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DYNAMIC RESPONSE OF TRANSFER FUNCTION ON MATLAB PLATFORM

OBJECTIVE

To analyze and compare the dynamic response a second order OLTF with a PD controller in two different configurations i.e. in cascade and feedback.

TRANSFER FUNCTION AND ITS RESPONSE IN OLTF TO A UNIT STEP

The OLTF of the second order system is given by

$$G(s) = \frac{k}{s^2 + 2s + 20}$$

and the PD controller is given by:

$$C(s) = 80(s+5)$$

In either configuration of the controller, the Closed Root loci are identical. The difference would be in the zeros of the resulting system which would subsequently affect the step response as well.

$$Hcascade(s) = \frac{80k(s+5)}{s^2 + (80k+2)s + (400k+20)}$$

And,

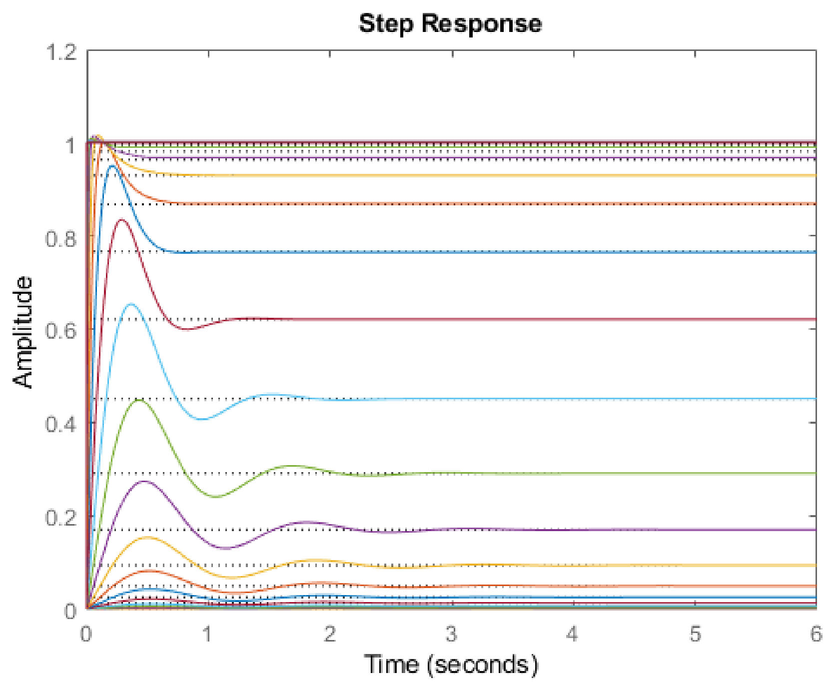
$$Hfeedback(s) = \frac{k}{s^2 + (80k+2)s + 400k + 20}$$

In general, addition of a **zero on LHP** increases the overshoot, decrease the peak time, and decrease the rise time; the settling time is not **affected** too much. In other words, a LHP **zero** makes the **step response** faster.

Response of the System to Step Input

As the gain is varied, the dynamic response of both the systems is measured.

Configuration: Cascaded Controller



In this configuration, the presence of zero typically speeds up the response of the system. Apart from that as k becomes larger and larger, the response of becomes closely similar to the input and theoretically approaches to step function as k tends infinity.

