Control Engineering
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Lecture - 28
The Performance of Feedback Systems (Contd…)

We first summarize our previous discussion on the various transient response and steady-state response measures with respect to a standard second-order system. You will recall the standard second-order system had this model (Refer Slide Time: 1:18) this is the open-loop or the forward path part, output is y let me say, the error is e and here is the reference r and the closed-loop Y(s) by R(s) is equal to omega n squared over s squared plus 2 zeta omega ns plus omega n square. This is your standard second-order system.

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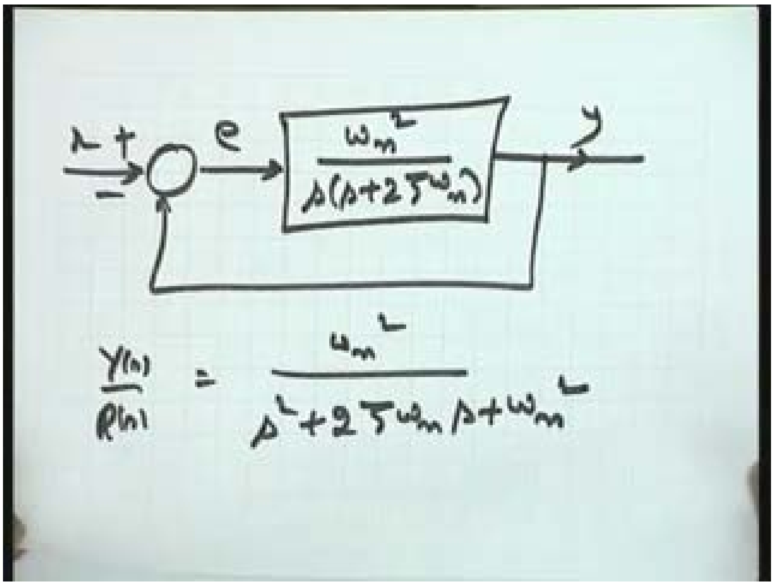

As far as the transient behavior is concerned, we found that it is given by the response to a step input and various measures were defined as follows: t r equal to pi minus cos inverse zeta over omega d; recall that your omega d is equal to omega n 1 minus zeta squared under the root where omega d is the damped frequency and omega n is the natural frequency of the system. In addition to t r we used we measured t p which we defined as pi over omega d. M p the peak overshoot is e to the power of minus pi zeta over 1 minus zeta under this root and t s is equal to 4 by zeta omega n these are the measures of transient performance which we had taken. And if you recall the steady-state performance to a step input gave you a zero steady-state error for the standard second-order system. However, for a unit ramp input the value of steady-state error obtained was 2 zeta by omega n.

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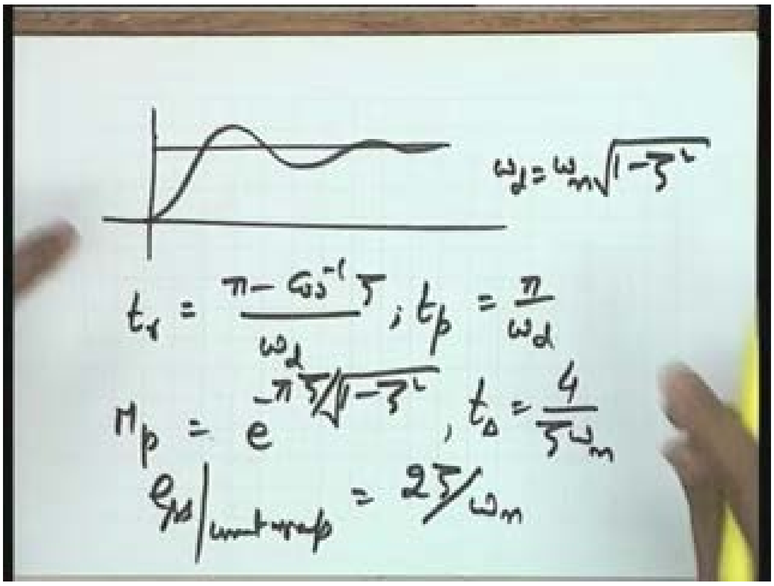

So please see that the question arises how do we specify these performance measures, how do they come across, how do they represent the total behavior of a system. You will recall, I made a statement that omega n normally you will like to be very high because as you can see from here (Refer Slide Time: 3:21) a high omega n leads to better speed of response because it appears in the denominator here. A high omega n means a lower t p because it is here and hence lower t p means the rise time the system rise will be faster. A high omega n helps you here as well as here. So it means a high omega n is the requirement if you want to improve both the steady-state accuracy and the transient response of the system. However, as I told you that this omega n is limited by bandwidth considerations or the considerations of implementation of your control scheme.

See this point, because you may require high omega n and that high omega n you may be able to achieve with a very high value of parameter in a system let us say an amplifier gain. If high omega n requires a very large amplifier gain then the implementation of that particular gain will lead you to saturation problems and hence the value of that omega n cannot be achieved.
so what I want to say is this that probably the omega n rise is possible by suitable design of the hardware, suitable design of amplifiers, suitable design of filters so that all those problems which prohibit the use of high omega and could be taken care of at that stage.

Two primary considerations for limitations of omega n are the noise considerations and the implementation of design taking high omega n that may create certain problems. This is one consideration. Once omega n is decided the other parameters which cuts across all through you see is zeta as far as standard system is concerned. The personality of a standard system is described by two parameters only: zeta and omega n. so having talked of omega n let us see how do you regulate zeta. Please see that look at this. Help me please what will happen if zeta is reduced.

From this expression it may not be that visible but you will be able to recall the overall normalized curves we have obtained. This is (Refer Slide Time: 5:43) let us say a typical curve for zeta equal to 0.5 then a curve for zeta equal to 0.3 will look like this, a curve for zeta equal to 1 will look like this and so on. So you can just see, if you have decided on omega n based on the considerations we have already discussed then the value of zeta is guided by the following factors: 1) lower the zeta better is the rise time. Though I mentioned to you that over the range of zeta we normally take the change in rise time is not very appreciable but still this is one of the considerations that lower the value of zeta quicker is the response reaching to 100 percent value and hence better is the speed of response for lower zeta. Similar is the conclusion for t p, well t p also for zeta lower will become lower. You can see that this is the value of t p here (Refer Slide Time: 6:41) this becomes the value of t p here so again better is the speed of response.

Look at the steady-state error, the steady-state error also helps; this condition is also favorable because lower value of zeta gives you lower steady-state error to ramp input and the question now appears on M p and t s.

What are your conclusions on M p and t s please?
On M p it is very clearly visible that lower the value of zeta more closer you are to instability because with lower value of zeta the peak overshoot is increasing and the peak overshoot is guided by the hardware considerations also you see; your system may not be able to withstand this much of signal in that particular case you limit the peak overshoot or you limit the peak overshoot by stability considerations also so that because of any parameter variations a system with large peak overshoot may not become unstable. This is one point which limits the use of zeta.

