Power System Engineering
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Lecture - 55
Load frequency control (Contd.)

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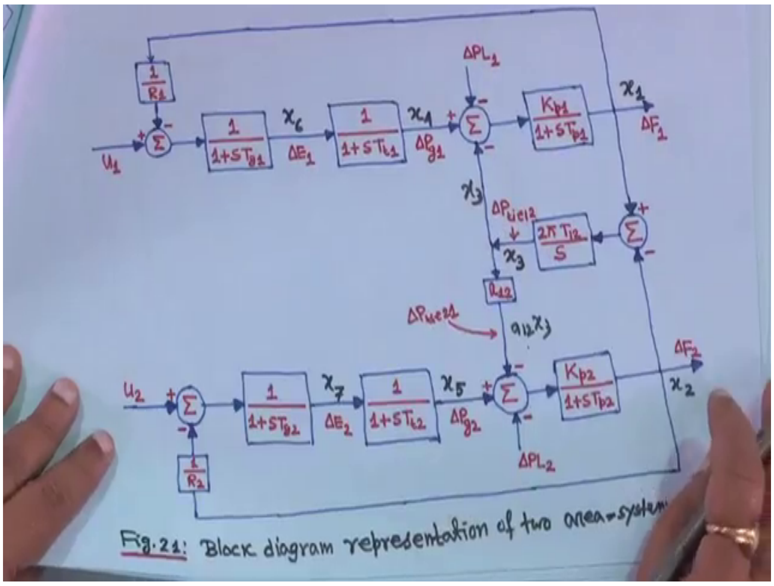

Fig. 21: Block diagram representation of two area-system

Next look all these things I am making it for you such that when you will go through you know it will be very easy for you to this thing even without looking into the book you can make it of your own right. So, now, next is x 3 next is x 3 this one right.

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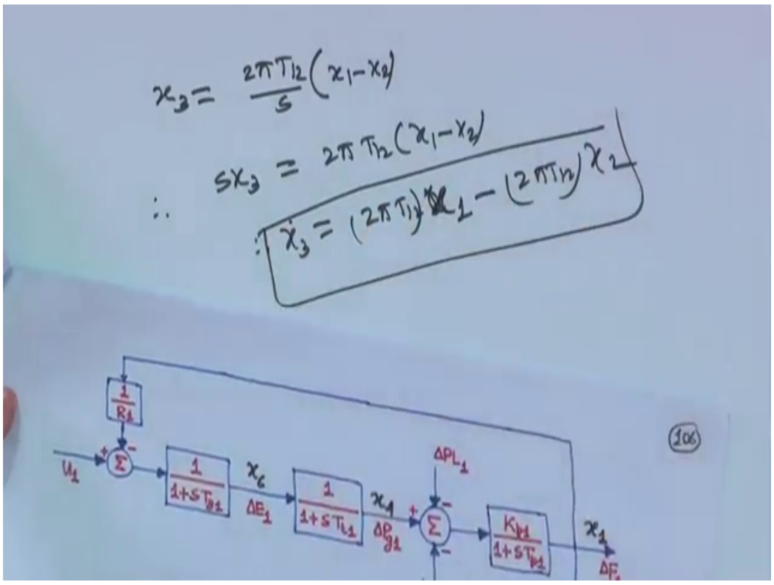

So, in this case if you look in the block diagram it that x 3 is equal to x 3 is equal to 2 pi T 12 upon s 2 pi T 12 upon s into this is actually x 1. So, this is x 1 and this is x 2; so into x 1 minus x 2 right. So, it is a plus x 1 it is minus x 2 x 1 minus x 2 right; that means, s x 3 is equal to 2 pi T 12 x 1 minus x 2; that means, x 3 dot is equal to 2 pi T 1 two I make breaking the bracket 2 pi T 12 your x 1 minus 2 pi T 12 into x 2. So, this is your what you call x 3 dot. So, if you this is a third equation.

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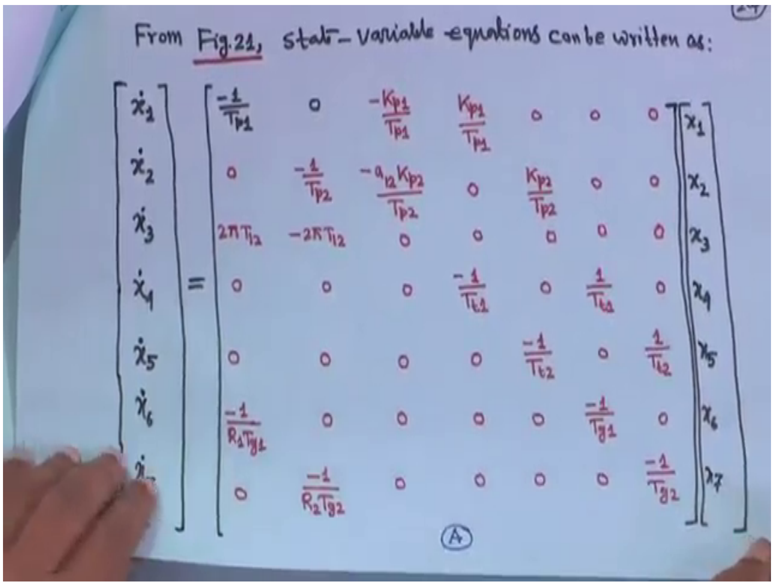

If you look at the third equation x 3 dot is equal to 2 pi T 12 x 1 minus 2 pi T 1 to x 2 rest of the your what you call elements are 0 right this is the third equation.

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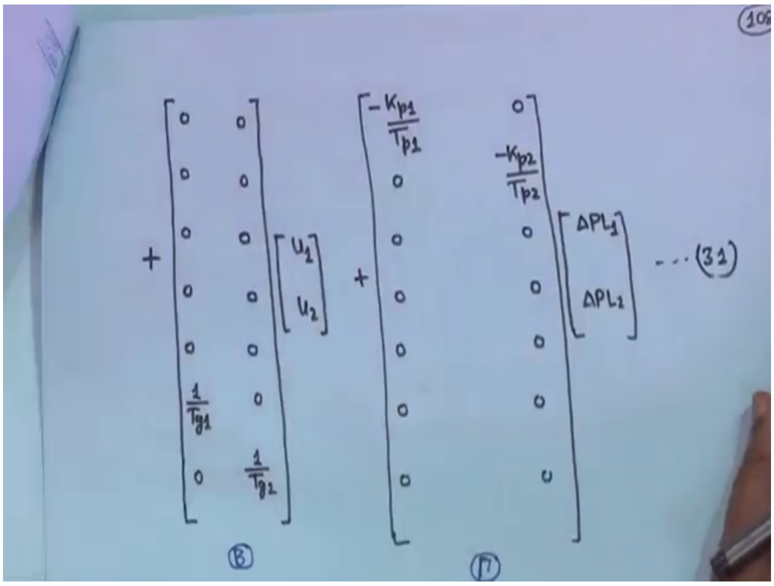

And similarly for the third row both your this is B matrix this is gamma matrix third row this is 0 this is also 0 right because no u are delta PL is involved there next is your x 4 dot. So, this is my x 4 this is my x 4. So, x 4 is equal to actually x 6 upon 1 plus s t t 1 right. So, this is x 4.

