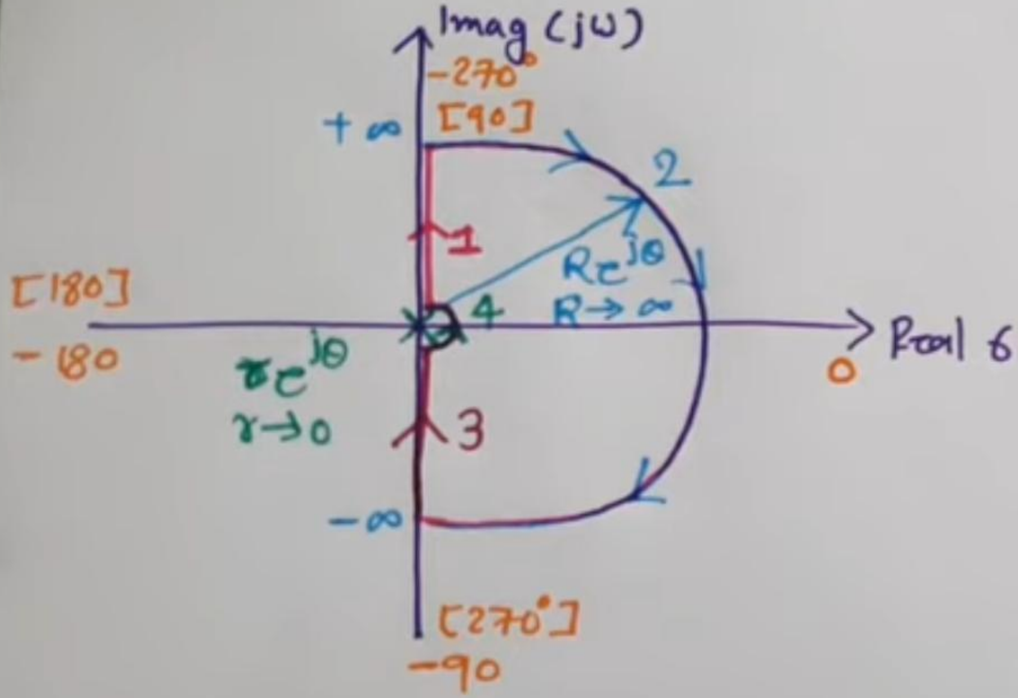
- It contains three major steps

1] Polar Plot

2] Inverse Polar plot

3] Nyquist Contour



1] $s = j\omega \rightarrow$ Polar plot

$G(j\omega)\,H(j\omega)$.

2] $s = \lim_{R \to \infty} Re^{j\theta}$, θ: 90 to -90

Find, $G(s)H(s) = \lim_{R \to \infty} G(Re^{j\theta})\,H(Re^{j\theta})$

3] $s = -j\omega \rightarrow$ Inverse polar plot

4] $s = \lim_{r \to 0} re^{j\theta}$, θ: -90 to 90

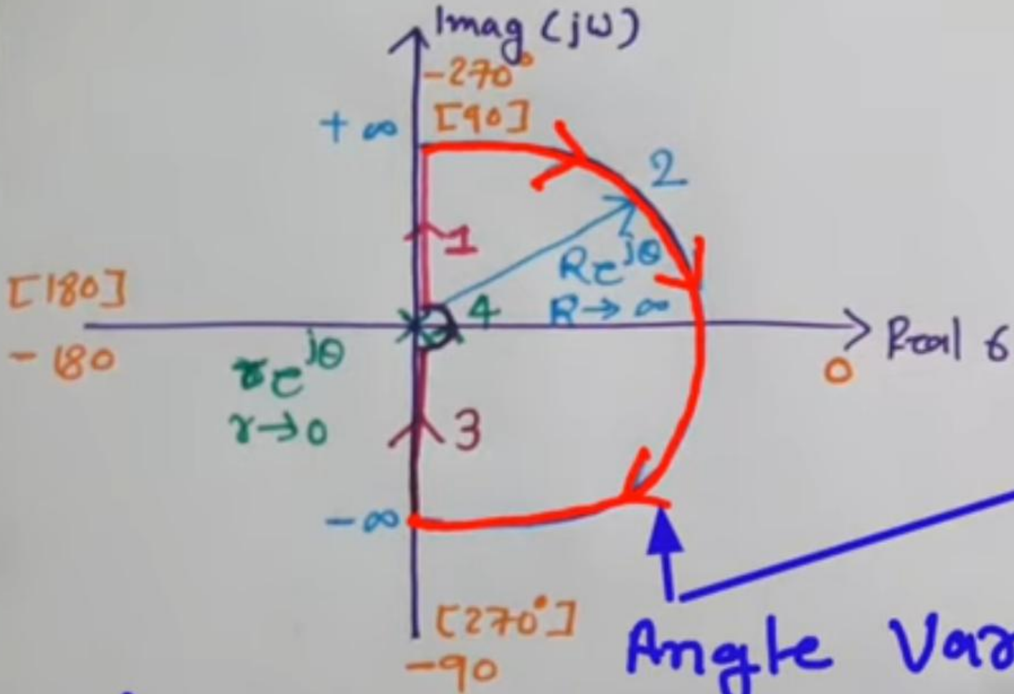
Find, $G(s)H(s) = \lim_{r \to 0} G(re^{j\theta})\,H(re^{j\theta})$