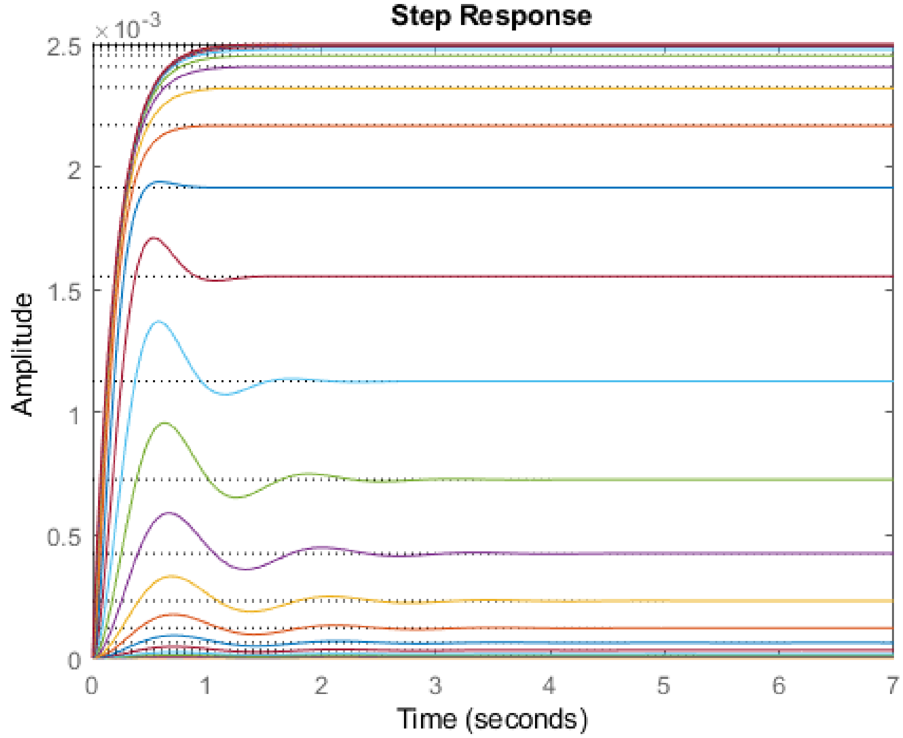
$$\lim_{k\to\infty} Hcascade(s) = 1$$

Which can be clearly seen from the time response. Apart from that the oscillatory behavior reduces on increasing k which must be because of the imaginary part of the poles of the closed loop slowly being pushed down to zero. And thus, one pole goes to zero and other goes to infinity.

Configuration: Feedback Controller

In this configuration, with increase in k oscillations diminish altogether similar to the cascaded controller (since both would have same root loci). And it can be interfered from the response that as k tends to really large values response becomes similar to a first order system which would mathematically be written as:

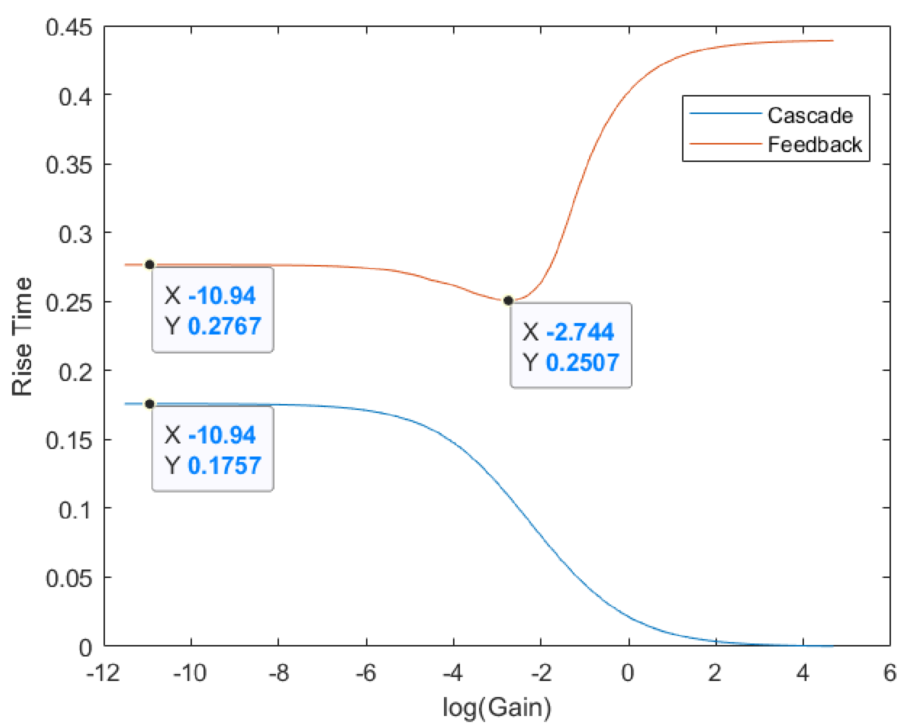
$$\lim_{k\to\infty} Hcascade(s) = \frac{1}{80(s+5)}$$



Similar to the last configuration, pole reaches the -5 however size there is no zero this time, pole-zero cancellation in transfer doesn't take place.