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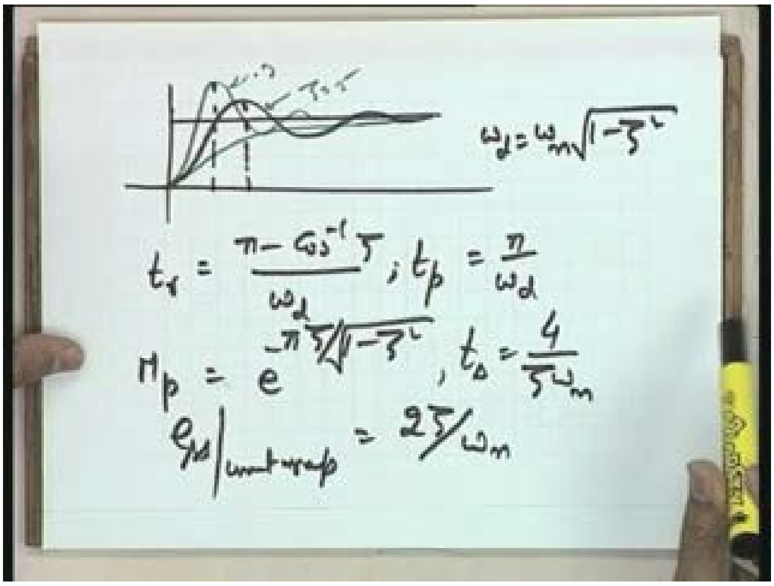

What is the other point? Please see, the other point is the settling time.
You will recall the settling time curve, it was not that simple, it was not a linear curve or a simple nonlinear curve, it was a complicated curve omega n ts. Once omega n is fixed up omega n ts is on this axis and here I take zeta on this axis. You will just remember that this is the fall of the omega n ts value as zeta is decreased then from this point there was a sudden jump an increase a jump an increase a jump and so on. This let me not repeat it you see, this I explained to you that this is the behavior the system has and this particular value is zeta is 0.68 if you take a 5 percent tolerance. For 5 percent tolerance minimum value of zeta is 0.68 and if you take 2 percent tolerance this value of zeta which gives you not the minimum value

of zeta the value of zeta which gives you minimum normalized settling time is 0.68, for 2 percent tolerance zeta is equal to 0.8.

Please, let me point out an error here. In one of my lectures this minimum value of zeta (Refer Slide Time: 9:10) I reported 0.76 that value is as reported in the literature. Please see I have done my own calculations and found that the minimum value of zeta really turns out to be 0.8. You can also do in your calculations and verify this fact. So we will be using this minimum value of zeta zeta equal to 0.8 for a 2 percent tolerance band. Now just see, when zeta decreases you see your settling time is point………. So it means up to this particular point if you have reached the settling time is minimum.

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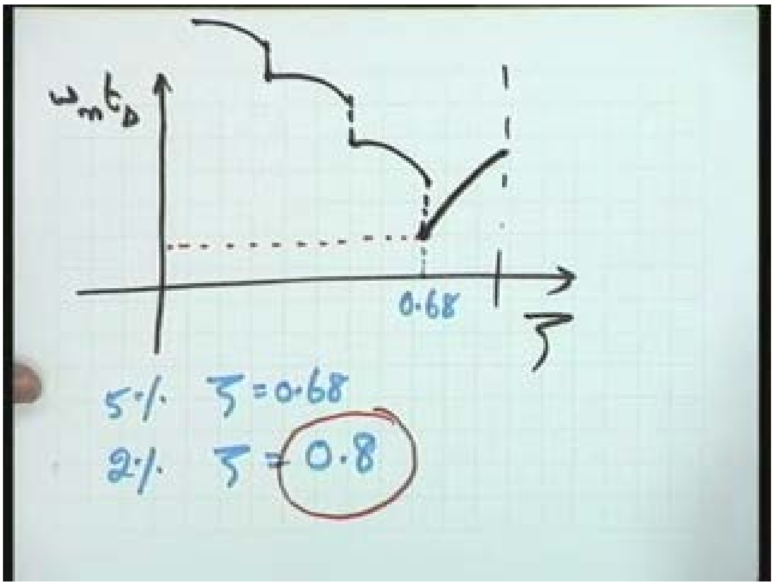

Now you may have a response for example. You cannot say that it is a good response. Let us say this is a response, rise time is very fast and take another response in this particular response you see though the rise time in the green curve is larger but still you may like to go for it because of the merit that its settling time is small. This is the settling time in this particular case. It has settled in this curve while as far as the red curve is concerned you find that this is the settling time because settling time is the time after which the curve does not come out of the band. So you see that raise time is not the only indication of speed of a system, after all you will very much like that the system should settle down as quickly as possible to the desired level. So in this particular case though the rise time is good but the setting time is more than the green curve while in this particular case (Refer Slide Time: 10:47) the rise time is poor but the settling time is small and hence you see that the conflict between rise time and settling time is to be resolved depending upon the application.

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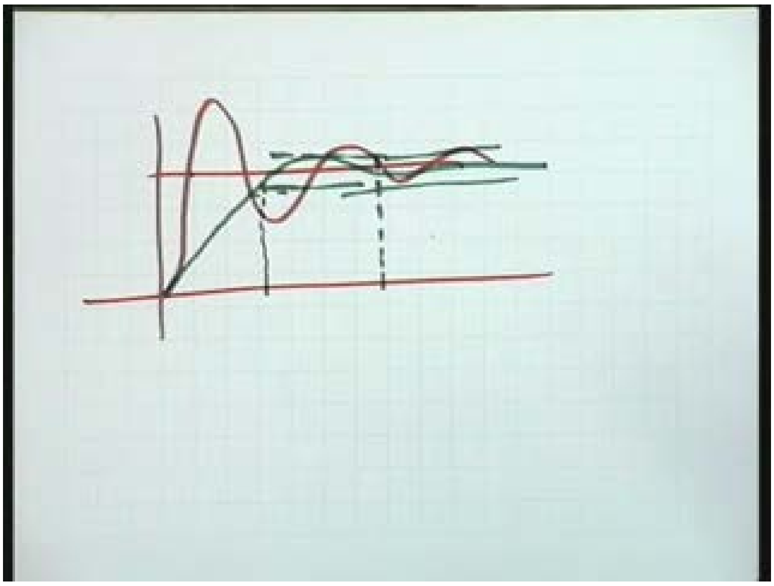

So it depends upon the application you do not want a sluggish initial response in that case you will like to opt for the red curve and if you want the system to settle down quickly, well, the green curve is the optimum choice. So what I want to say is that between the rise time and settling time there may be some sort of decision process involved as is in this particular curve and that depends upon the specific application under consideration.

Coming back to this at least this is obvious that zeta between 0 and 0.68 should be preferred or preferably why this range, preferably zeta 0.68 or around this region is alright provided other parameters suffice. Now, if you have to go for lower setting time go to this side (Refer Slide Time: 11:45) but at least going to this side does not serve any purpose because if you go to this side, please see from 0.68 to 1 or from 0.8 to one you are sacrificing both the settling time and the rise time the system is definitely becoming sluggish, you are neither improving settling time nor the rise time if you go in the range between 0.68 to 1. But if you go in this particular range you are gaining on rise time, you are gaining on steady-state accuracy but there is a slight there is an increase in settling time and there is an increase in peak overshoot and therefore a suitable compromise has to be seen to resolve the conflict and the requirement of the specific application will come to help us you see we cannot resolve it without that specific requirements of hardware, specific user requirements will have to be taken into account to see which particular parameter or which particular specification is more important but this is obvious that between 0 to 0.68 the value should be taken and this value should be avoided from 0.68 to this side to zeta equal to one for a 5 percent tolerance from 0.8 to 1 for a 2 percent tolerance so that the system does not become sluggish.