- It contains three major steps

1] Polar Plot

2] Inverse Polar plot

3] Nyquist Contour



1] $s = j\omega \rightarrow$ Polar plot

$G(j\omega)\,H(j\omega)$.

2] $s = \lim_{R\to\infty} Re^{j\theta}$ $\boxed{\theta : 90 \text{ to } -90}$

Find, $G(s)H(s) = \lim_{R\to\infty} G(Re^{j\theta})\,H(Re^{j\theta})$

3] $s = -j\omega$ Inverse polar plot

$s = \lim$ … $e^{j\theta}$, $\theta : -90$ to 90

Find … m $G(re^{j\theta})\,H(re^{j\theta})$

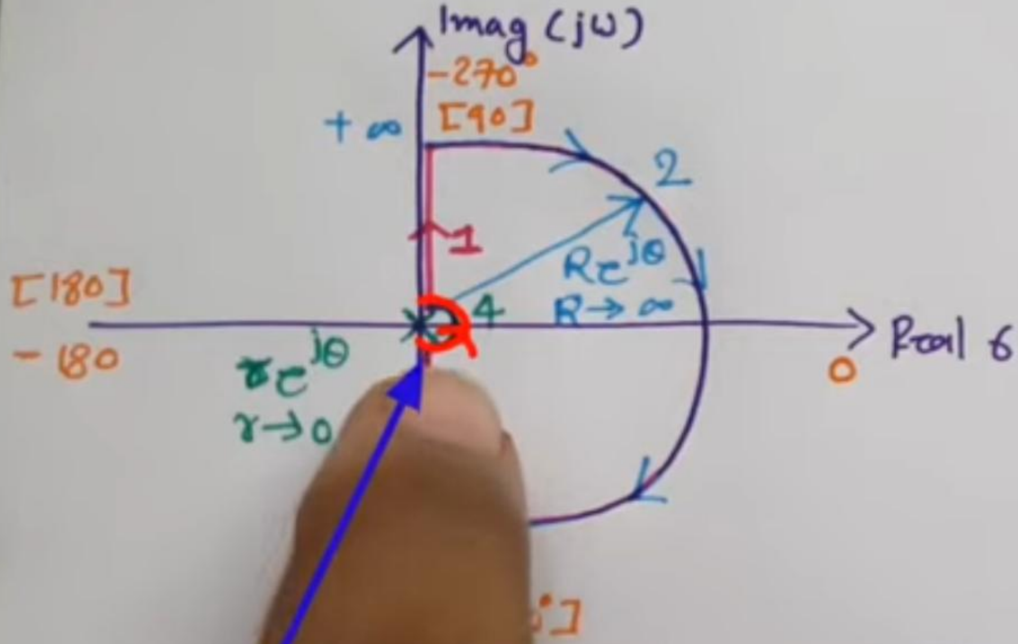
Angle Varies from +ve to -ve means Clockwise motion of circle

- It contains three major steps

1] Polar Plot

2] Inverse Polar plot

3] Nyquist Contour



1] $s = j\omega \rightarrow$ Polar plot

$G(j\omega)\,H(j\omega)$.