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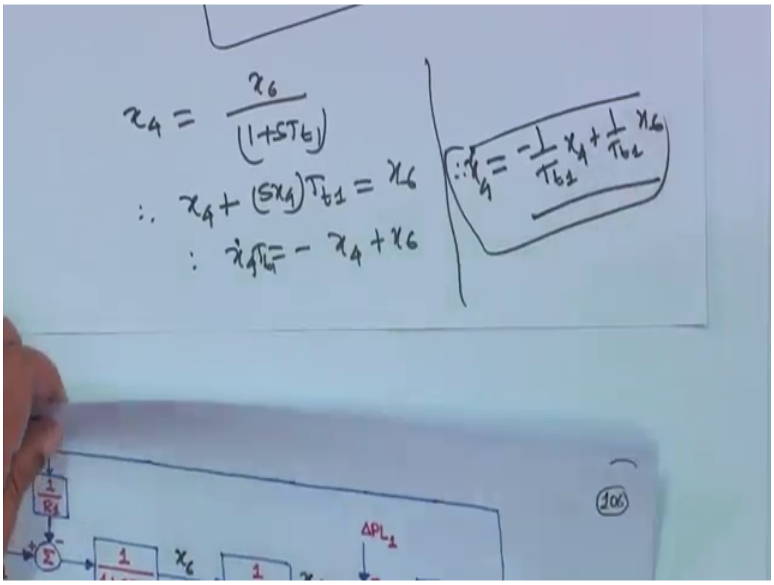

So, I am making it this way if they look x 4 is equal to your x 6 divided by 1 plus ST t 1 right; that means, x 4 plus s x 4 into Tt 1 is equal to x 6.

That means this is actually x 4 dot therefore, x 4 dot is equal to minus x 4 x 4 dot Tt 1 is equal to minus x 4 plus x 6 right; that means, here I am making it; that means, x 4 dot is equal to your minus 1 upon Tt 1 x 4 plus 1 upon Tt one x 6. So, here also know you involve this is this is your x 4 dot here also know you involve low delta p l is involve already these two elements will be there in that a matrix right. So, if you see the x 4 dot it is minus 1 upon Tt 1 x 4 plus 1 upon Tt 1 x 6 it will look minus all are 0, first three minus 1 upon Tt 1 this into x 4 it fifth one is not there then one upon Tt 1 your x 6 right 0 and similarly on the fourth row because know you know delta p l is there. So, here it is 00 here also it is 00.

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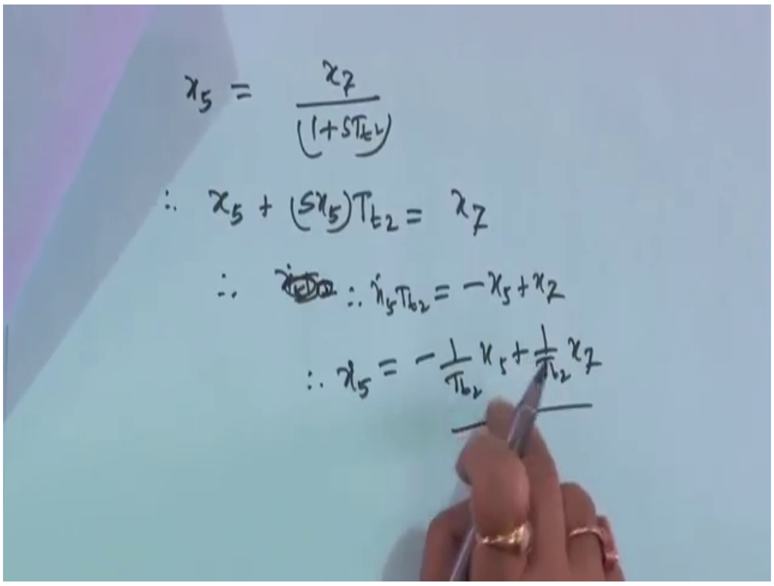

Next you consider that x 5 right that is your this one x 5 this one. So, similarly you can write x 5 is equal to x 7 upon 1 plus ST t 2; that means, we can write x 5 is equal to x 7 divided by one plus STt 2 then cross multiply. So, it will be x 5 plus Sx 5 Tt 2 is equal to x 7; that means, this is your x 5 dot is equal to you know I let me make Tt 2 here also x 5 dot Tt two is equal to minus x 5 plus x 7 right therefore, x 5 dot is equal to minus 1 upon Tt 2 x 5 plus one upon Tt 2 x 7 right.

So, here also no you know delta PL is involve only a matrix has to be filled a fifth element and the seventh one there is the if you look at the fifth row. So, first four as zero it is minus 1 upon Tt 2 x 5 minus one upon Tt 2 x 5 this 1 minus 1 upon Tt 2 x 5 plus sixth element is zero one upon Tt 2 x 7. So, one upon Tt 2 x 7 this is your fifth row and here also fifth one is here it is 00 because no u is involved and here also it is 00 because no disturbance thing is involved right. So, this is your x 5 then if you come to x 6 this one this one if you come right then just it will be like this rather than the writing on the notebook you are making note of this thing I thought I i will make it here such that it will be easy for you to understand right.

So, now x 6 x 6 will be look this u 1 will be there it is plus minus this x 1 is coming here. So, this is your x 1.

