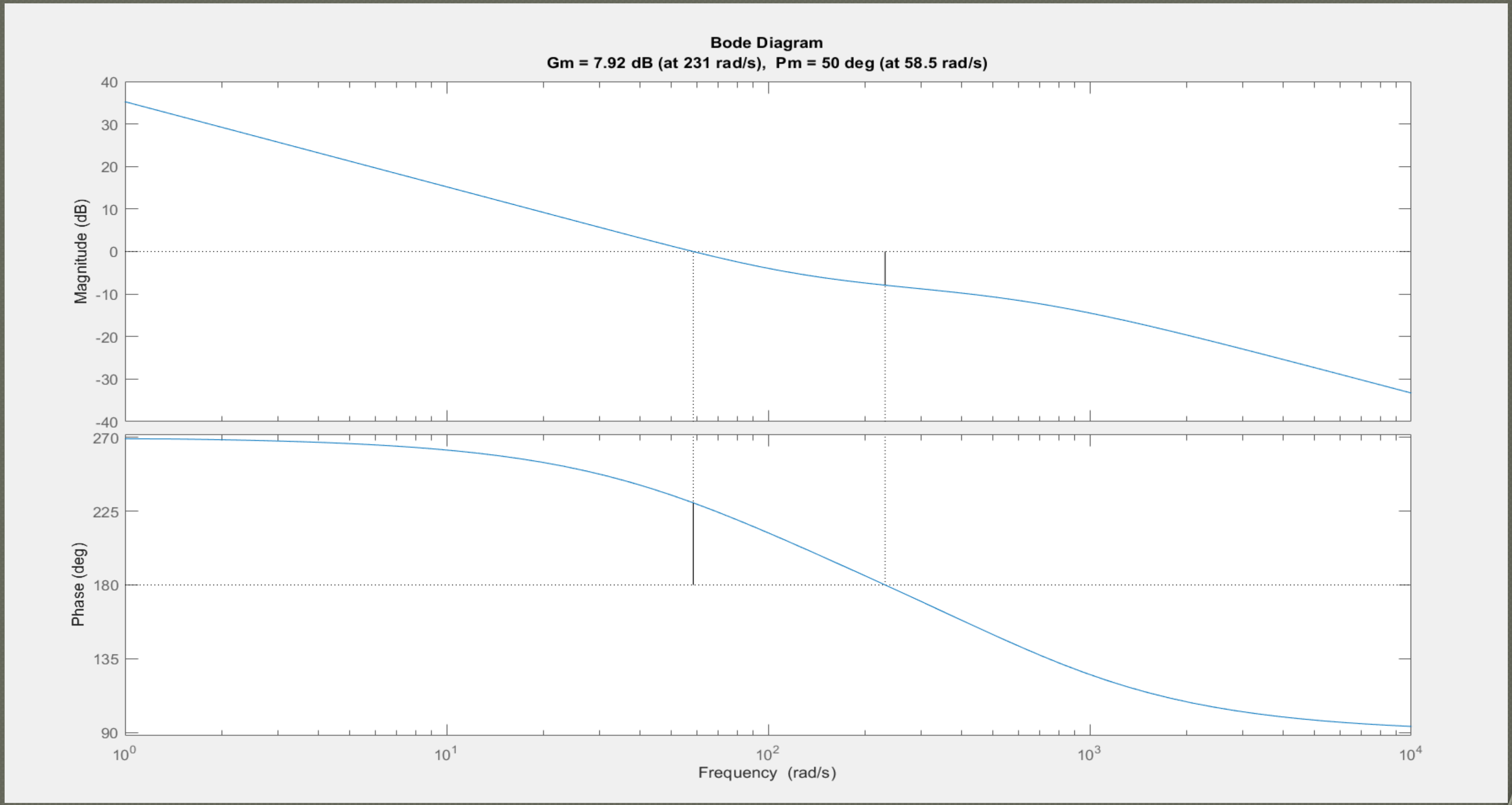
Bode plot without controller:-

```
Gp =

  -4.34e04 s + 5.062e06
  ---------------------
  s^2 + 651 s + 4.126e04
```