Now I can just conclude this particular point that what happens in industry, what are the applications, how do they resolve these issues. The applications, general applications I will say normally take zeta between 0.4 and 0.7 where the user has not given you very specific quantitative information, he says I want a good system that is all, if he says I want a reasonably good system and he does not specify the goodness quantitatively in that particular case the designer in his wisdom will like to settle for a peak over for a zeta between 0.4 and 0.7 somewhere because it really meets the specifications of all the types and gives you a very good compromise, this is what is the general observation.

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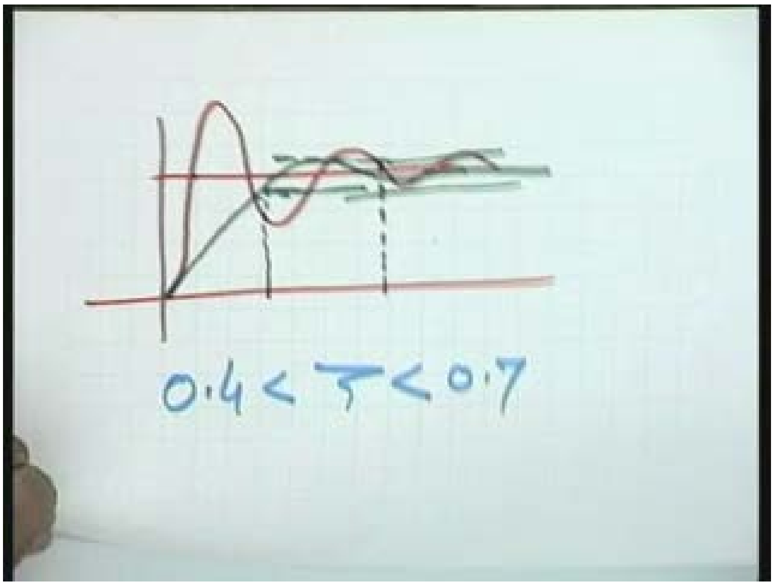

But if the user says, look, whatever you may do I want a very highly accurate system that is the static accuracy is the specific demand of the user. Can you help me, now come on please help me? Initially I told you, if my point has been well taken, please see I say that if it is a general requirement if the user has not given you any specific quantitative requirement maybe 0.4 to 0.7 meets your requirement on the peak overshoot, on the rise time, on the settling time and other factors. So settle down for some value between this range.

Now there is a user who gives you a design problem and says look, the static accuracy is the prime requirement whatever you may do, can you help me what value of zeta and omega n is in your mind for this type of application that static accuracy is the prime requirement…… [Conversation between Student and Professor – Not audible ((00:15:01 min))] Yes, you will recall for a standard system, we are talking about standard system, what will happen to the other systems we will see later. e ss is equal to 2 zeta by omega n. First of all you will take care of the hardware design appropriately so that omega n can be enlarged to meet his requirement.

And secondly, you will take a small value of zeta for some very typical application the value of zeta as low as 0.1 may also be acceptable what will happen, your system will oscillate but let it oscillate before it settles when the user says I do not mind that you should also not mind. So zeta is equal to 0.1 I know that the transient performance will not be good but he says I do not mind that and he says that static accuracy is the prime requirement in that particular case. Let the system oscillate, the only thing is that you will have to be very careful that the parameters of your system do not wander because if such a high oscillation is there then there is a risk of system becoming unstable also and the user naturally does not require that. So you see the robustness of the system very carefully. If the robustness requirements are satisfied go for zeta as low as 0.1 so that good static accuracy requirement can be given to the user. These are the specific applications I said.

There are some applications, for example, a robot is carrying a nut you see and it has to put at the proper place and in between there are certain obstacles and you really do not want the robot to oscillate. The gripper of the robot the load it is carrying that should not oscillate

because it can hit the other points on its path, there is a certain trajectory path. In an industry environment you cannot give a clear trajectory path to the robot and you therefore want that the robot gripper should not oscillate and you can probably afford a little more time for the robot to reach its point in that particular case please tell me what is your design requirement?
You can afford more time but you cannot let the robot oscillate, let the rise time also maybe more does not matter, amplitude should be small and therefore you will like to settle for zeta equal to 1 is a good compromise.

If you make zeta greater than 1 you see what is the use you see, after all whatever may be the application if zeta equal to 1 you have taken and because of parameter misadjustments there is a little 1 to 2 percent overshoot in the actual system that probably the user will not mind.
So, zeta equal to 1 seems to be a reasonable design because it is a good compromise between the requirement that you do not want an oscillation and the requirement that the settling time should be small. These two requirements if you have to meet probably a good compromise is zeta equal to 1. This is also a very specific application. So I want to conclude my discussion on this point that, well, for specific applications very specific design will come up but otherwise we will be mostly concerned for the values of zeta between 0.4 and 0.7 stretching a little on both the sides, it could go to 0.8, it could go to 0.3 it depends upon the specific requirements these will be my designs.

Omega n I cannot even give you numerical values please because really it depends upon the system hardware, it depends upon the system configuration, the range of omega n cannot be given it can be as low as 1, it can be as high as 1000 so you see that the range cannot be given because it really depends upon the system hardware so that is why the value of zeta I am specifying to you it is between the range to 0.4 and 0.7.

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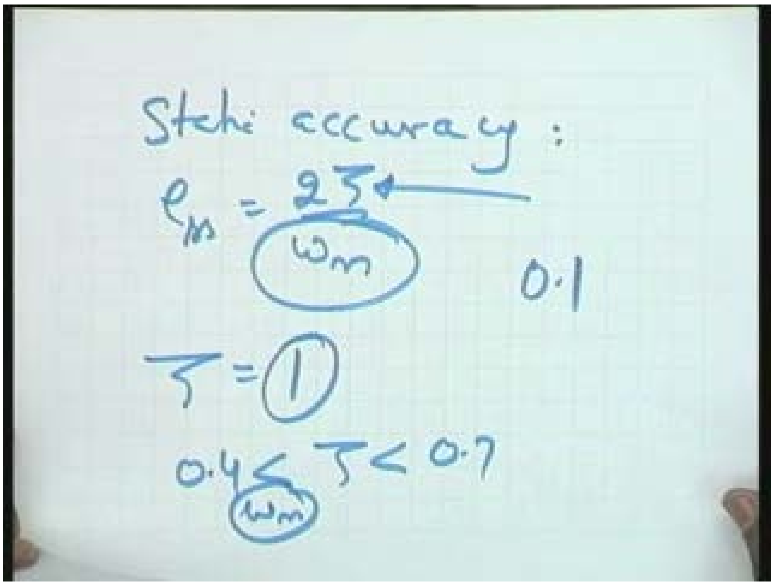

And if I translate my requirements, you see, characteristic equation of the system is s squared plus 2 zeta omega ns plus omega n squared equal to 0 the two roots are s 1, 2 minus zeta omega n plus minus j omega n 1 minus zeta squared under the root. You will recall that these are the points corresponding to the roots. This was the omega n circle, this is your omega n magnitude and this is minus zeta omega n and this is a zeta curve, this is a zeta curve (Refer

Slide Time: 19:33). Can you tell me what should be the region in the s plane for the closed-loop poles for the requirements on the omega n and the zeta value we have specified? Come on help me. first of all there has to be some minimum value of omega n because after all otherwise the rise time may become too large and that minimum value of omega n let me assume is guided by this particular circle of radius omega n 1 a minimum value of omega it is an omega n circle. A maximum value of omega n as dictated by the hardware and noise considerations let me say that this is omega n 2 (Refer Slide Time: 20:18) the numerical values I have not given you.