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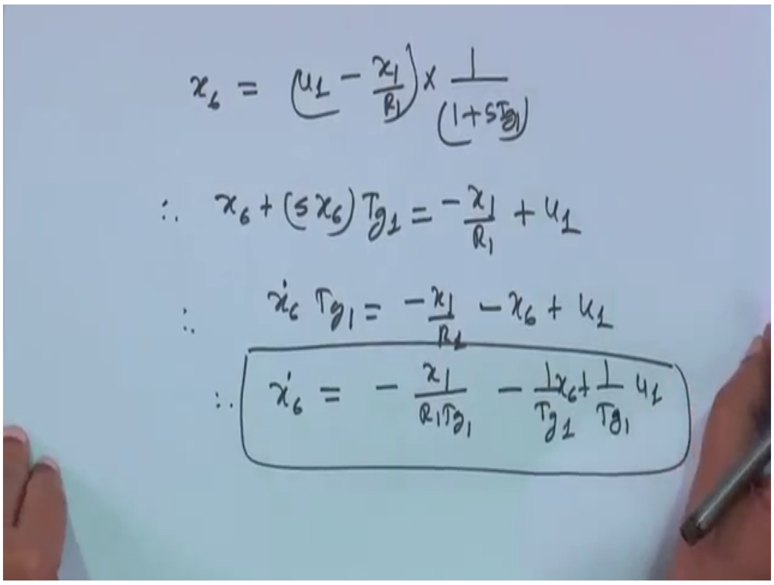

So, basically it will be x 6 is equal to u 1 minus x 1 upon r 1 into 1 upon 1 plus s t g 1 right; that means, we can write that x 6 is equal to we can write x 6 is equal to u 1 minus your x 1 upon r 1 into your 1 upon 1 plus s t g 1 right. So, if you go for cross multiplication it will be x 6 plus your s x 6 into Tg 1 this one writing first minus x 1 upon r 1 plus u 1 right.

That means we can write s x 6 is x 6 dot right Tg 1 is equal to this one writing first minus x 1 by r 1 minus this one we are writing first x 6 plus u 1 therefore, your x 6 dot is equal to minus x 1 upon r 1 Tg 1 minus 1 upon Tg 1 plus 1 upon minus 1 upon Tg 1 x 6 then one upon Tg 1 u 1 right. So, this is the equation where I am making all sort of things by chance this is a recording thing right and continuously you have to move right if I make any mistake anywhere if you observe throughout this course because many places I have tried to derive hope hoping that things are ok.

But if you see that any point or anything I have missed or something written you know incorrectly, but later hopefully it has been corrected right, but still you point out to me hopefully things are hopefully things are right. So, because in the nobody is sitting in front of me then they can rectify cell on the blackboard when you write if we miss any term immediately they point out sir you have missed the term right, but here nobody is there in front of me right. So, anyway. So, this x 6 dot will be your then this if you come to the sixth element then it will be a 61 will be minus 1 upon r 1 Tg 1. So, if you come to that that it is x 1. So, minus 1 upon r 1 Tg 1.

Then you are directly come to the sixth element of that sixth row right because rest and between all that for your what you calls six two six three six four six five a six three six four your a 61 a 62 a 63 a 64 a 65 all are 0. So, all are actually 0 right these are 0 then sixth element is coming your minus 1 upon Tg 1 here minus 1 upon Tg 1 into x 6 and in the u that sixth element one upon Tg 1 u 1 is there. So, will go to the B matrix that sixth row B matrix this is a sixth row. So, here it is 1 upon Tg 1 it is 0 node delta PL is involve here. So, it is 0, but it is 1 upon Tg 1 right.

So, similarly if you write your last equation that is your x seven right if you write the last equation x 7 look at here last equation if you write here x 7. So, this is actually your x 2 this is x 2. So, it is u 2 minus x 2 upon r 2 into 1 upon 1 plus St g 2 is equal to x 7. So, this one we can write that your x 7 is equal to from this from here.

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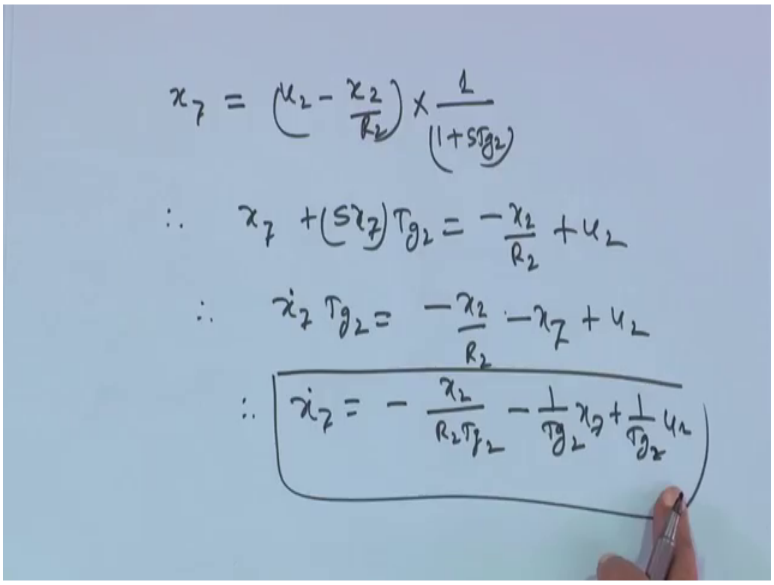

Only from here only right it is u 2 minus your x 2 upon r 2 into your one upon one plus s Tg 2 go for a cross multiplication it will be then x 7 plus S x 7 then Tg 2 writing this one first minus x 2 upon R 2 then we are writing u 2 right or Sx 7 is equal to your x 7 dot then Tg 2 is equal to this one writing first minus x 2 upon R 2 then after that this minus x 7 this one and plus u 2 right.

Or x 7 dot is equal to minus x 2 upon R 2 Tg 2 minus 1 upon Tg two x 7 plus 1 upon Tg 2 u 2 right this is your x 7 dot. So, u 2 is involved here u 2 is involved here other things is only a 72 and your what you call a 77 these two elements are there in the a matrix right. So, a 72 is minus one upon R 2 Tg 2 and then this one a 77 minus 1 upon Tg 2 and last one is that it is your u u it is 1 upon Tg 2 u 2 is there. So, here it is 1 upon Tg 2 u 2 u 2 is there right therefore, it is 0 first one then 1 upon Tg 2 u 2 and here it is 00 and this is delta PL 1 delta PL 2 u 1 u 2 right.

So, this is equation 31 equation 31 means all together this one this is left hand side. It is x dot this matrix is x right and this one your Bu and this is gamma if you observe one thing you will see because of this tie line power flow this one diagonal element is actually 0, but rest all are your what you call have a negative sign at least in the diagonal and because of this tie line that this one element is here is 0. So, this is a 7 into 7 matrix right and this is your 7 into 2 b matrix and this is gamma matrix. So, this is say your 7 into 2 again. So, this is what you call that that you can write now x dot is equal to x plus Bu plus gamma p.