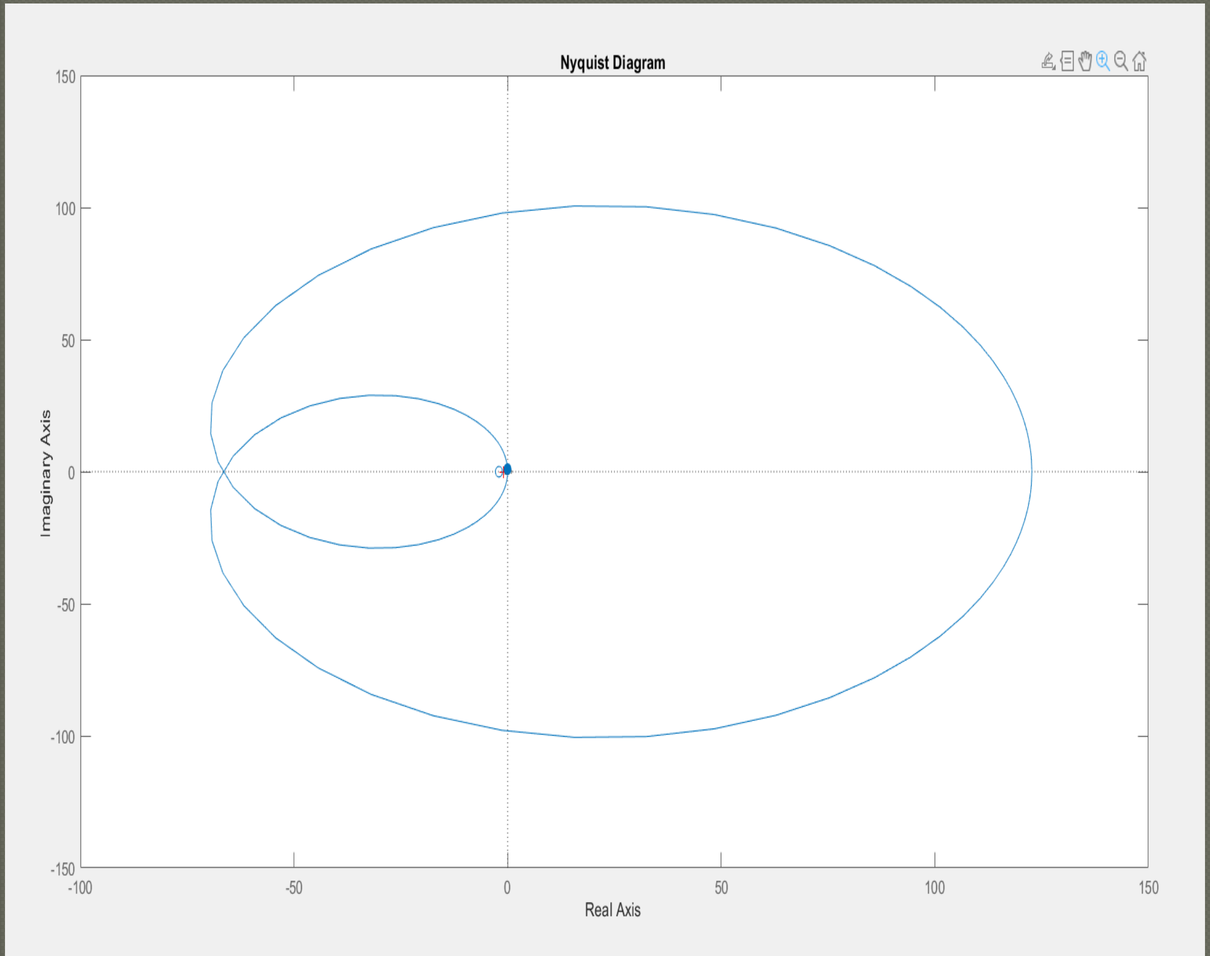


Bode plot with controller:-

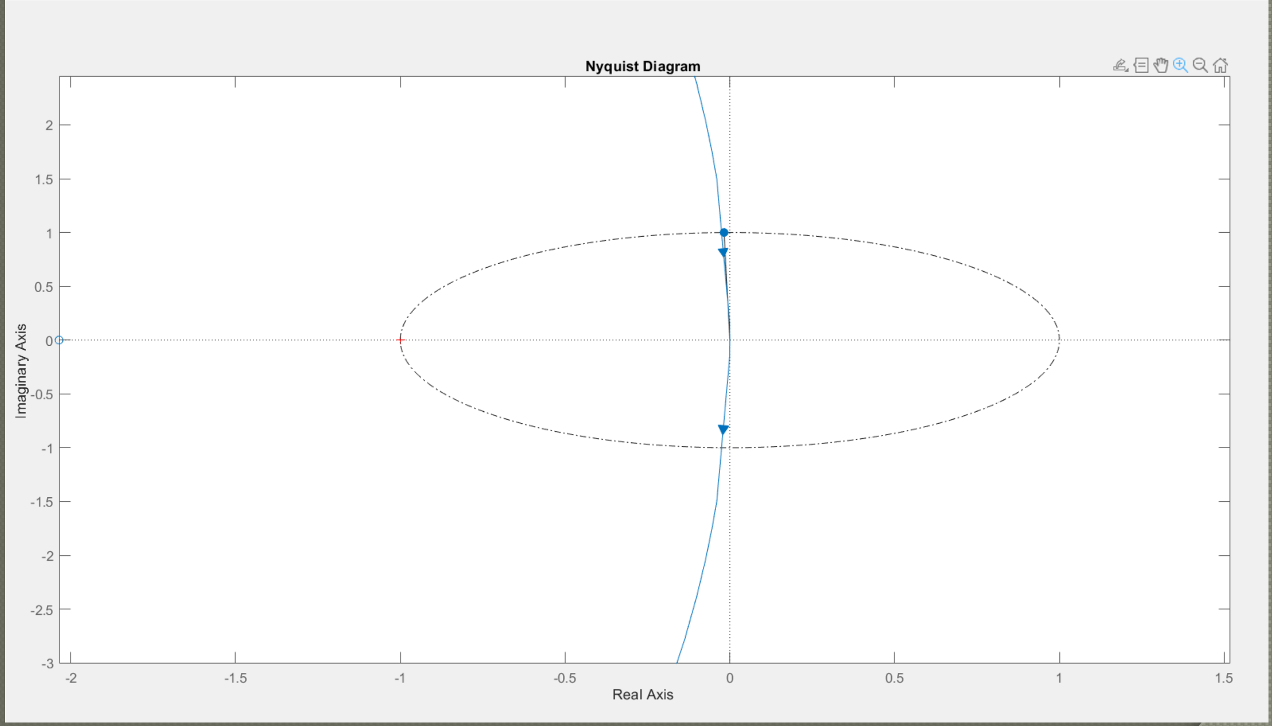
```
G =

  -217 s^2 + 4869 s + 2.384e06
  ----------------------------
   s^3 + 651 s^2 + 4.126e04 s

Continuous-time transfer function.
```