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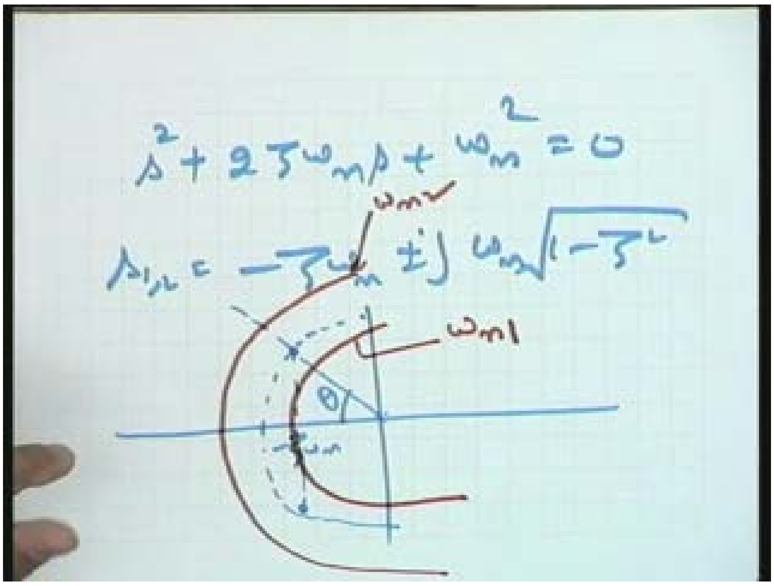

Let us say that the value of zeta I take this, corresponds to zeta equal to 0.4, it means I will take this angle as cos inverse 0.4 I will take this as the value of zeta equal to 0.7 cos inverse 0.7 it means, please see, the complex root has to lie in this particular region and a corresponding point will lie in the lower region. So you use that, I have now given you the regions in the s plane, in a general application the closed-loop poles of the system are supposed to lie in this particular region in the states where there will be two poles only and the two poles preferably should lie in this region. These red curves guided by the considerations of the natural frequency and the green curves guided by the considerations of damping. I hope this is okay please.

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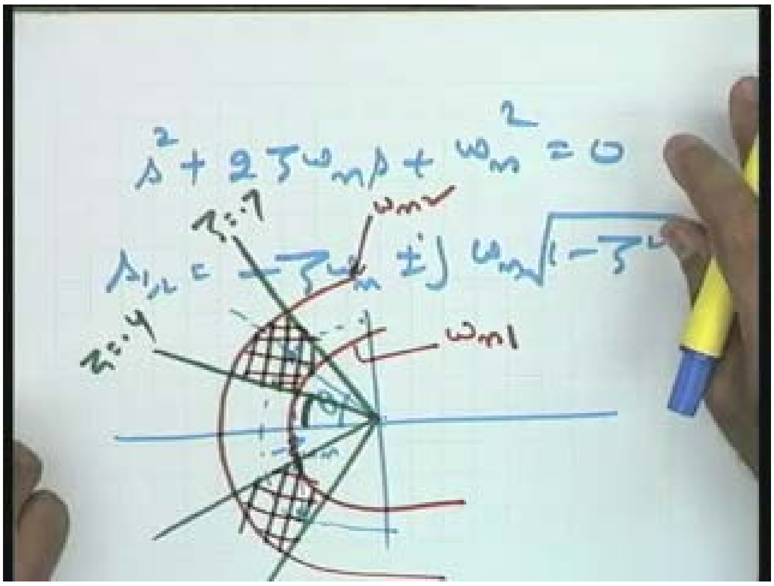

So, so far you see the discussion has been limited to a standard second-order system: Y(s) by R(s) is equal to omega n squared over s squared plus 2 zeta omega ns plus omega n square.
Now please help me when I take up the variations from the standards. After all my actual system may not belong to this category, it may have more than two poles, it may have zeros also so how do I handle those situations is my next point you see. Those situations can be handled this way.

Let me assume that the system has a 0. Can you help me a situation, you already know the situation please I can assure you on the basis of the tutorial problems we have considered. Can you help me with the situation that there will be a 0 here and there will be two poles in the two poles closed-loop poles of the system, this type of situation, have you ever come across this type of situations in the numericals you have handled.

[Conversation between Student and Professor – Not audible ((00:22:29 min))] Yes, please see that intentionally if you are introducing a PD control in the system what will be the closed-loop transfer function of the system? If you apply a PD control on a second-order system your transfer function is going to look like this. So it means, now in this particular case it has got two poles and a 0 and I really do not know how the system will behave when this particular 0 is also available or is either because of the system hardware or you have introduced because of your controller whatever maybe the reasons. But this 0 is now available and hence I want to study the effect of this 0 on the transient response.

Help me, I think you will not mind if I change the gain of the system by a factor 1 by z that is I multiply this by 1 by z, why do I do it? Please see, I am doing it only because of this consideration that the steady-state value of y should be equal to 1 so that my comparison is with respect to 1 that's all, it is after all a gain, I can add any amount of gain in the system through amplifiers. 1 by z is not affecting my dynamics; I am studying the effect on the dynamics. So you can see that if s tends to 0 the value of y will go to 1 which is the steady-state value for a step input, you calculate the value of y for step input which will turn out to be equal to 1 so there is no other consideration other than this that the transient response I want to study with respect to a steady-state value of unity and therefore I have multiplied it by a gain of 1 by z.

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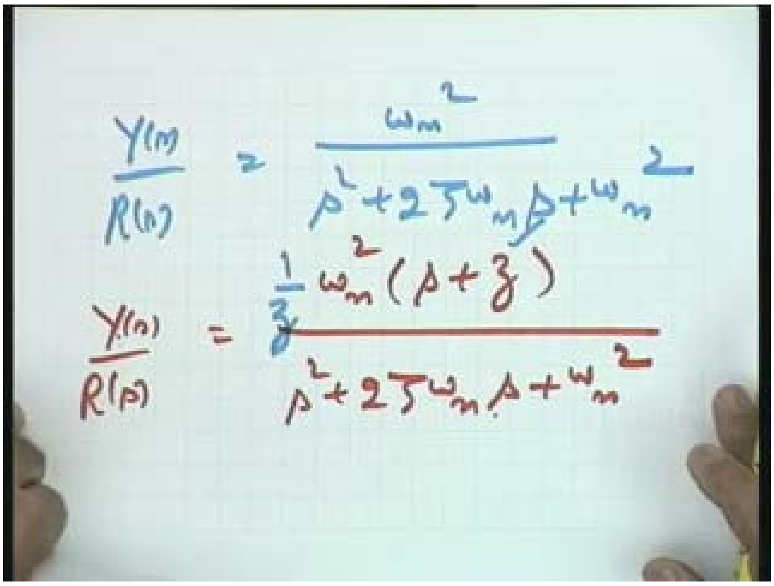

So, if this is the situation then Y(s) by R(s) becomes equal to omega n squared by z (s plus z) divided by s squared plus 2 zeta omega ns plus omega n square. You will not mind if I write this as Y(s) equal to omega n squared over s squared plus 2 zeta omega ns plus omega n squared plus 1 by z s omega n squared over s squared plus 2 zeta omega ns plus omega n squared. Please look at this, hopefully it is right. Look at this equation. R(s) of course on both the sides.