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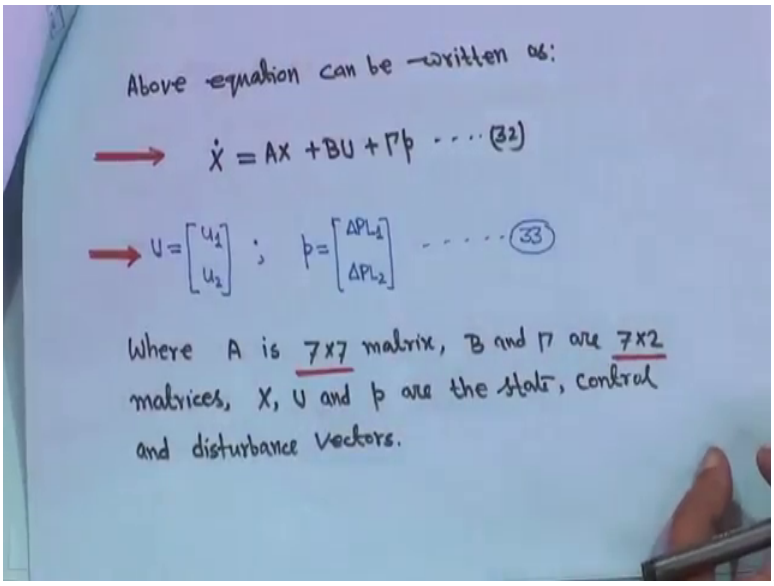

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Now, that means, this equation is written as x dot is equal to x plus Bu plus gamma p in this form this is equation 32 where u is equal to u 1 u 2 and p is the disturbance vector delta PL upon delta PL 2 where a is a seven into seven matrix I told you B and gamma are 7 7 into 2 matrices x u and p are the state control and disturbance vector right our state variable whatever we have chosen you can you alternate also or even interchange also this way that way no problem, but you will get the same result you will get the same result right. So, suppose if we want this equation is equal to x dot is equal to x plus Bu plus gamma p suppose it is uncontrolled.

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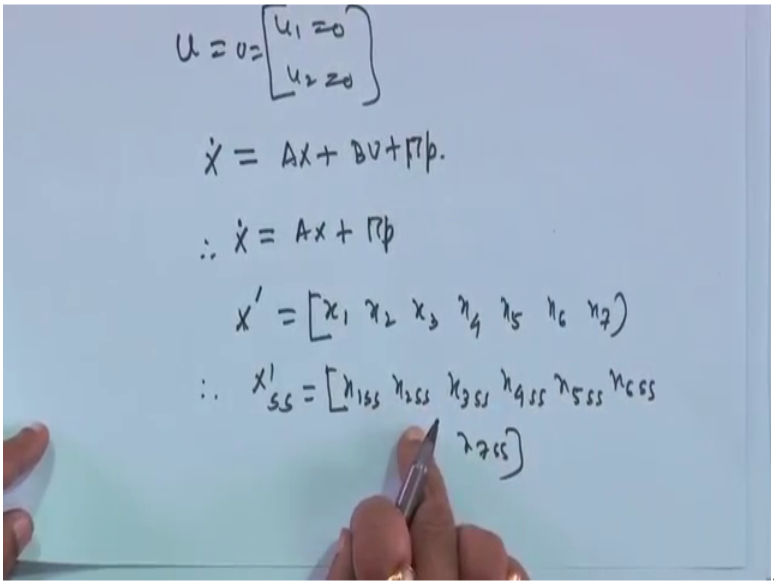

Suppose u is 0 u is 0 means actually is equal to u 1 is equal to 0 u 2 is equal to 0 it is uncontrolled mode therefore, this equation x dot is equal to a x plus b u plus gamma p right as u is 0; that means, this equation can be written as x dot is equal to say uncontrolled mode uncontrolled mode plus gamma p it is uncontrolled mode when u is equal to 0 now at steady state I told you suppose steady state means suppose you are x I am making it as a transpose say x dash x transpose your x 1 x 2 x 3 x 4 x 5 x 6 and x 7 right now this is transpose. So, it is steady state actually a steady state if you put this transpose this all will be x 1 s s x 2 s s x 3 s s all the steady state value x 4 s s these were also you have seen for single area x 6 s s and x 7 s s right.

So, these are all the your what you call the steady state value. So, when all these things all these state variable reaches to a steady state the derivative is 0 the derivative is 0 right.

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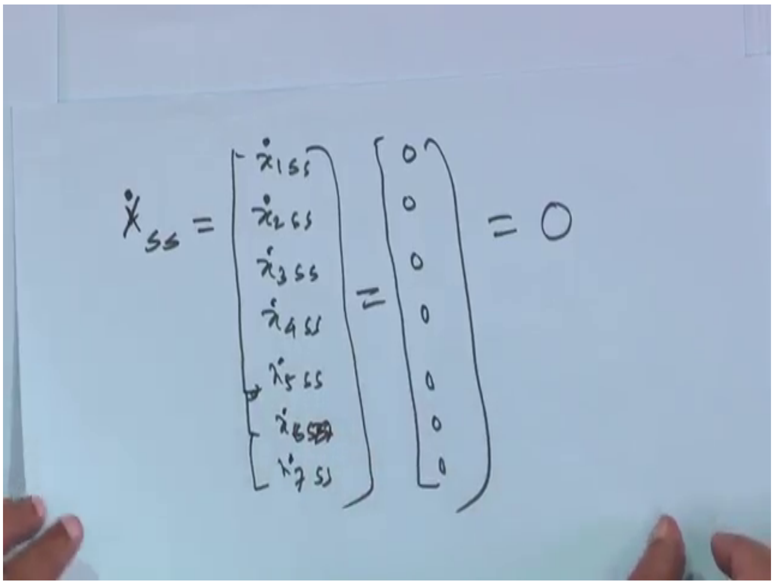

So; that means, I mean; that means, if you take I mean if I put like this rather than transpose now suppose if I make it like this x s s is equal to your x 1 s s x 2 s s x 3 s s s s means steady state right x 4 s s x 5 s s x 6 s s x 6 s s and x 7 s s right these are the thing x steady state if you make their dot suppose x s s then if you x s dot then x 1 steady state dot x dot dot dot dot dot all the steady state dot.

So, at steady state when all the state variables reach to a steady state means it will be 0000000 right all seven zeros are there. So, it will resist to restore to the steady state therefore, in this equation when you put x is equal to your x s s; that means, your writing on the next page.

