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UNIT-5 (Lecture-4)

Nyquist Stability Criterion

The Nyquist Stability Criterion

The Nyquist plot allows us also to predict the stability and performance of a closed-loop system by observing its open-loop behavior. The Nyquist criterion can be used for design purposes regardless of open-loop stability (Bode design methods assume that the system is stable in open loop). Therefore, we use this criterion to determine closed-loop stability when the Bode plots display confusing information.

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The Nyquist diagram is basically a plot of G(j* w) where G(s) is the open-loop transfer function and w is a vector of frequencies which encloses the entire right-half plane. In drawing the Nyquist diagram, both positive and negative frequencies (from zero to infinity) are taken into account. In the illustration below we represent positive frequencies in red and negative frequencies in green. The frequency vector used in plotting the Nyquist diagram usually looks like this (if you can imagine the plot stretching out to infinity):

However, if we have open-loop poles or zeros on the jw axis, G(s) will not be defined at those points, and we must loop around them when we are plotting the contour. Such a contour would look as follows:





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The Cauchy criterion

The Cauchy criterion (from complex analysis) states that when taking a closed contour in the complex plane, and mapping it through a complex function G(s), the number of times that the plot of G(s) encircles the origin is equal to the number of zeros of G(s) enclosed by the frequency contour minus the number of poles of G(s) enclosed by the frequency contour. Encirclements of the origin are counted as positive if they are in the same direction as the original closed contour or negative if they are in the opposite direction.

CONTROL SYSTEM-IThe Cauchy criterionEIC-501When studying feedback controls, we are not as
interested in G(s) as in the closed-loop transfer function:
G(s)

1 + G(s)

If 1+ G(s) encircles the origin, then G(s) will enclose the point -1.

Since we are interested in the closed-loop stability, we want to know if there are any closed-loop poles (zeros of 1 + G(s)) in the right-half plane.

Therefore, the behavior of the Nyquist diagram around the -1 point in the real axis is very important; however, the axis on the standard nyquist diagram might make it hard to see what's happening around this point 5

CONTROL SYSTEM-I Gain and Phase Margin

Gain Margin is defined as the change in open-loop gain expressed in decibels (dB), required at 180 degrees of phase shift to make the system unstable. First of all, let's say that we have a system that is stable if there are no Nyquist encirclements of -1, such as : 50

s^3 + 9 s^2 + 30 s + 40

Looking at the roots, we find that we have no open loop poles in the right half plane and therefore no closed-loop poles in the right half plane if there are no Nyquist encirclements of -1. Now, how much can we vary t he gain before this system becomes unstable in closed loop?

The open-loop system represented by this plot will become unstable in closed loop if the gain is increased past a certain boundary.



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The Nyquist Stability Criterion

The Nyquist diagram can be viewed by typing: nyquist (50, [1 9 30 40])



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Gain and Phase Margin

Phase margin as the change in open-loop phase shift required at unity gain to make a closed-loop system unstable.

From our previous example we know that this particular system will be unstable in closed loop if the Nyquist diagram encircles the -1 point. However, we must also realize that if the diagram is shifted by theta degrees, it will then touch the -1 point at the negative real axis, making the system marginally stable in closed loop. Therefore, the angle required to make this system marginally stable in closed loop is called the phase margin (measured in degrees). In order to find the point we measure this angle from, we draw a circle with radius of 1, find the point in the Nyquist diagram with a magnitude of 1 (gain of zero dB), and measure the phase shift needed for this point to be at an angle of 180 deg.



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