Why did I manage this way, why did I manipulate the equation this way?
I think some of you might have noted this. As far as this component of the response is concerned it is your standard second-order system response. And how about this component, this is a scale factor 1 by z (Refer Slide Time: 25:18) otherwise this component is the derivative of the standard second-order response because there is an s factor is coming normalized by this particular factor, the scale factor of 1 by z is there.

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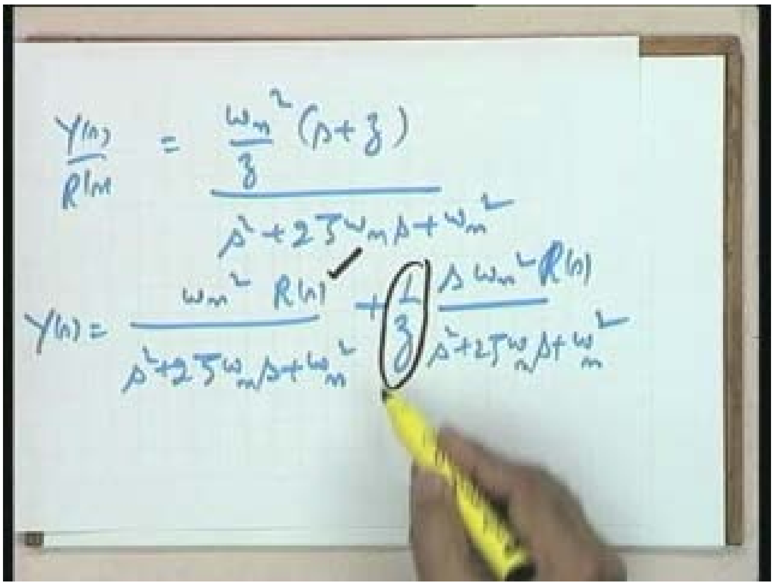

Now, what type of transient response do I expect please?
The transient response I expect is the following: this was your standard second-order system (Refer Slide Time: 25:42) and the transient response because of the derivative component added to it is expected to look like this, just add a derivative component to this, initially the derivative is large because the slope is large then the derivative is small because the slopes are small and hence the effect of the derivative will be very large in the initial portion of the response and not in the later portion because the derivatives are large in the initial portion of the curve. So the curve has been lifted up you see as far as the initial response is concerned because of the presence of 0. However, see the scale factor, 1 by z is the scale factor, look at this, this was the region which you said that mostly your closed-loop poles will lie in this region, this is what we have said, mostly the closed-loop poles lie in this region. So it means as far as the decay of response is concerned the decay of response is guided by zeta omega n because zeta omega n is the real portion of the complex conjugate poles and the response decay is guided by e to the power of minus zeta omega nt.

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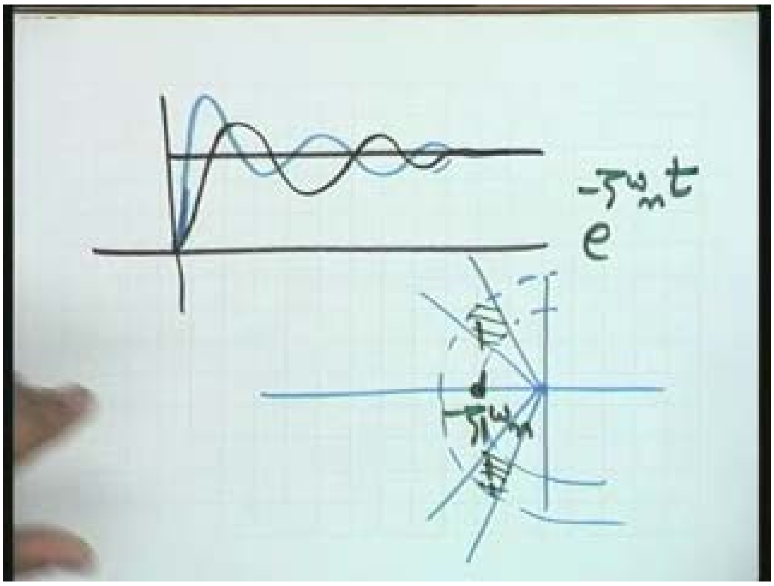

You please note that the decay of the response is guided by e to the power of minus zeta omega nt the other term is a sinusoidal term. So the decay of the response is guided by the real part of these particular poles and now in addition to this there is a 0. So 0 is scale factor of the 0 is 1 by z, please see, if z is equal to 0 that is if a 0 lies close to the origin in that particular case the effect on the response is very large. But if z is equal to infinity that is your 0 lies deep further into the left-half plane in that particular case the effect on the response is negligibly small.

So you see that relative position, yes please…….. [Conversation between Student and Professor – Not audible ((00:27:53 min))] yes, this is another point I will answer this point, in my discussion I will keep this point also. You see that first let me complete this and then go to his point. you see, assuming that the 0 is in the left-half plane in that particular case you find that the 0 deep into the left-half plane has a lower effect on the system and the 0 close to the imaginary axis has larger effect on the system.

The guideline which you can by extensive simulation you can verify is this that relative to this position of the complex conjugate poles…….. please note, this is a very important statement useful in design, relative to this particular position if the 0 is roughly five times away in that particular, this is the region I have given you the region of 0 the 0 naturally will be on the real axis if it is a real zero, I am considering only one 0 you see, if the 0 is roughly five times away in that particular case its effect on the transient response can be considered negligible. If that is the case what is big thing we have achieved out of this? What I want to say is this that all the performance measures of rise time, settling time, peak overshoot and all others the peak time they with respect to zeta and omega n (Refer Slide Time: 29:24) with respect to only denominator of this transfer function can be used for a system with a 0 provided the 0 lies in this particular region and not in this region.

So you can really assume as if 0 is not present and in your design exercise you can go ahead with the same relationships we have derived, standard correlations which we have derived for a standard second-order system will become applicable here when the 0 lies in this particular range. This is very important because you are going to use this information in your design.

Suppose it does not, after all a PD controller cannot be designed only because of this consideration. So if it does not please see the only thing we normally do is this that you design your system and test it by simulation whether it satisfies your requirement or not and one more thing you take care of is that suppose the design requires a value of zeta equal to 0.4 which corresponds to an overshoot of 25 percent so what you do is you design for a value of 0.5 so that you know that the 0 will push the pronounced peak and if you have designed for 0.5 which is let us say 16.3 percent after all the deterioration because of 0 may take it towards 25 percent which may turn out to be acceptable to you. However, the final value will have to be confirmed using simulation.