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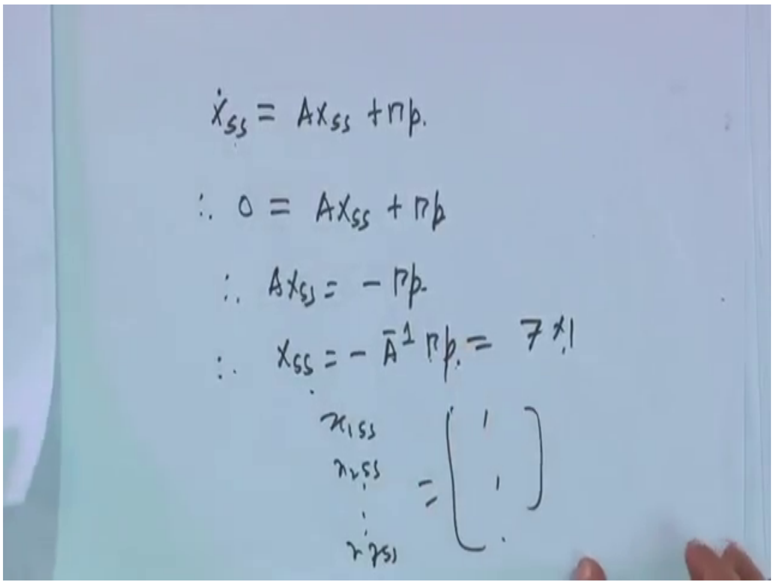

That means your X s s dot X s s dot is equal to s s plus gamma p; that means, my this one actually this is 0 X s s is steady state I told you that all the steady state values this will be actually is equal to 0 right. So, all X s s dot will be 0 therefore, this 0 is equal to A x s s plus gamma p.

That means A x s s is equal to minus gamma p multiplied both sides by a inverse; that means, x s s which will minus a inverse gamma p right only thing is that a inverse has to exist, but for this kind of system let me tell you a inverse exists; that means, you know a inverse it is a 7 into sin matrix gamma gamma matrix is also known to you right and because they are p load disturbance is also known to you p l 1 p l 2 everything is known to you parameters are known to a matrix parameters are known to you; that means, if the this one actually it will be this will become a your what you call 7 into 1 right.

So, in that case your what you call this all the steady state values x 1 s s x 2 s s everything you everything will get I mean all the seven state variables whatever I have shown right all this your this thing your steady state values you will get. So, all these steadies, but at steady state this is actually x 3 dot this is steady state values of all x 1 s s x 2 s s all.

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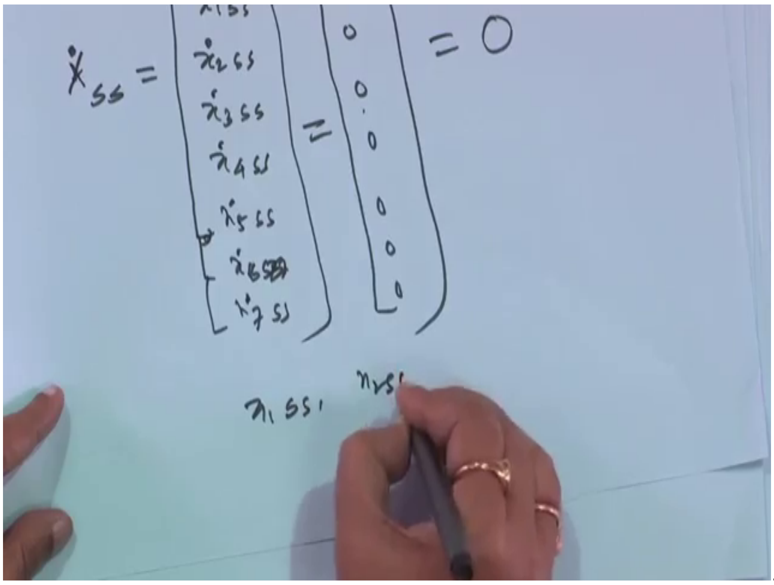

You will get and; that means, the steady state values of all the values you will get all the seven state variables in MATLAB you can easily verify if you know the MATLAB take some parameter and just check you will get all these values right.

So, that is why what you call that this is easy way to find out the steady state value of course, that a inverse has to exist right it has to exist then only it is your only it is possible otherwise it is not possible right. So anyway, this will be a 7 into 7; that means, all the values whatever will get first one will become X s s when X s s second one x 2 s s up to x 7 s s whatever we will get this side all the steady state values will get you can easily verify in the MATLAB also right.

So, that is why this is your what we told that about x dot is equal to x plus B u plus gamma p.

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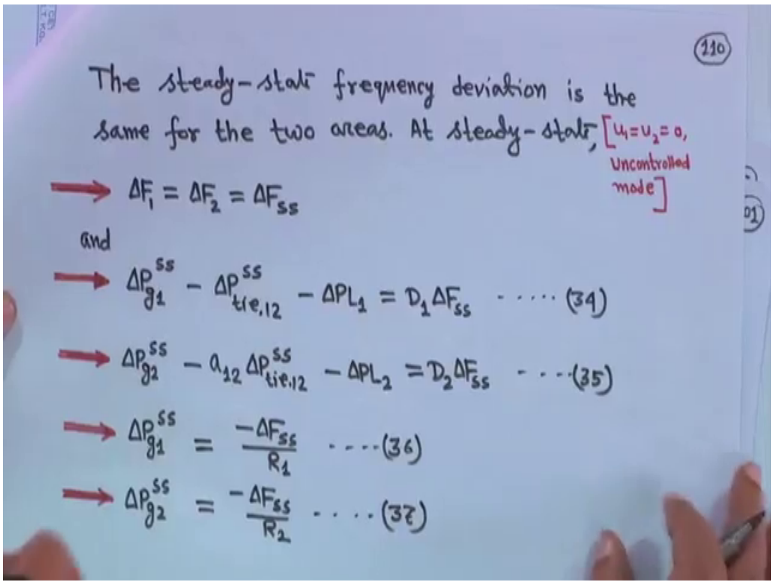

Now, now we have to go for this that is how told you how to go first steady state analysis for all the variables now mathematically we will see also from here same as before will proceed that the steady state frequency deviation is, but they are here you are getting you are what you call this steady state value whatever you are getting here directly all the numerical values, but we have to obtain some mathematical expression for that so; that means, at the steady state actually even it is a two area system as steady state that your delta F 1 actually is equal to delta F 2 is equal to delta F SS and we are considering this is uncontrolled mode that is I told you u 1 is equal to u 2 is equal to 0 uncontrolled mode written here in reading right.

So, this delta F 1 is equal to delta F 2 is equal to delta F SS, this is a steady state at steady state both the area steady state error is same therefore, for power balance equation that.

