Control Systems

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Contents

1	**PID Controller**	**1**
1.1	Introduction	1
2	**Polar Plot**	**1**
2.1	Introduction	1
2.2	Example	1
2.3	Example	2
2.4	Example	2

***Abstract*—The objective of this manual is to introduce control system design at an elementary level.**

Download python codes using

```
svn co https://github.com/gadepall/school/trunk/
    control/ketan/codes
```

1 PID Controller

1.1 Introduction

2 Polar Plot

2.1 Introduction

2.1.1. Sketch the Polar Plot of

$$G(s) = \frac{\left(1 + \frac{s}{29}\right)(1 + 0.0025s)}{(s^3)(1 + 0.005s)(1 + 0.001s)} \tag{2.1.1.1}$$

Solution: The following code generates the polar plot in Fig. 2.1.1

```
codes/ee18btech11029.py
```

- The polar plots use open loop transfer function to determine the stability and hence reference point is shifted to $(-1, 0)$
- If $(-1, 0)$ is left of the polar plot or $(-1, 0)$ is not enclosed, then it is stable

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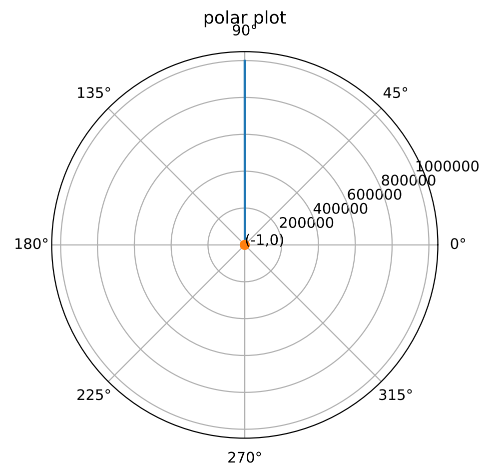

Fig. 2.1.1

- If $(-1, 0)$ is on right side of the polar plot or $(-1, 0)$ is enclosed by polar plot then it is unstable.
- If $(-1, 0)$ is on the polar plot then it is marginally stable

In Fig. 2.1.1, $(-1, 0)$ is on the polar plot so the system is marginally stable.

2.2 Example

2.2.1. Sketch the Polar Plot of

$$G(s) = \frac{1}{s(1 + s^2)} \tag{2.2.1.1}$$

Solution: From (2.2.1.1),

$$G(\jmath\omega) = \frac{1}{\jmath\omega(1 - \omega^2)} \tag{2.2.1.2}$$

$$\left|G(\jmath\omega)\right| = \frac{1}{\left|\omega(1 - \omega^2)\right|} \tag{2.2.1.3}$$

$$\angle G(\jmath\omega) = \begin{cases} \frac{\pi}{2} & \omega > 1 \\ -\frac{\pi}{2} & 0 < \omega < 1 \end{cases} \tag{2.2.1.4}$$

The corresponding polar plot is generated in Fig. 2.2.1 using codes/ee18btech11023.py

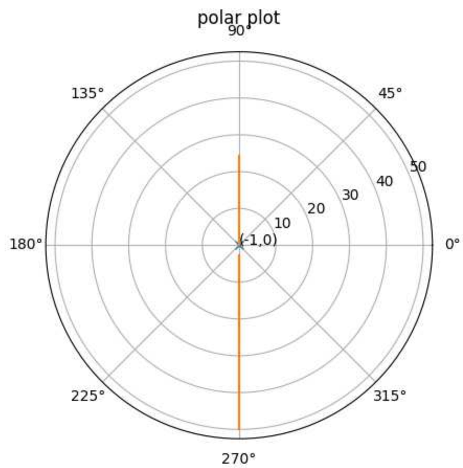

Fig. 2.2.1

In Fig. 2.2.1, (–1,0) is exactly on the polar plot. Hence, the system is marginally stable.

2.3 Example

2.3.1. Sketch the Polar Plot for

$$G(s) = \frac{1}{(1+s)(1+2s)} \tag{2.3.1.1}$$

Solution: The following code generates Fig. 2.3.1

codes/ee18btech11012.py

The polar plot is to the right of $(-1, 0)$. Hence the closed loop system is stable.

2.4 Example

2.1. Sketch the direct polar plot for a unity feedback system with open loop transfer function

$$G(s) = \frac{1}{s(1+s)^2} \tag{2.1.1}$$

Solution: The polar plot is obtained by plotting (r, ϕ)

$$r = |H(\jmath\omega)||G(\jmath\omega)| \tag{2.1.2}$$

$$\phi = \angle H(\jmath\omega)G(\jmath\omega), 0 < \omega < \infty \tag{2.1.3}$$

The following code plots the polar plot in Fig. 2.1

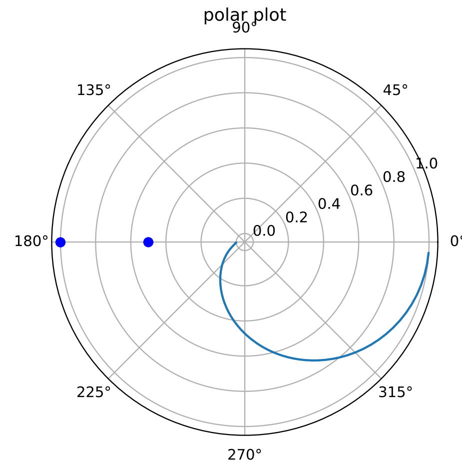

Fig. 2.3.1

codes/ee18btech11002/polarplot.py

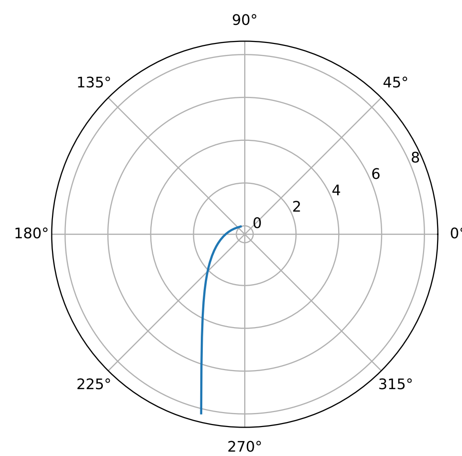

Fig. 2.1: Polar Plot

2.2. Sketch the inverse polar plot for (2.1.1)
Solution: The above code plots the polar plot in Fig. 2.2 by plotting $\left(\frac{1}{r}r, -\phi\right)$

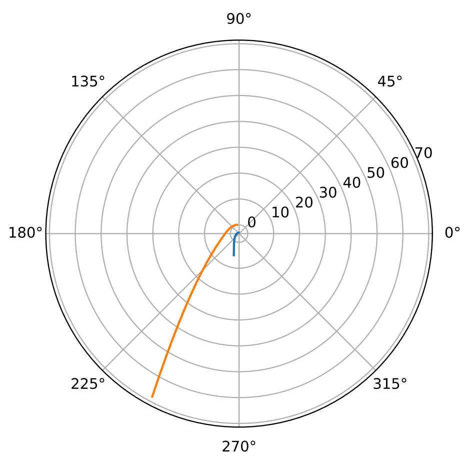

Fig. 2.2: Inverse Polar Plot