2] $s = \lim_{R\to\infty} Re^{j\theta}$, θ : 90 to -90

Find, $G(s)H(s) = \lim_{R\to\infty} G(Re^{j\theta})\,H(Re^{j\theta})$

3] $s = -j\omega \rightarrow$ Inverse polar plot

4] $s = \lim_{r\to 0} re^{j\theta}$ $\boxed{\theta : -90 \text{ to } 90}$

Find, $G(s)H(s) = \lim_{r\to 0} G(re^{j\theta})\,H(re^{j\theta})$

When angle varies from -ve to +ve, circle is in Anticlockwise direction.

Stability using Nyquist plot

→ $N = P - Z$

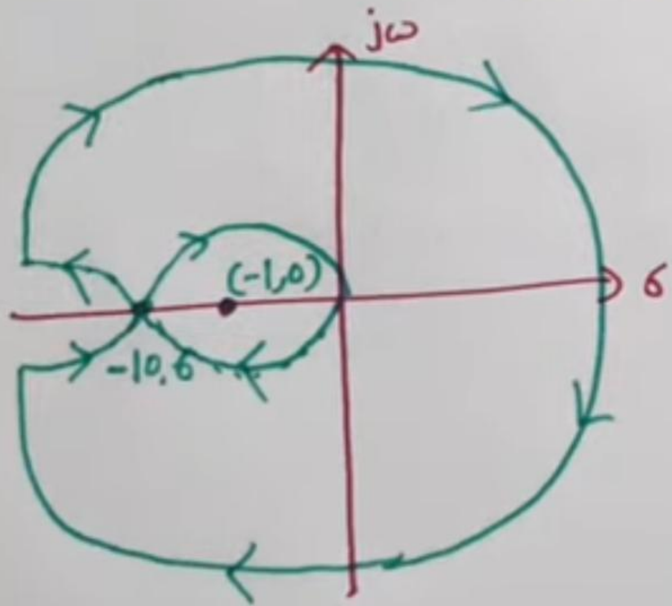
- N is positive for Anti clockwise encirclement around (-1, 0)
- N is negative for clockwise encirclement around (-1, 0).

P is Open loop Poles of System on RHP
Z is Close loop Poles of System on RHP

Note: Nyquist plot stability identification is possible for Open loop and Close loop system, Also It is applicable for minimum phase and Non minimum phase system.

for Open loop and Close loop system, Also it is applicable for minimum phase and Non minimum phase system.

Example $G(s)H(s) = \dfrac{(4s+1)}{s^2(s+1)(2s+1)}$



- $N = P - Z$

$\boxed{P = 0}$

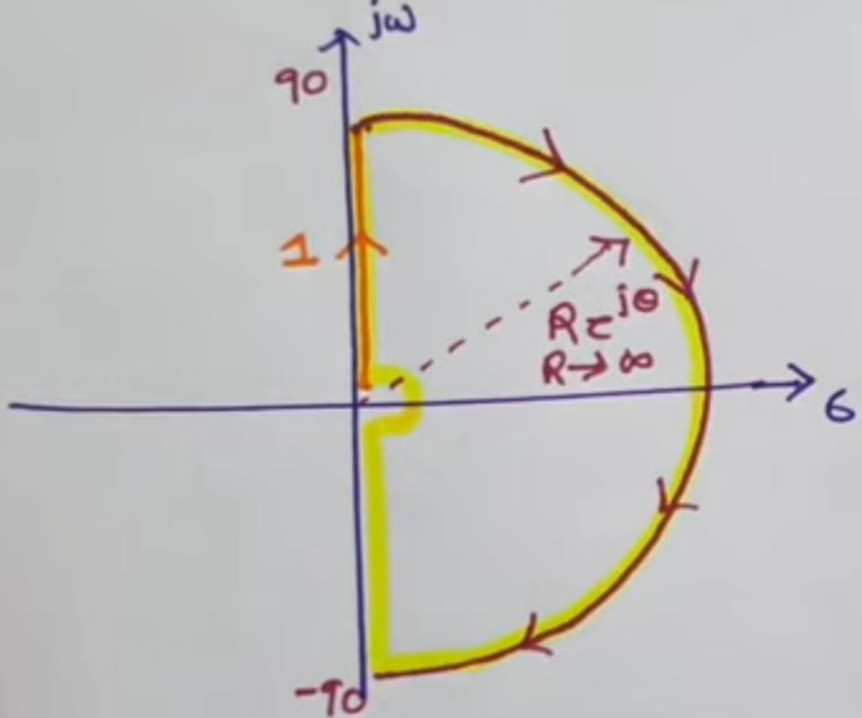
$\boxed{N = -2}$

$\rightarrow -2 = 0 - Z$

$\Rightarrow \boxed{Z = 2}$

- So, there are two poles of close loop system on RHP. so, system is unstable.