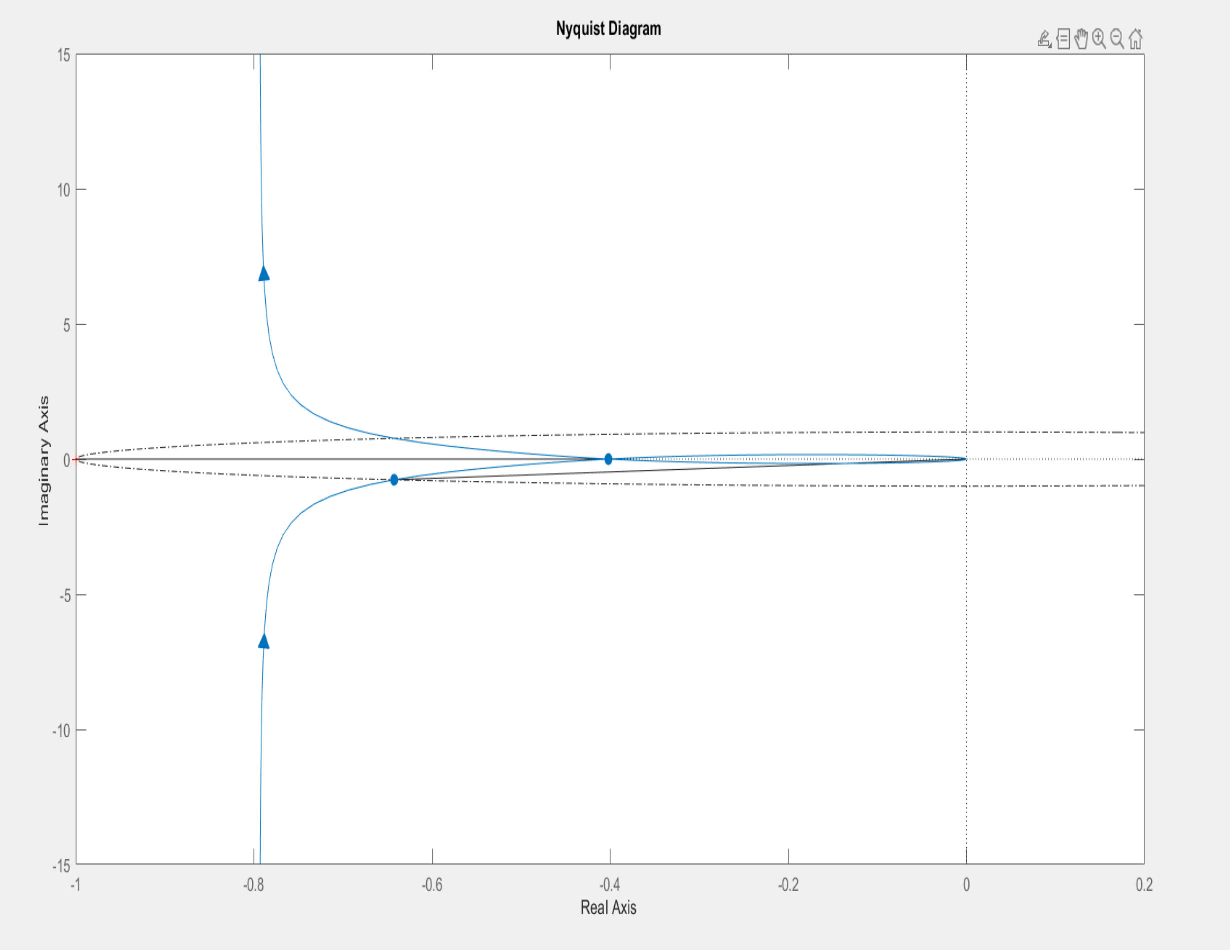
Nyquist plot without controller:-



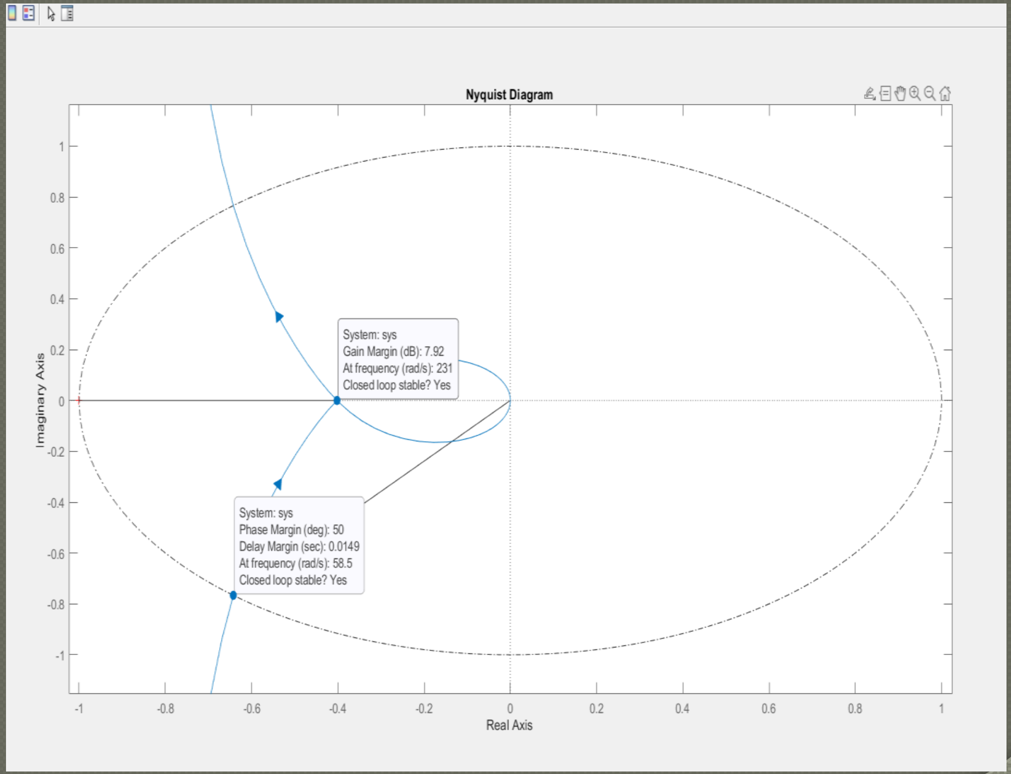

```
ans =

 -579.8522
  -71.1478
```



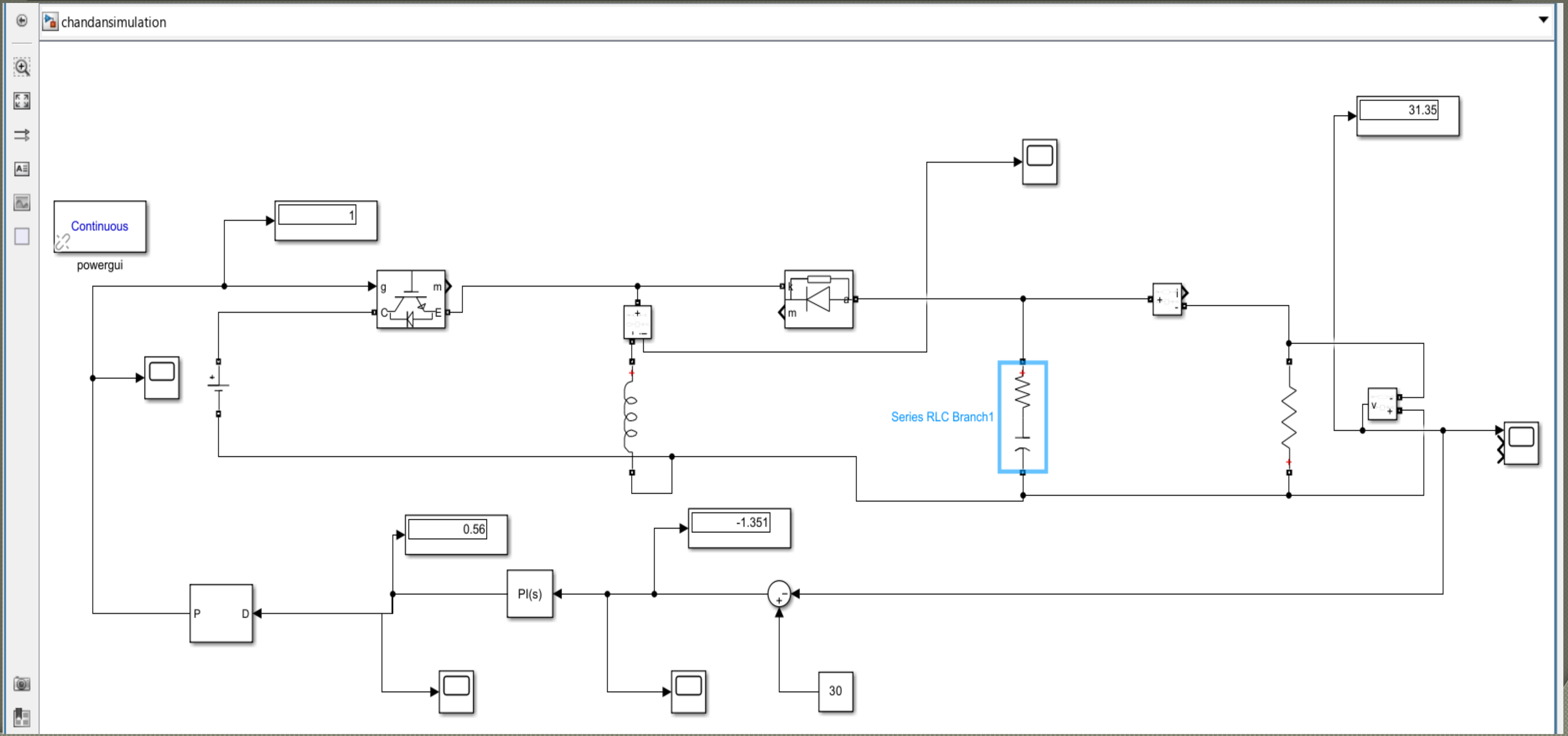
Nyquist plot with controller:-




```
ans =

         0
 -579.8522
  -71.1478
```



ESR model of Buck-Boost converter:-



Calculation for ESR :-

→ As we know the small signal model for ESR model

$$\frac{v_o}{d} = \frac{\frac{V_{in}}{(1-D)^2}\left(1-\frac{sDL}{R(1-D)^2}\right)(1+src)}{\frac{LC}{(1-D)^2}\left[s^2+\frac{s}{RC}+\frac{r}{L}(1-D)^2\right]+\frac{(1-D)^2}{LC}}$$

here $L = 10\times10^{-3}$

$C = 480\times10^{-6}$

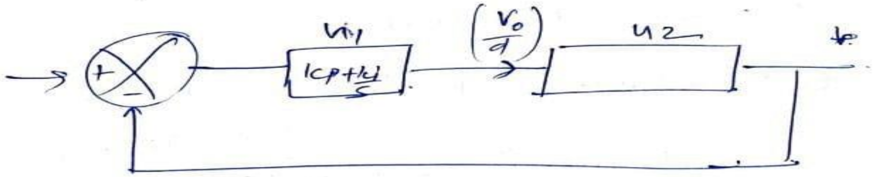
$D = 0.55$

$V_{in} = 14$ volt.

$R = 3.2\,\Omega$

→ when we use PI controller.

$$\frac{\frac{V_{in}}{(1-D)^2}\left(1-\frac{sDL}{R(1-D)^2}\right)(1+src)\left(k_p+\frac{k_i}{s}\right)}{\frac{LC}{(1-D)^2}\left[s^2+\frac{s}{RC}+\frac{r}{L}(1-D)^2\right]+\left(\frac{(1-D)^2}{LC}\right)}$$



$$= \frac{H_1\cdot H_2}{1+H_1\cdot H_2}$$

→ in Root locus we draw for OLTF from which we know

Calculation of ESR:-(continued)

$$\frac{V_{in}}{(1-D)^2} = 69.1358$$