PERFORMANCE COMPARISON OF THE TWO CONFIGURATIONS

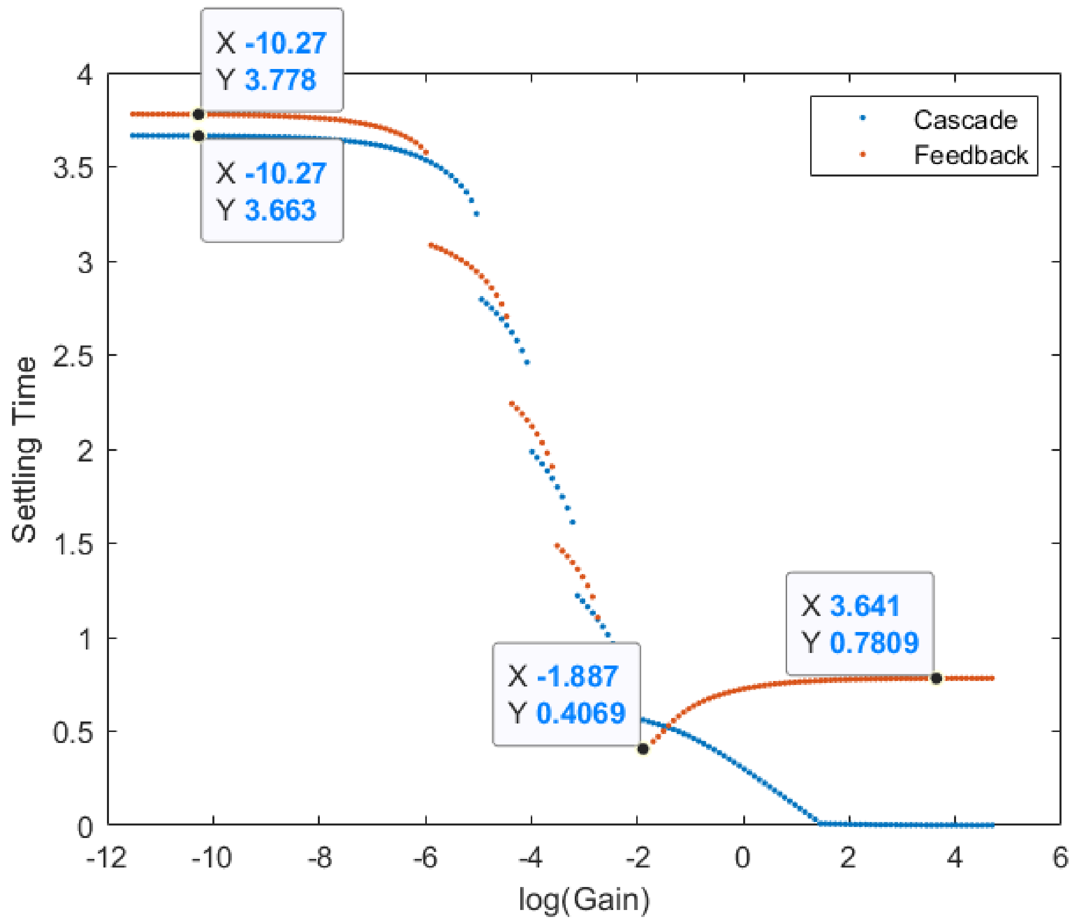
RISE TIME



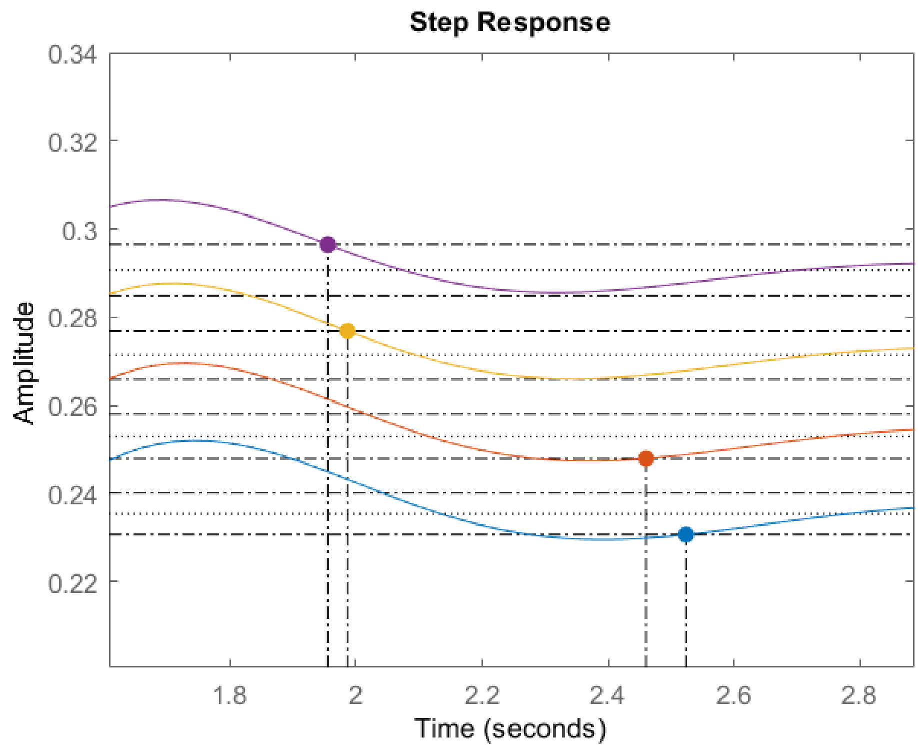
As could be inferred from the graph above, for the cascaded system with increase in Gain the Rise Time decreases i.e. the system responsiveness increases whereas for the feedback configuration there is an optimal value of k for minimum rise time is minimum. With further increase in k rise time only increases thus making the system slower.

Settling Time

Settling time basically corresponds to how quickly the system reaches the steady state value. Although both the configurations' settling time decreases but for feedback system eventually settles down to a constant value (corresponding