So you see that, as far as the design cycle is concerned, you will look at these two points: either your 0 satisfies this requirement or if 0 does not satisfy your requirement reenter the design cycle and take a value of zeta so that it accounts for this effect of the 0 the pronounced peak is taken account of in deciding the value of zeta for which you are making a design. Instead of 0.4 I may make a design for 0.5 and see that well, the final peak overshoot whatever comes may maybe acceptable to me. If the simulation does not give you acceptable value you have to reenter this particular system.

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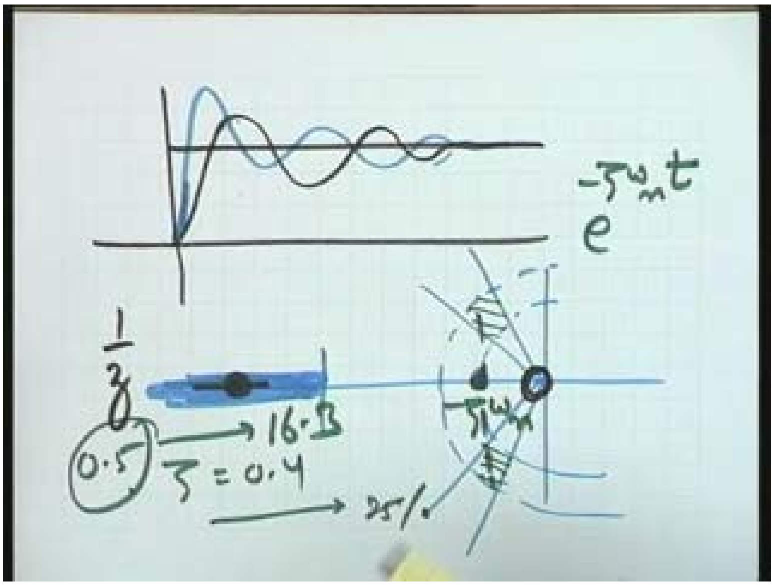

His question please?
His question is this that is it necessarily required that a 0 is always in the left-half plane? Please see this point; it is not necessarily required because a 0 in the right-half plane does not affect the stability of the system. But let me make a comment that in most of the physical situations a 0 in the right-half plane does not occur but for the systems which have dead time. You see, a dead time is modeled as e to the power of minus s tau D. A good approximation of dead time is 1 minus s tau D by 2 divided by 1 plus s tau D by 2 this is a good approximation of dead time. So you see that…. and this dead time is very common in process control applications. Mostly process control applications are equipped with, they definitely give you the dead time values and hence though 0 is not explicitly visible in dead time but its effect is equivalent to a 0 in the right-half plane because this is closely modeled by this and hence a 0 over here.

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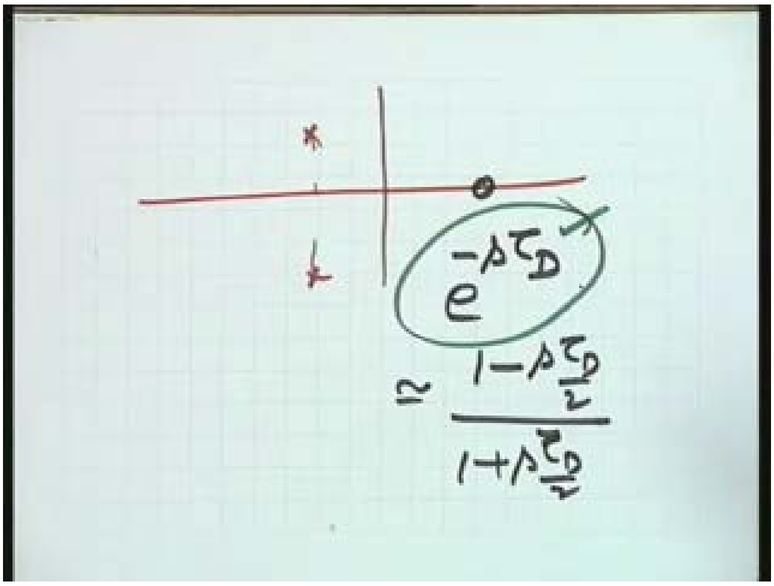

Now you see that if a 0 comes over here what will happen?
It means the peak overshoot or the derivative instead of getting added up it actually gets subtracted. So what is the response you expect help me? The response you get if there is a 0 in the right-half plane this is the situation, if there is a 0 in the right-half plane I may give you a typical response like this (Refer Slide Time: 33:19). Initially the peak overshoot will go down, the curve may not be nice you see but qualitative explanation should be taken that the derivative scaled by the factor 1 by z will be subtracted from here and therefore the overshoot will not be there but see that the great effect will be that the response will become very sluggish. So e to the power of minus s tau d is a very poor effect on the system it makes the response very sluggish and as far as peak overshoot is concerned the peak overshoot may also be affected because of this but the primary effect is this that the response becomes sluggish.

So his question a very important question for you is that the 0 in the right-half plane is allowed as far as stability considerations are concerned and the 0 comes up quite often in process control applications because of the dead time prevalent in the hardware.

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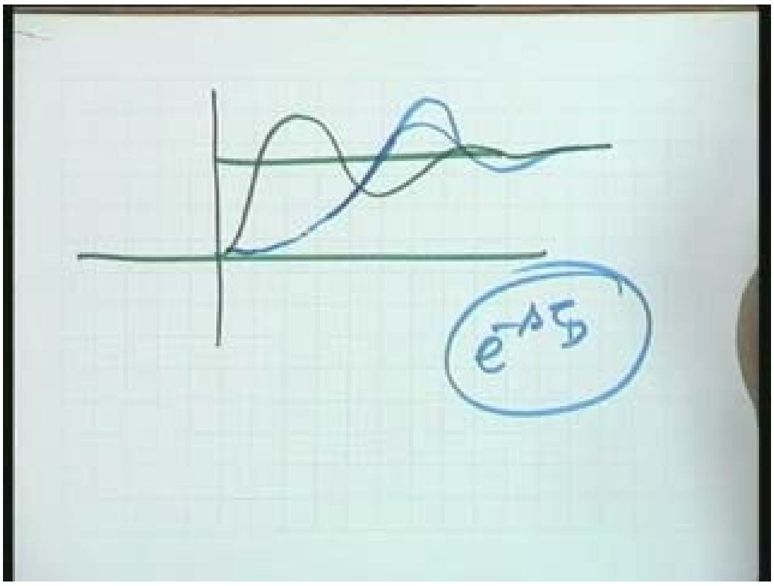

Let me go to the next situation. The next situation Y(s) by R(s) I say that, well, I have taken a second-order model a model which will never occur in a real life situation. Real life situation normally will consist of higher order models, please see. So let me exemplify it by including one more pole into the system and then I will extend the logic to higher order systems maybe fifth order, tenth order or any order system you see, do not limit your considerations to a standard second-order system. As I said, standard second-order system is an important design tool with us. This is a system…….