$$\frac{LC}{(1-D)^2} = 23.704 \times 10^{-6}$$

$$k_p = 0.005$$

$$k_i = 0.471$$

$$\frac{1 + 69.1358\left(1 - \frac{s \times 0.55 \times 10 \times 10^{-3}}{3.2 \times (1-0.55)^2}\right)(1 + sr \times 480 \times 10^{-6})\left(0.005 + \frac{0.471}{s}\right)}{23.704 \times 10^{-6}\left[s^2 + \frac{s}{3.2 \times 480 \times 10^{-6}} + \frac{r\,(1-0.55)^2}{10 \times 10^{-3}} + \frac{1}{23.704 \times 10^{-6}}\right]}$$

$$\frac{1}{23.704 \times 10^{-6}} \downarrow 42186.97$$

$$\frac{1 + 69.1358\,(1 - s\,8.4876 \times 10^{-3})(1 + sr \times 480 \times 10^{-6})(0.005s + 0.471)}{s^3(23.704 \times 10^{-6}) + s^2 \times \frac{23.704 \times 10^{-6}}{3.2 \times 480 \times 10^{-6}} + \frac{s \cdot r}{10 \times 10^{-3}}(1-0.55)^2 \times 23.704 \times 10^{-6} + 42186.97}$$

Calculation of ESR:-(continued)

$$1 + \gamma \frac{(1155 s^3 - 27279 s^2 - 1.321 \times 10^7 s)}{19440 s^3 + 1.025 \times 10^7 s^2 + 3.46 \times 10^{13} s + 2.671 \times 10^{10}}$$

→ Now Root of

$$\gamma \frac{(1155 s^3 - 27279 s^2 - 1.321 \times 10^7 s)}{19440 s^3 + 1.025 \times 10^7 s^2 + 3.461 \times 10^{13} s + 2.671 \times 10^{10}}$$

→ pole (three poles)