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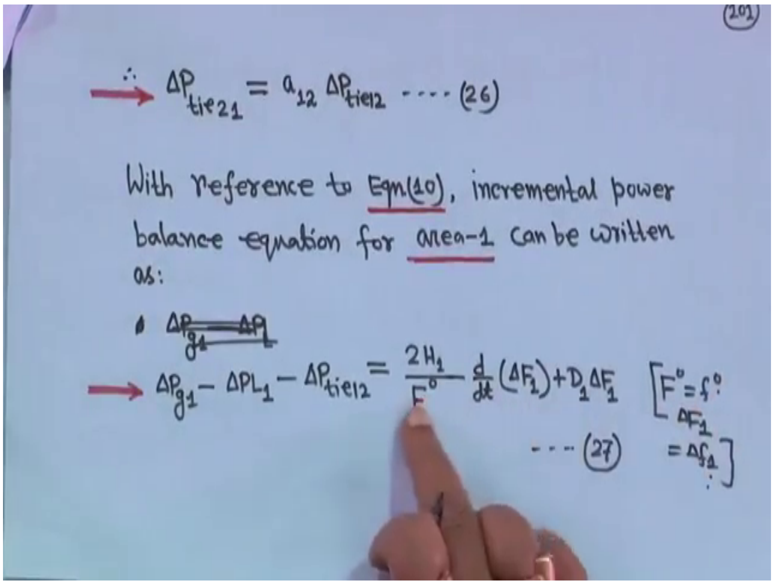

What you call that earlier this equation for power balance equation now look at that that at steady state it will be delta P g 1 s s do not disturbance will be there as it is it will be delta P tie 12 s s right from our general knowledge only we are trying to make it as steady state I told you that any derivative of any state will become 0. So, at d d t of delta F one will be zero because it has these two the steady state and this will be actually del D 1 into delta F 1 s s right.

A steady state this term will vanish because it derivative will become 0; that means, this equation delta P g 1 s s instead of P g 1 you are making s s the steady state delta P g 1 s s minus delta P tie 12 s s minus delta PL one is equal to d 1 into delta F SS right. This is actually coming from equation 27 similarly your this thing only this part will be vanished right.

So, similarly what you call similarly for the area two if you write I told you that area two in the case of area two equation will remain same. It will be it will I did not write that one, but understandable it will be delta P g 2 minus delta PL2 minus it will be delta p tie 21. Hence it will be minus a 12 into delta P tie 12 is equal to it will be 2 h2 upon F 0 into d d t of delta F 2 plus d 2 into delta F 2 for the area two understandable and again this part will be vanish for the area two and in that case it will become delta P g 2 s s minus delta P tie 21 s s actual is equal to minus a 12 delta p tie 12 s s steady state error.

Here also for area two I told you how I will make it using minus delta PL 2 is equal to d 2 into delta F SS this is actually equation 35 right and we also know from isolated system same philosophy will be applied here the delta P g 1 steady state actually minus delta F SS upon R 1 in this in the case of your isolated case we have seen that delta P g s s actually is equal to minus delta F SS upon R, but here two area systematics. So, for area one delta P g 1 s s will be minus delta F SS upon r one and delta P g two s s is equal to minus delta F SS upon R 2 this is equation 36 this is equation 37.

Now, this delta P g 1 s s and delta P g 2 s s you substitute here that mean this equation will be function of delta F SS and delta P tie 12 s s s similarly delta P g 2 s s is equal to minus delta F SS upon R 2 this you substitute here here you will substitute then this equation will become function of your what you call delta P a your this you know it is in that in terms of delta P tie 12 s s and delta F SS. So, this equation also in terms of delta F SS and delta P tie 12 s s this equation also will become in terms of your delta F SS and delta P tie 12 s s they solve these two equations solve these two equations right.

So, I am not putting and showing it here it is understandable delta P g 1 s s you put it here right and make one equation and here also delta P g 2 s s you make it here make this a another equation and solve this right. So, if you solved it.

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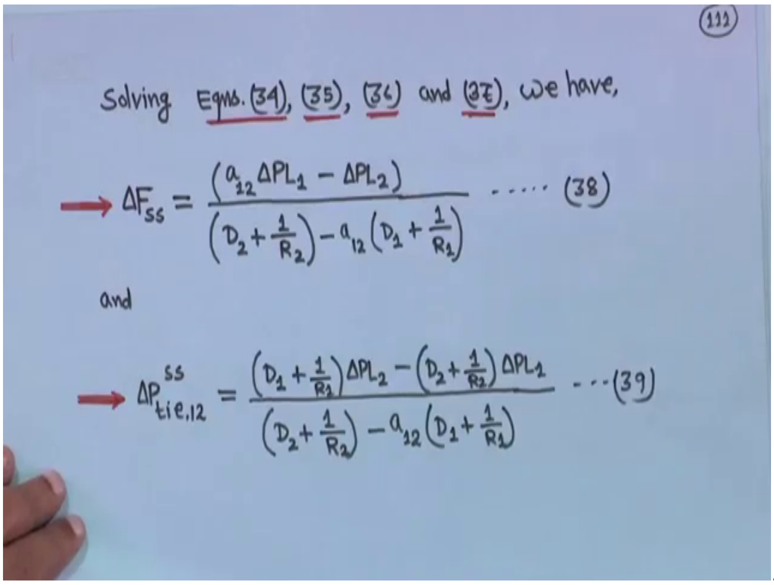

Because it is a linear equation solving. So, no need to do it you will be able to do it right. So, if you do. So, and solve it then that is why I am writing solving equation 34, 35, 36, and 37 the way I told you will get delta F SS is equal to a 12 delta PL 1 minus delta PL 2 right divided by d 2 plus 1 upon R 2 minus a 12 into d 1 plus 1 upon R 1 this is equation 38.

That means at steady state uncontrolled mode two area system actually frequency deviation of both the areas are same right it is not delta F 1 s s or delta F 2 s s it will be same and type and delta P tie 12 s s after solving those 2 equations you will get d 1 plus 1 upon R 1 into delta PL2 minus d 2 plus 1 upon R 2 into delta PL 1 divided by d 2 plus 1 upon R 2 minus a 12 d 1 plus 1 upon R 1. So, numerator numerators are different, but denominator both cases it is same d u d 2 plus 1 upon R 2 minus a 12 d 1 plus 1 upon R 1 this is equation 39; that means, uncontrolled mode at least this expressions are known to us right and if and this expression is known to us means that is your delta Pg 1 s s is equal to minus del F SS upon R 1. So, you know the del F SS you can easily find out delta Pg 1 and delta Pg 1 s s and delta Pg 2 s s.

But this is the expression right you can solve it you please solve it of your own.