Draw a Nyquist plot for $G(s) = \dfrac{1}{s^2(1+s)(1+2s)}$



1) $s = j\omega \longrightarrow$ polar plot

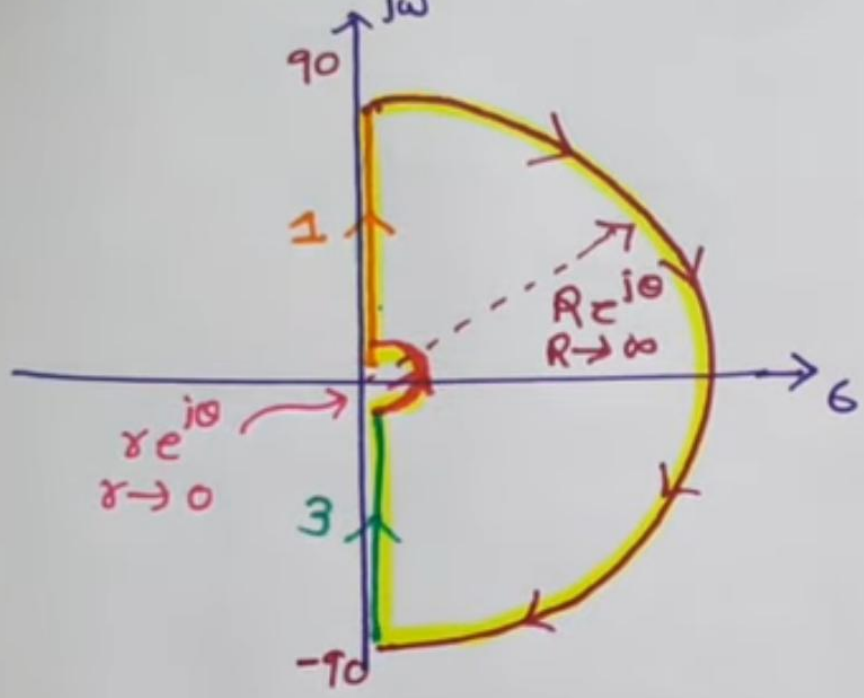
2) $s = \lim_{R\to\infty} Re^{j\theta}$, θ: 90 to -90

$$G(s) = \lim_{R\to\infty} \frac{1}{R^2 e^{2j\theta}(1+Re^{j\theta})(1+2Re^{j\theta})}$$

$$= \lim_{R\to\infty} \frac{1}{2R^4 e^{4j\theta}(1+\frac{1}{Re^{j\theta}})(1+\frac{1}{2Re^{j\theta}})}$$

$$= \lim_{R\to\infty} \frac{1}{2R^4} e^{-4j\theta}$$

$$\overline{\quad s^2(1+s)(1+2s)\quad}$$



1] $s = j\omega \longrightarrow$ polar plot

2] $s = \lim\limits_{R\to\infty} Re^{j\theta}$, θ: 90 to -90

$$G(s) = \lim_{R\to\infty} \frac{1}{R^2 e^{2j\theta}(1+Re^{j\theta})(1+2Re^{j\theta})}$$

$$= \lim_{R\to\infty} \frac{1}{2R^4 e^{4j\theta}\left(1+\frac{1}{Re^{j\theta}}\right)\left(1+\frac{1}{2Re^{j\theta}}\right)}$$

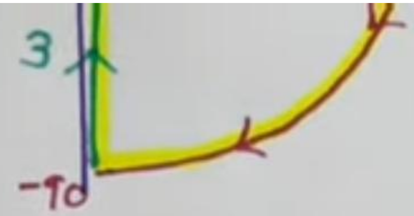
$$= \lim_{R\to\infty} \underbrace{\frac{1}{2R^4}}_{Mag = 0} \; \underbrace{e^{-4j\theta}}_{\text{phase: } -360 \text{ to } 360}$$