to the first order systems' settling time for really high values of k) greater than cascaded one which has really small settling time (corresponding to response as unit step for large k values)

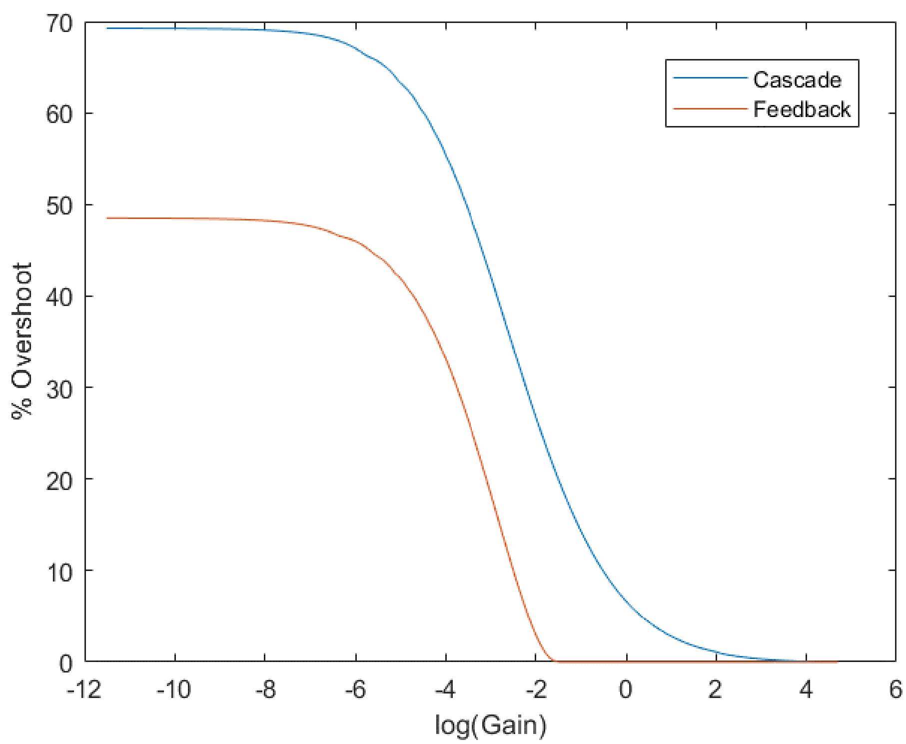


One technical thing to note here is the discontinuity which is observed in settling time of both configurations. This is because of the way settling time is defined. It's basically a hard-mathematical limit to the value of output. This would vary greatly if your output is an oscillatory one and therefore the Settling time depends greatly on frequency, phase and the envelope too (signifying the exponential decay) of the oscillations as well. It will get more clearer from the graph shown below:



Overshoot

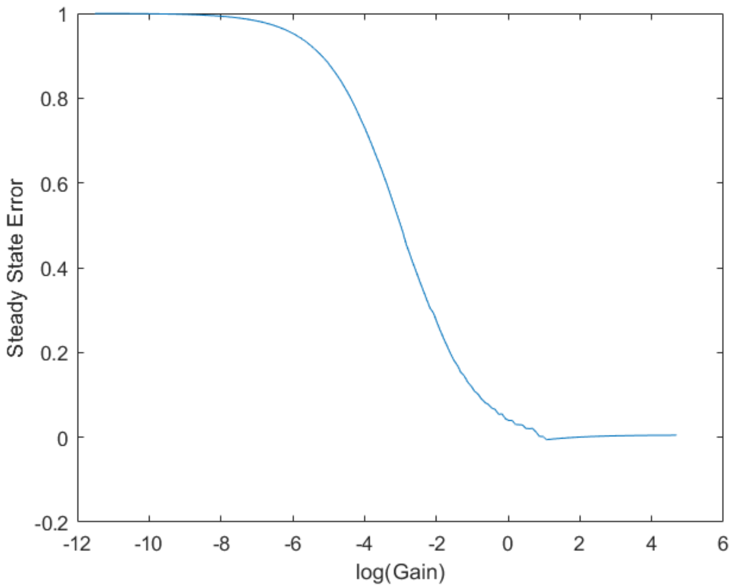
Overshoot typically decreases for both the systems because of the decreases in the imaginary part of the poles as explained earlier. Characteristics observed are shown below:



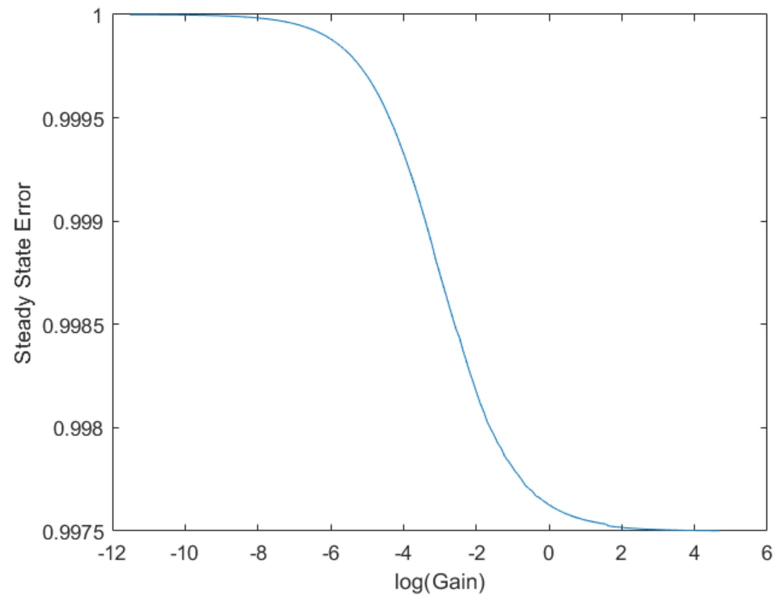
It is required to make a point that the feedback system overshoot is always less than the other.

STEADY STATE ERROR

Steady State is a really important parameter while considering the dynamic response. Usually errors accumulate in the system during the transient phase which are reflected once the steady state is achieved.



Cascade Configuration



Feedback Configuration

As could be seen above, with the increase of Gain in cascade configuration, the error is eventually eliminated. However, the same is not true for feedback controller configuration. It never reaches the step input.

CONCLUSION

For the given controller and system, the cascade configuration turns out to be better in most of the aspects. It has lesser rise time, decreasing steady state error wrt gain as well as settling time is comparable to feedback controller. At higher gains cascade configuration outperforms in settling time as well by taking almost negligible settling time whereas feedback settling time saturates to ~0.78. Although the overshoot is comparably higher but that too is less than 10% for gains greater than unity.

Thus it is advisable to use cascade configuration for control.