(a) $1.0 \times 10^4 (-0.0264 + 4.2187 i)$

(b) $1 \times 10^4 (-0.0264 - 4.2187 i)$

(c) 0

→ three zeros

(a) 0

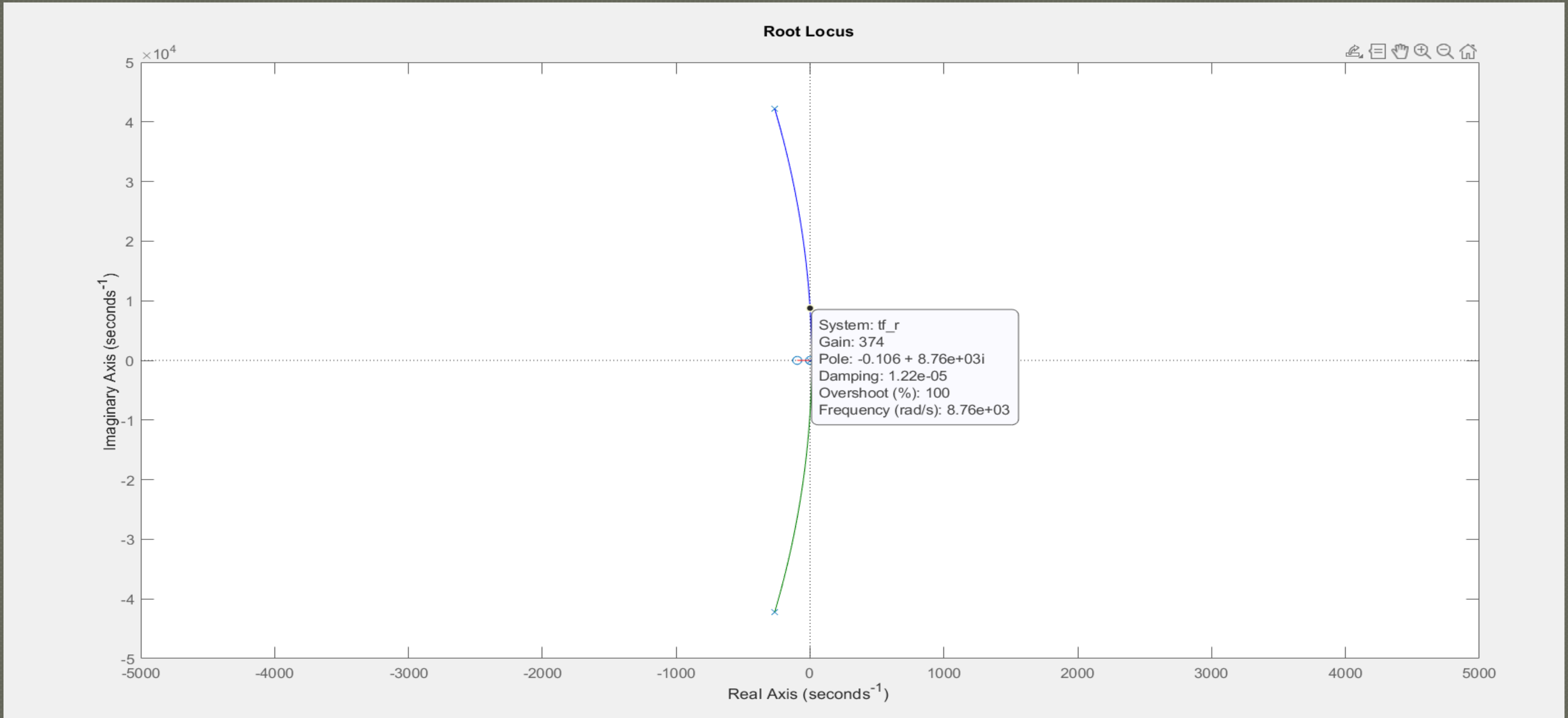
(b) 119.4137

(c) -95.7955

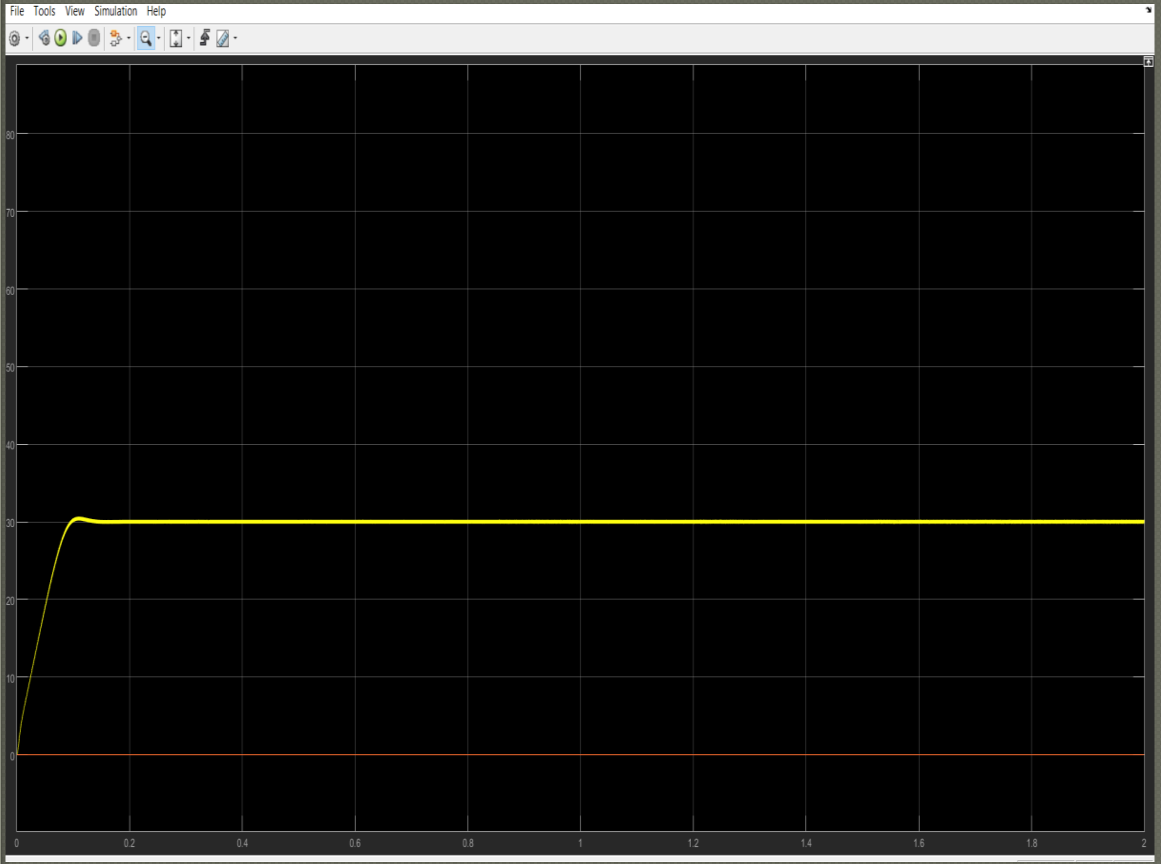
Varying ESR value:-

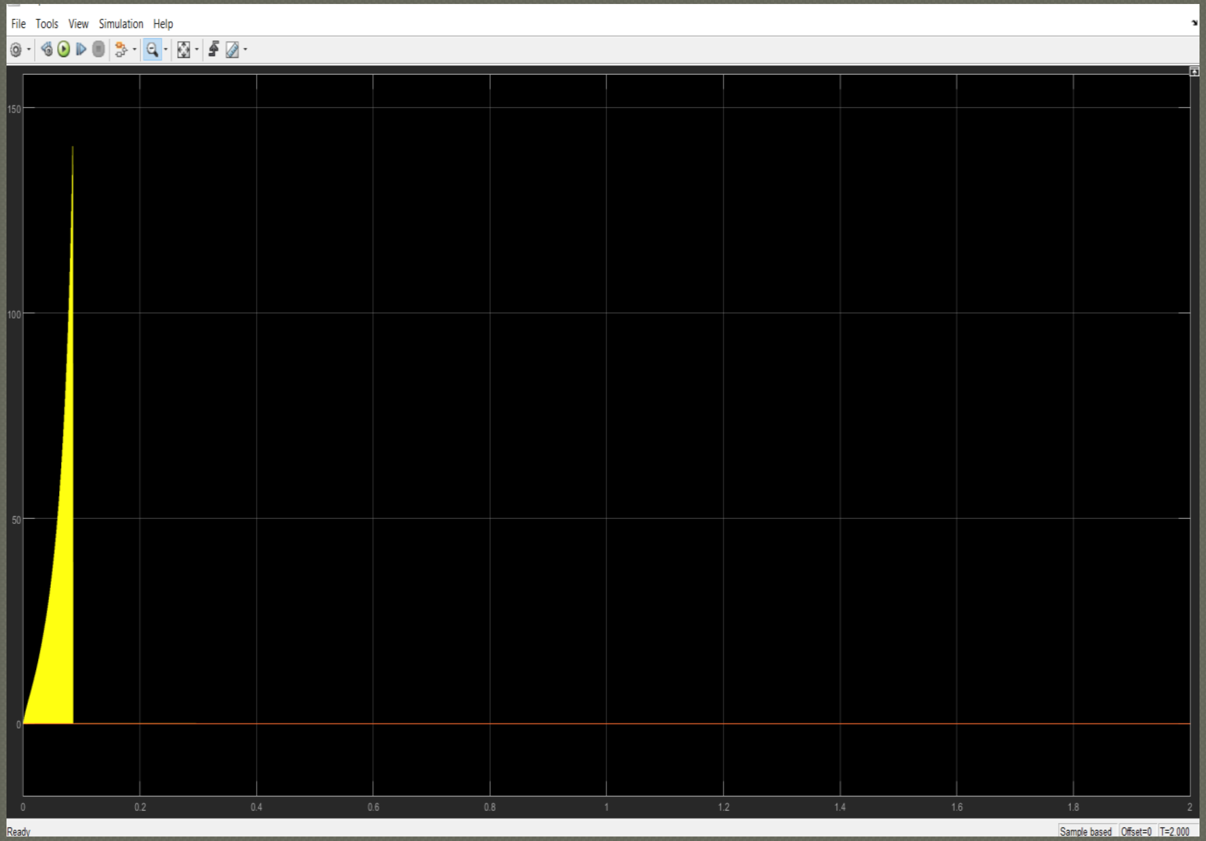
```
tf_r =

        1155 s^3 - 27279 s^2 - 1.321e07 s
  -----------------------------------------------
  19440 s^3 + 1.025e07 s^2 + 3.46e13 s + 2.671e10

Continuous-time transfer function.
Model Properties

ans =

   1.0e+04 *

  -0.0264 + 4.2187i
  -0.0264 - 4.2187i
  -0.0000 + 0.0000i


ans =

         0
  119.4137
  -95.7955

>>
```