Tell me please, just normalize it for me so that the response is taken with respect to a steady-state value of 1, help me please, what should I do. I want normalization of this particular transfer function so some constant here and there so that the steady-state response turns out to be 1 multiplied by p please see this is the normalization I have got.

Now look at the effect of this. Looking at the effect of this I find that there will be two modes in the system: one mode is e to the power of minus pt. Of course the residue is going to dictate the magnitude of this particular mode. The other mode is e to the power of minus zeta omega nt, again the residue is going to dictate the magnitude of this particular mode. So the total response of the third-order system is based on these factors. One: the two modes the two modes now naturally will depend upon the relative location in the s plane, you can see that. If a pole is deep into the left-half plane it decays faster. So you see that if there is a pole towards infinity its presence is not going to affect the transient performance of the system because it will almost instantaneously decay. But if it is close to the j omega axis or if it is close to these poles of interest to you in that particular case its presence is going to affect the transient performance because its decay is going to be comparable to the decay of e to the power of minus zeta omega nt. Another factor of course is that the magnitude of the decay is guided by the residues.

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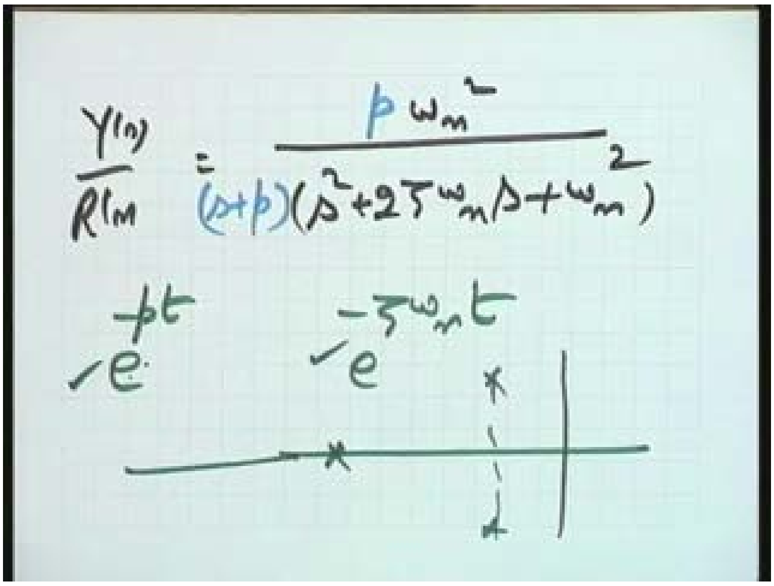

Now, again without going to the quantitative aspects of the effect of this particular pole let me generalize it to any system a higher order system a tenth order system for example. I say that for a tenth order system or an nth order system in general let me say that the design has given you this situation of poles and zeros. This is the design (Refer Slide Time: 37:21) there are two poles in this region depending upon the specifications you have imposed and all other poles lie in this region whether real poles or complex conjugate poles all other poles lie in this region and this particular region is about or at least more than five times the real part of the complex conjugate poles, at least five times. In that particular case, you may take more than one pole, you can say that in this particular case the poles are insignificant and hence as far as the steady transient behavior of the system is concerned it can be neglected and your transient behavior is primarily guided by these two poles and hence the design can take care of only zeta and omega n.

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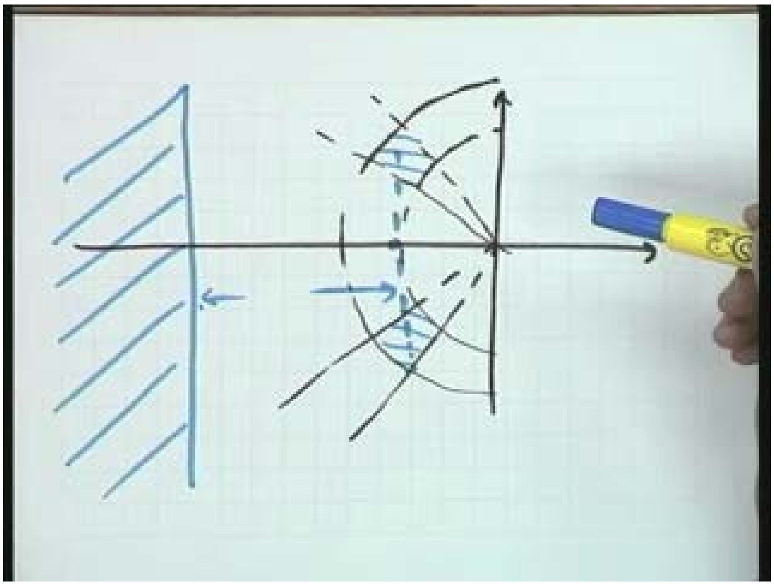

Please see that if you are using the word zeta and omega n for a system these terms become meaningless unless the system is a second-order system. I hope you agree with my point. The terms zeta and omega n are meaningless unless the system is a second-order system. So, if you are using the terms zeta and omega n for a higher order system it means it is your responsibility to ensure that all the other poles other than the two poles given over here are giving insignificant contribution to the transient response of the system. This I will refer to as the dominance condition. So it is your responsibility to see that the dominance condition is satisfied.

Unless the dominance condition is satisfied….. it does not mean that you cannot enter into the design cycle in that case, in that case the only thing I can say that well you design for some zeta and omega n check by simulation whether your design is acceptable to you or not, if not well it is a trial and error process. Go, enter into the trial and error process and see to it that finally simulation confirms your design requirements.

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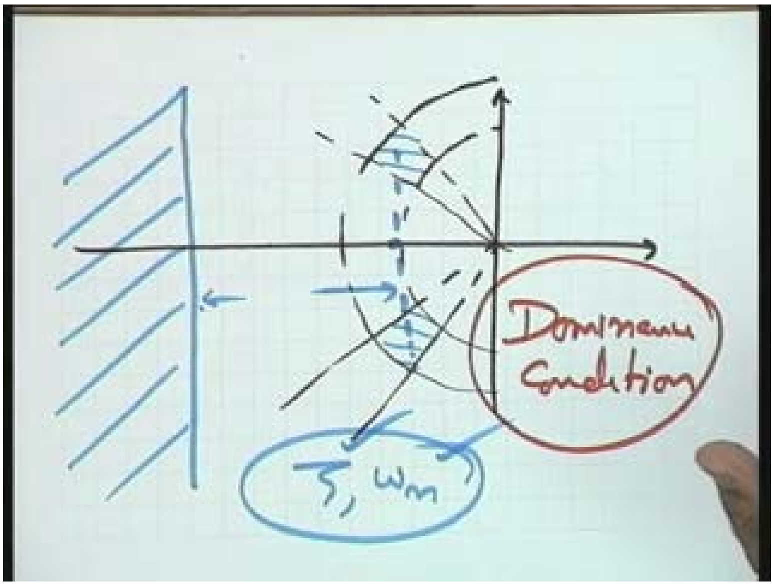

One point, very interesting…,, as I said that today you may not realize it but all the design exercise is going to use what I am saying today. One important point is the following. You see that these are the poles maybe the idea comes from you (Refer Slide Time: 39:53) these are the two poles and there is another pole the dominance condition is not satisfied, very poor situation as far as dominance condition is concerned, I do not say that the response is poor but as far as the dominance condition is concerned it is a very poor situation is it not? So these are the complex, you can definitely in for this particular system if you say that the performance of this system is given by zeta and omega n where zeta and omega n are given by these numerical values I think you are making a very wrong statement.