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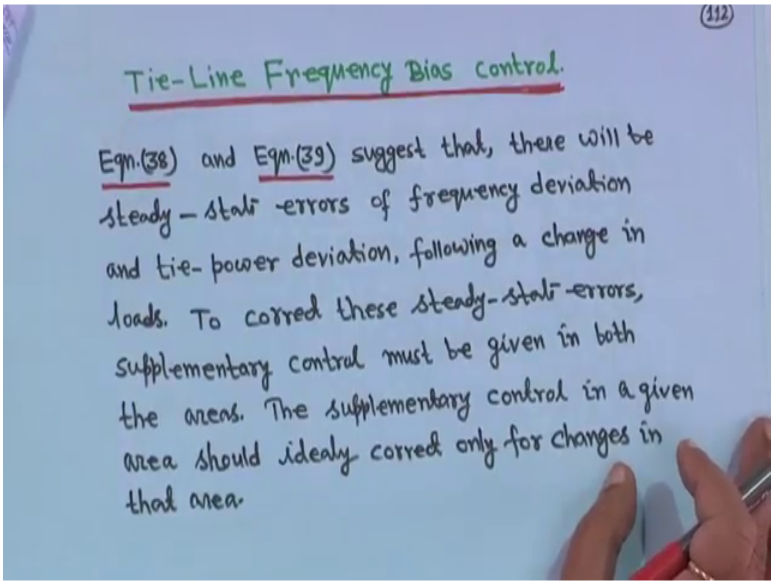

And just get in this is simple thing right now once this is done delta F SS and delta your p tie 12 s s.

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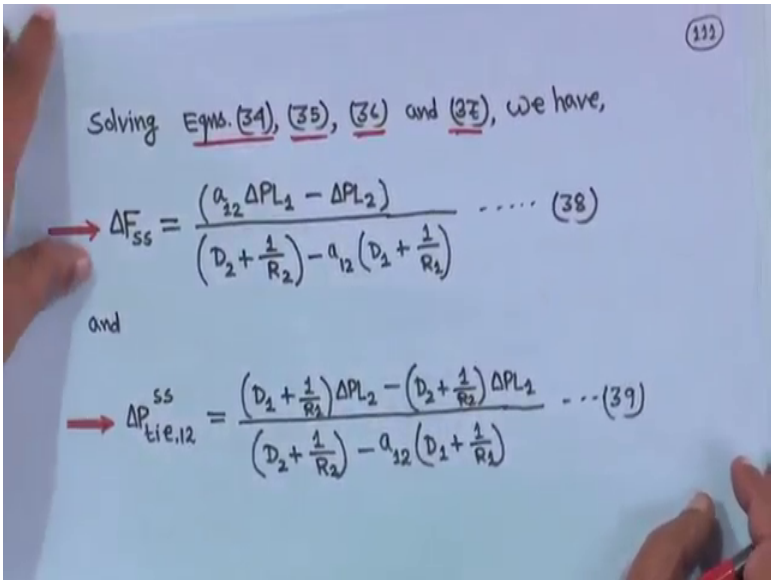

And just before moving further from this equation only suppose in area one disturbance is only there in area one this disturbance is there in area one and area two suppose disturbance delta P 2 is equal to 0 there is no disturbance in the area one.

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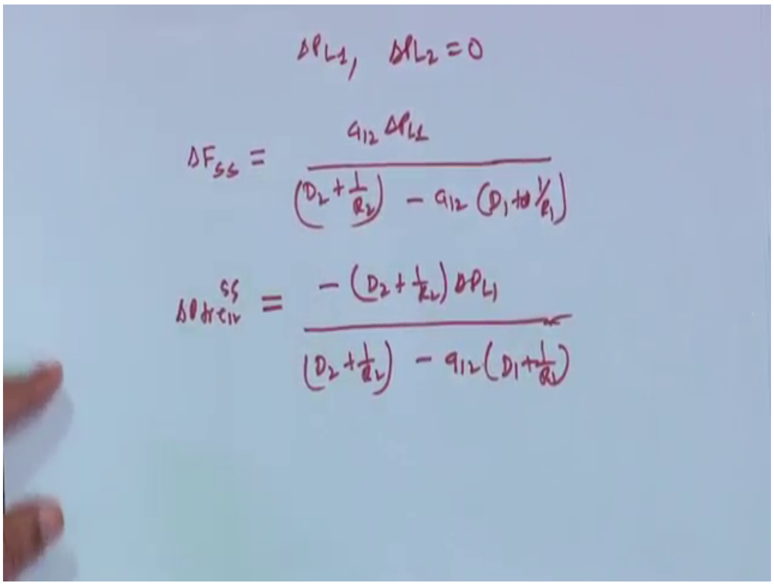

So, in that case this equation this equation will become delta F SS is equal to a 12 delta PL 1 divided by d 2 plus 1 upon R 2 minus a 12 d 1 plus 1 upon R 1.

Similarly, in the tie power equation if your what you call delta P l 1 is your delta P l 2 is equal to 0 if delta P l 2 is equal to 0 in the tie power equation then it will be it delta P tie

12 steady state is equal to right delta P l 2 is 0. So, this term will not be there it is minus your d 2 plus 1 upon R 2 delta P l 1 divided by same thing same denominator minus a 12 d 1 plus 1 upon R 1 right. So, this is your what you call a expression for this one.

Now, we know we know for example, everything we are talk this is in hertz this is this is actually in hertz and this is in per unit megawatt right this is not in per unit this is in hertz and this is in per unit megawatt now if we know.

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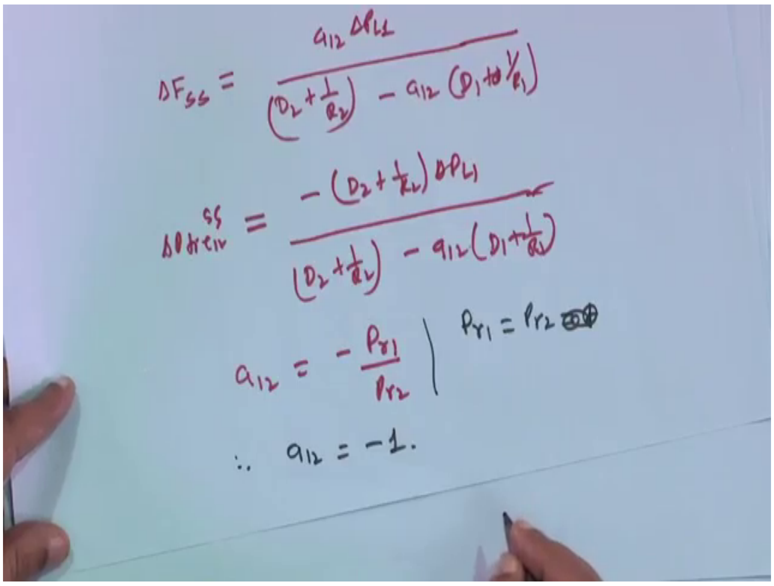

We have seen know a 12 is equal to minus P r 1 upon P r 2 right; that means, if we assume let assume area capacity ratio P r 1 P r 2 is equal to 1 there is P r 1 is equal to P r two that is their same; that means, a 12 is equal to minus 1. So, if we put here a 12 is equal to minus 1 here you put in this here, here, here, also here you put minus 1.