Bode plot with ESR:-

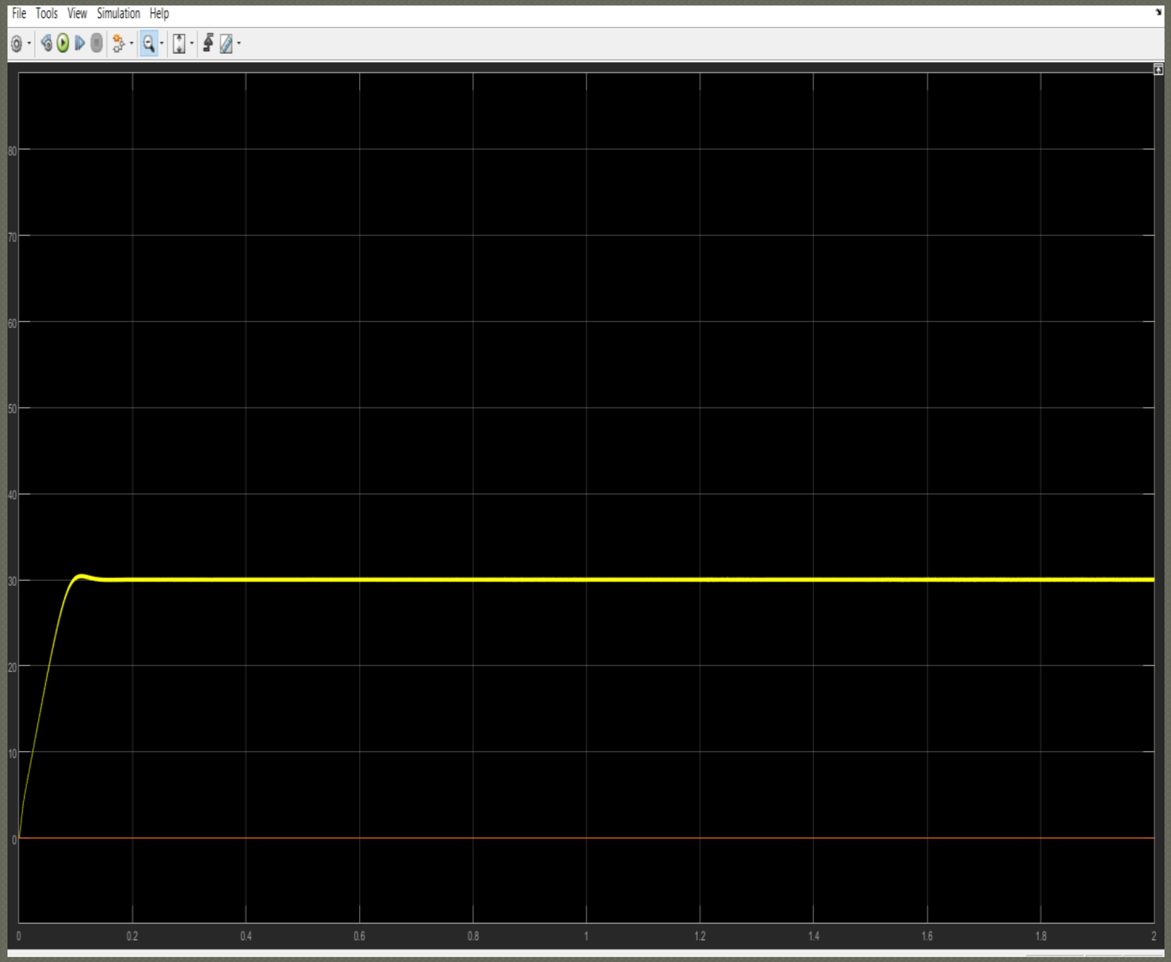


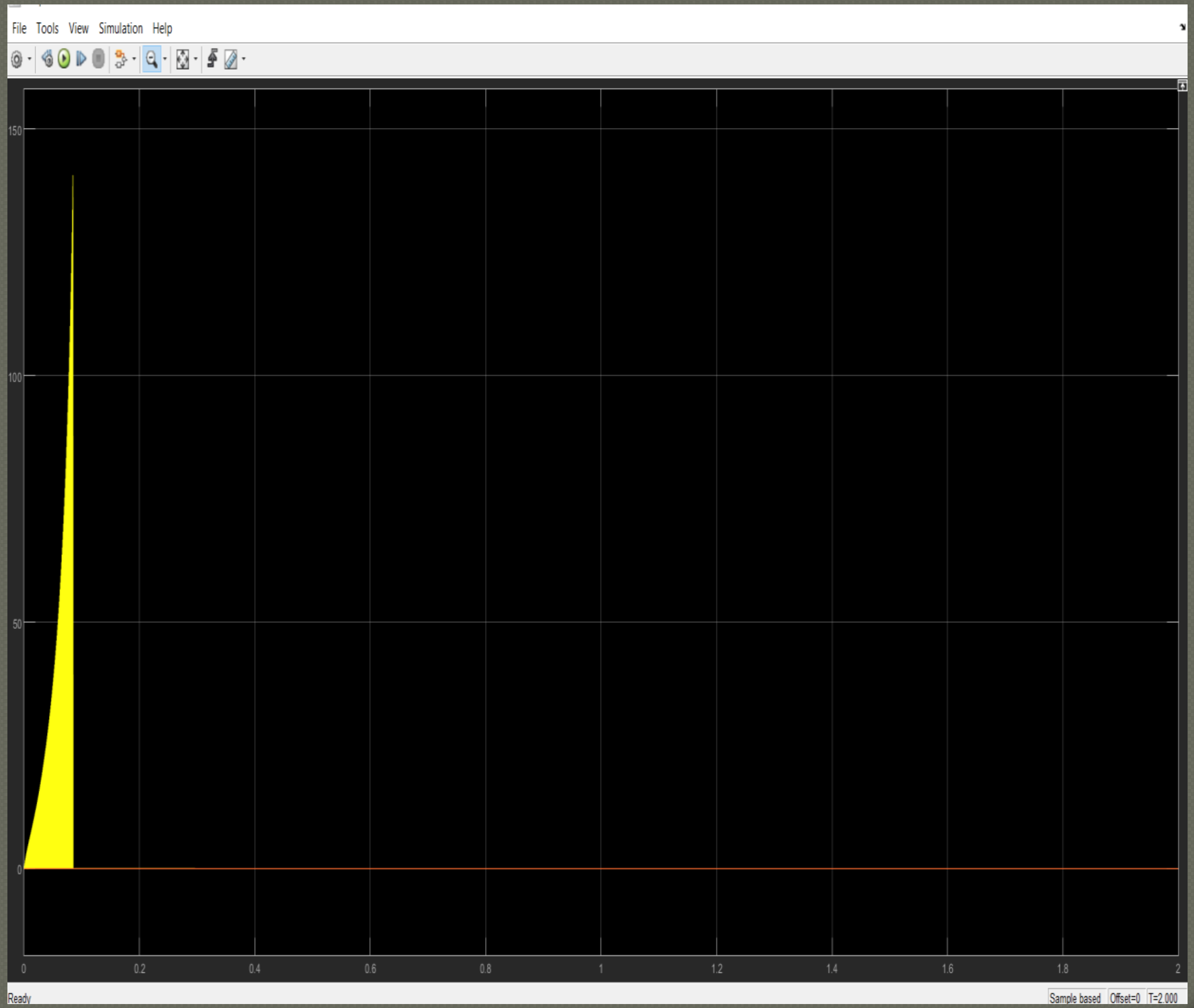
Plot for different value of ESR value(eg:0.1 ohm and 400 ohm):-