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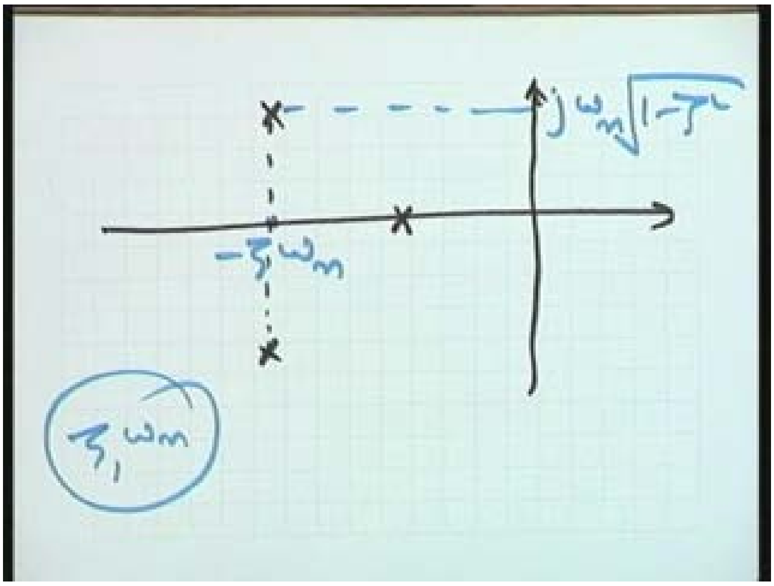

If zeta and an omega n are given by these numerical values and you say that the response is guided by zeta and omega n very wrong statement you are making. Tell me, in this particular case can anyone generate some idea how to go for the design, how to go for the design, very interesting point, I think yes, [Conversation between student and Professor: 40:54] the first-order term would prominent in………. first-order will now in this particular case if zeta omega n is equal to let us say minus 5 the first-order term will dominate in this as you said is it not?

Well, in that particular case you see that either these should become insignificant. If these two poles become insignificant then I can say that, well, my response is guided by this first-order term. But suppose that these two terms do not this first-order term does not dominate this gap is not large enough to say that the response is guided by the first-order factor. So, neither by the first-order nor by the second-order your response can be represented. It is a full third-order and hence a full third-order system response will have to be evaluative and you want to design this particular system for some peak overshoot and omega.

The user has given you some peak overshoot and settling time, the peak overshoot and settling time can be translated into zeta and omega n. Somehow if you can I can give you a hint, please see, well, I think the hint may give the answer to me. If somehow you take off this pole (Refer Slide Time: 42:02) in that particular case the situation will be a happy situation. If somehow you take off this pole ((sir between the component parts)) ((00:42:08 min)) Alokh did you say adding a 0? Yes. Yes. That is the answer please.

Just see that a 0 in the earlier discussion was the culprit, was creating problem, was giving you pronounced peak but after all a 0 you can introduce through a PD controller so why do not you design a PD controller and put a 0 here. Please see that if a pole you see if you put a 0 exactly on this the dynamics gets completely cancelled. It means the residue at that particular pole becomes 0. Putting a 0 on the pole means the residue becomes equal to 0 and hence the effect of that particular pole has been removed. But even if the 0 is close to the pole in that particular case the contribution of this particular pole on the transient response of the system will be small and therefore you can say that the dominance condition is satisfied and you can say that the response of the system third-order system with a 0 is dictated by these two complex conjugate poles and this is one of the design methods which we normally carryout. This is pole zero cancellation method in which a 0 is placed near a pole by design so that the effect of this particular pole can be minimized.

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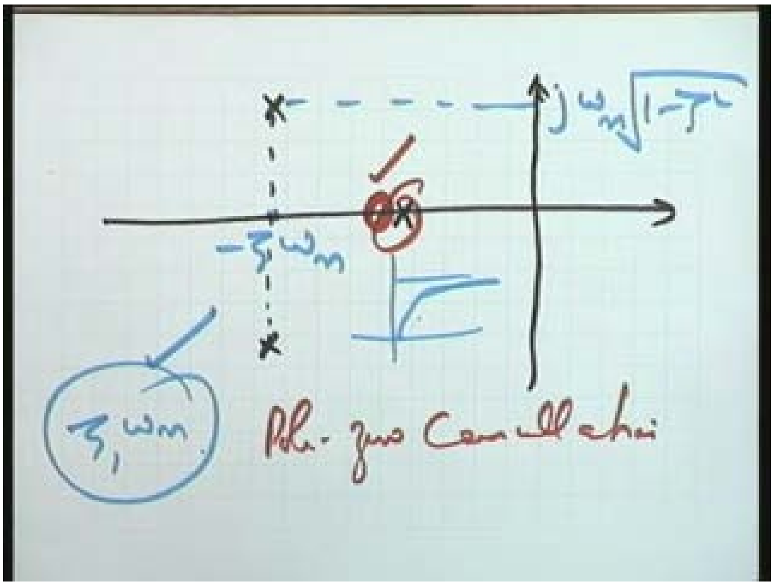

The effect is coming, you can just check because of the effect on the residue of the system. The residue of the system gets changed in the process. Well, the target was completing the discussion today but I see the time let me not start with the steady-state error.

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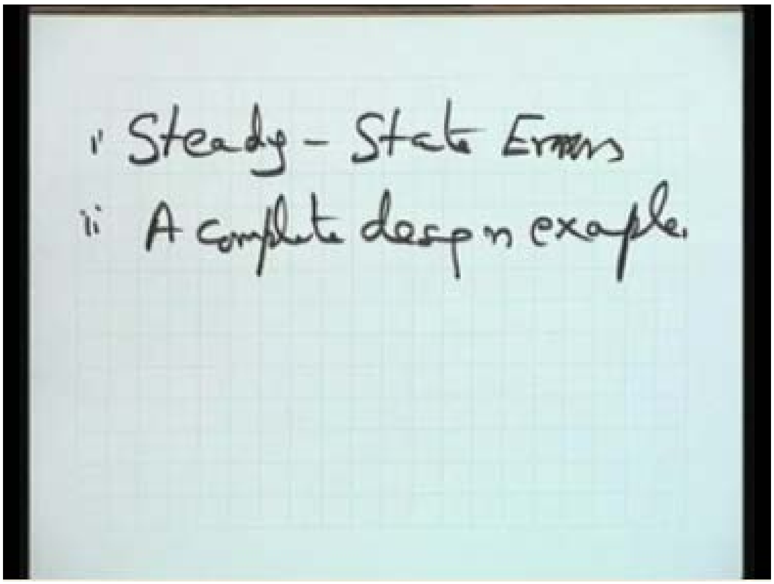

So I think tomorrow I am going to complete the discussion on the subject with the discussion on steady-state errors one point and second a complete design example. This is left and I am going to complete this tomorrow, thank you.