(Two circle ACW)

3) $s = -j\omega \longrightarrow$ Inverse polar plot

4] $s = \lim\limits_{r\to 0} re^{j\theta}$, θ: -90 to 90

$\underset{r \to 0}{}$



3) $s = -j\omega \longrightarrow$ Inverse polar plot

4) $s = \lim\limits_{r \to 0} r e^{j\theta}$, $\theta : -90$ to 90

$$G(s) = \lim_{r \to 0} \frac{1}{r^2 e^{2j\theta}(1 + r e^{j\theta})(1 + 2 r e^{j\theta})}$$

$$= \lim_{r \to 0} \underbrace{\frac{1}{r^2}}_{\text{mag} - \infty} \; \underbrace{e^{-2j\theta}}_{\text{phase} \to 180 \text{ to } -180}$$

(One circle CW)

$$= \lim_{R \to \infty} \frac{1}{2R^4 e^{4j\theta}(1 + \frac{1}{R}e^{-j\theta})(1 + \frac{1}{2R}e^{-j\theta})}$$

$$= \lim_{R \to \infty} \underbrace{\frac{1}{2R^4}}_{\text{Mag} = 0} \; \underbrace{e^{-4j\theta}}_{\text{phase} : -360 \text{ to } 360}$$

(Two circle ACW)

(One Circle cw)

→ Polar plot , $s = j\omega$.

$\cancel{G(j\omega) = \frac{1}{(j\omega)^2 \sqrt{\ldots}}}$

$$G(j\omega) = \frac{1}{(j\omega)^2 (1+j\omega)(1+2j\omega)}$$

Step 2 - write polar plot in standard form

- $G(j\omega) = |G(j\omega)| \angle G(j\omega)$
- $|G(j\omega)| = \dfrac{1}{\omega^2 \sqrt{1+\omega^2}\sqrt{1+4\omega^2}}$
- $\angle G(j\omega) = -180 - \tan^{-1}\omega - \tan^{-1} 2\omega$

$$G(j\omega) = \frac{1}{(j\omega)^2(1+j\omega)(1+2j\omega)}$$

Step 2 - write polar plot in standard form

- $G(j\omega) = |G(j\omega)| \angle G(j\omega)$
- $|G(j\omega)| = \dfrac{1}{\omega^2\sqrt{1+\omega^2}\sqrt{1+4\omega^2}}$
- $\angle G(j\omega) = -180 - \tan^{-1}\omega - \tan^{-1}2\omega$

Step 3 Find $\omega = 0$, $\omega = \infty$.

at $\omega = 0$, $|G(j\omega)| = \infty$, $\angle G(j\omega) = -180$

at $\omega = \infty$, $|G(j\omega)| = 0$, $\angle G(j\omega) = -360$

Step-4 - Saperate real and Imag. Parts.

$$G(j\omega) = \frac{1}{(j\omega)^2(1+j\omega)(1+2j\omega)} \times \frac{(1-j\omega)(1-2j\omega)}{(1-j\omega)(1-2j\omega)}$$

$$= \frac{-1\times(1-2\omega^2-3j\omega)}{\omega^2(1+\omega^2)(1+4\omega^2)}$$

$$= \frac{(2\omega^2-1)}{\omega^2(1+\omega^2)(1+4\omega^2)} + \frac{j\,3\omega}{\omega^2(1+\omega^2)(1+4\omega^2)}$$

$$= \frac{(2\omega^2-1)}{\omega^2(1+\omega^2)(1+4\omega^2)} + \frac{j3}{\omega(1+\omega^2)(1+4\omega^2)}$$

Step-5 - For Intersection to real axis, $\text{Imag}(G(j\omega)) = 0$

Step-6

$$(j\omega)^2 (1+j\omega)(1+2j\omega) \qquad (1-j\omega)(1-2j\omega)$$

$$= \frac{-1 \times (1-2\omega^2 - 3j\omega)}{\omega^2(1+\omega^2)(1+4\omega^2)}$$

$$= \frac{(2\omega^2-1)}{\omega^2(1+\omega^2)(1+4\omega^2)} + \frac{j\,3\omega}{\omega^2(1+\omega^2)(1+4\omega^2)}$$

$$= \frac{(2\omega^2-1)}{\omega^2(1+\omega^2)(1+4\omega^2)} + \frac{j3}{\omega(1+\omega^2)(1+4\omega^2)}$$