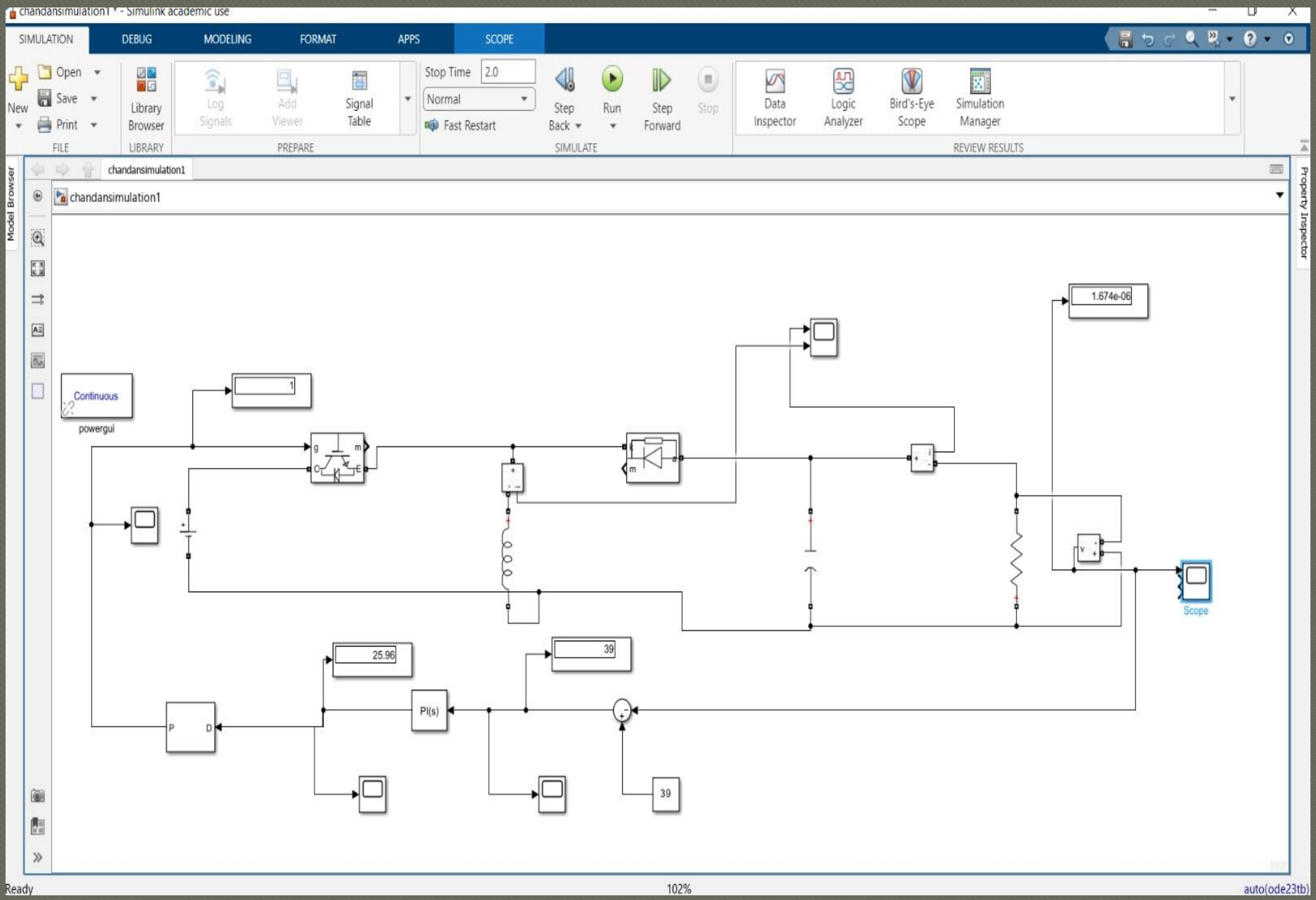


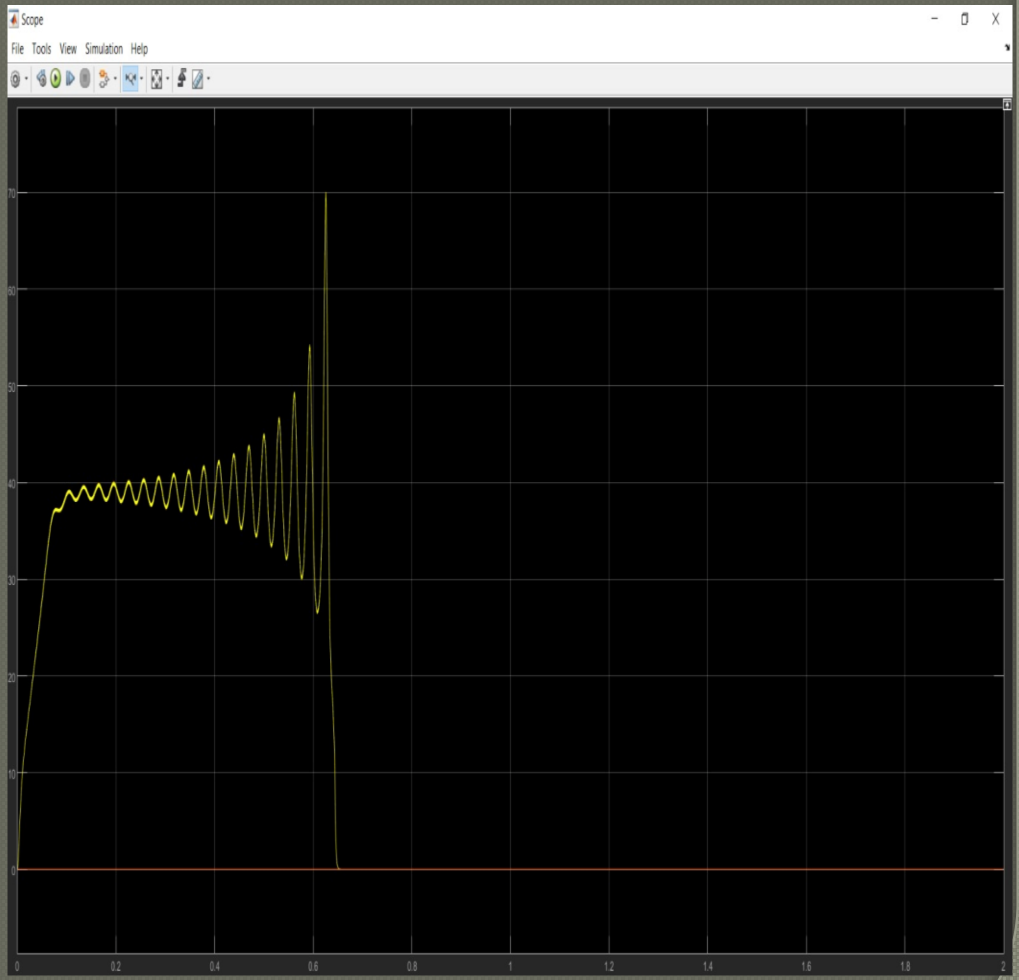
Graphs at different ESR value of 0.1 ohm and 400 ohm:-





Observations:-





IEEE Reference:-

- Sliding mode control of PV powered DC/DC Buck-Boost converter with digital signal processor

M. E. Şahın, H. İ. Okumuş and H. Kahvecı, "Sliding mode control of PV powered DC/DC Buck-Boost converter with digital signal processor," 2015 17th European Conference on Power Electronics and Applications (EPE'15 ECCE-Europe), Geneva, Switzerland, 2015, pp. 1-8, doi: 10.1109/EPE.2015.7309361.

Thank you