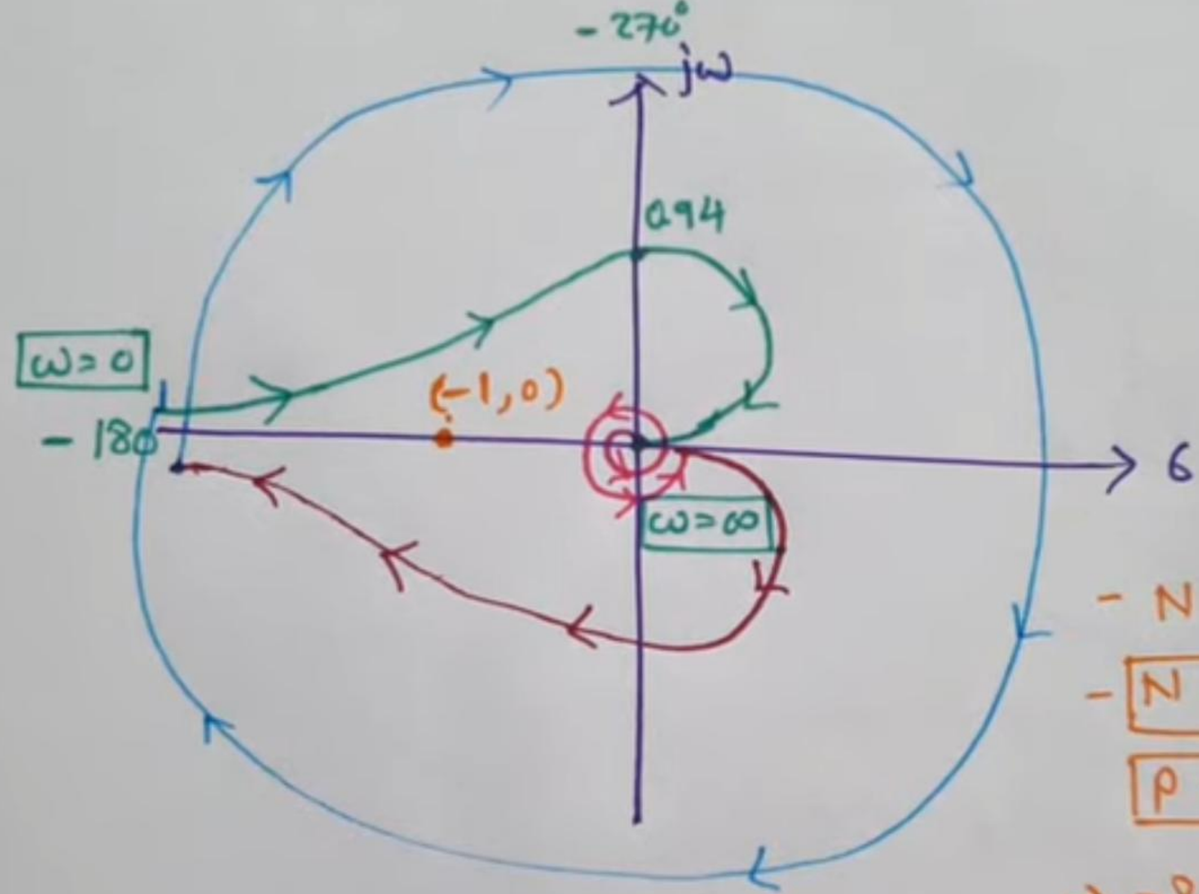
<u>Steps</u> - For Intersection to real axis, Imag $(G(j\omega)) = 0$

<u>Steps</u> - For Intersection to imag axis, Real $(K(j\omega)) = 0$

$\Rightarrow 2\omega^2 - 1 = 0$

$\Rightarrow \omega = 1/\sqrt{2}$, mag $= 0.94$, $\phi = -270^\circ$

$\Rightarrow \omega = \sqrt{2}$, mag = 0.94 , $\phi = -270^\circ$



$-N = P - Z$

$-\boxed{N = -2}$

$\boxed{P = 0}$

$\Rightarrow -2 = 0 - Z$

$\Rightarrow Z = 2$