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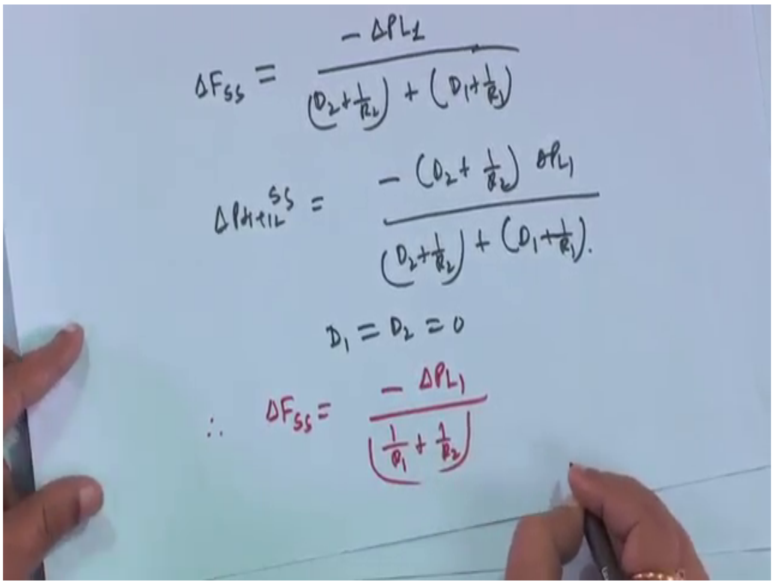

If you do. So, then you will get delta F steady state is equal to minus delta P l one divided by D 2 plus one upon R 2 and a 12 is minus 1 it will be then plus right. So, it will be plus D 1 plus 1 upon R 1 similarly delta P tie 12 s s here only it will be minus 1. So, it will be plus right therefore, delta P tie 12 steady state is equal to your minus D 2 plus 1 upon R 2 right then into delta P l 1 divided by D 2 plus 1 upon R 2 plus your D 1 plus 1 upon R 1 right now suppose you assume load is insensitive to the changes in frequency; that means, just for the sake of clarification some understanding say D 1 is equal to d 2 is equal to 0 say load is insensitive to changes in frequency.

If D 1 is equal to D 2 is equal to your 0 right then your delta F SS will be minus delta P l 1 as D 1 D 2 is equal to 0 it will be one upon R 1 plus 1 upon R 2 right similarly here also if D 2 is 0 D 1 D 2 both are 0.

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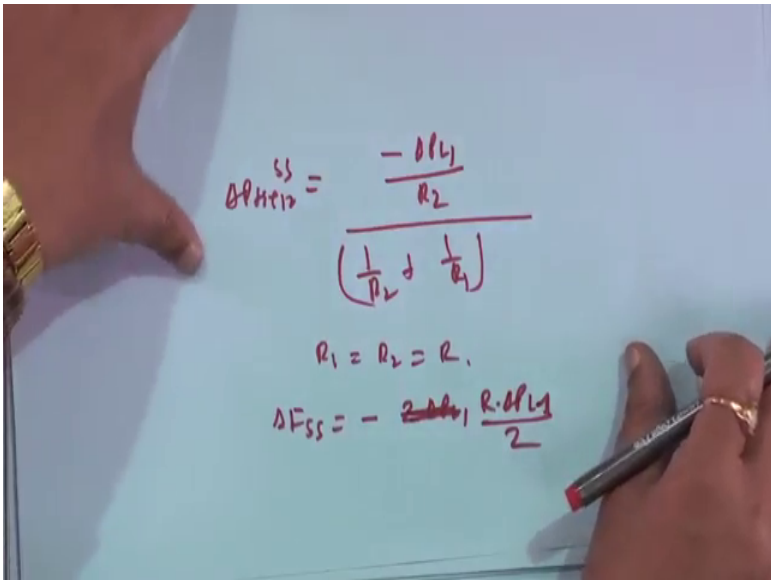

Then delta P tie 12 s delta P tie 12 steady state D 2 here D 1 D 20. It will be minus delta P l 1 divided by R 2 and here it will be 1 upon R 2 plus 1 upon R 1 this is delta P tie 12 s s and this is delta F SS right.

So, if you take if you take say R 1 is equal to R 2 is equal to R same value if you take right so; that means, delta F SS will become minus 2 delta P l 1 sorry minus your R into delta P l 1 right divided by two right you take R 1 is equal to R 2 is equal to R. So, it will be your minus R into delta P l 1 upon two similarly for tie power similarly for tie power if you take their same.

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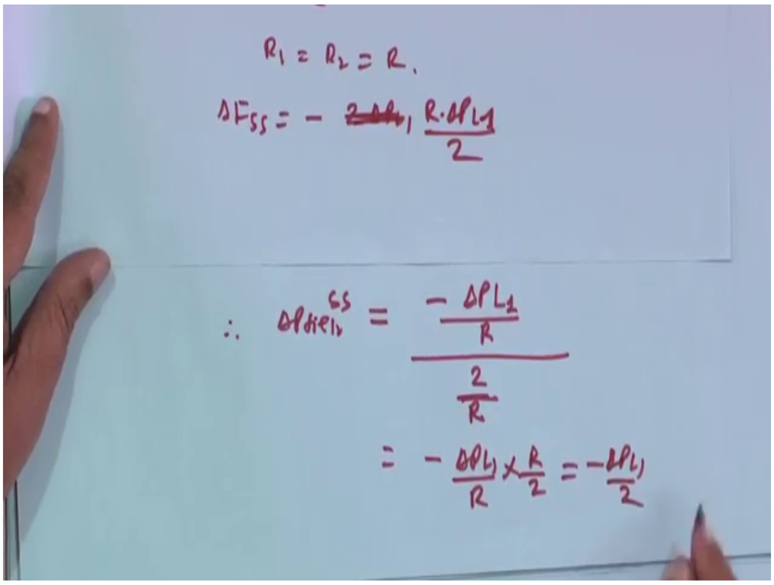

Then delta P tie one two s s steady state is equal to it is minus delta PL 1 divided by R we have taken both are same it will be two by R right; that means, minus delta PL 1 upon R right into R by 2.

So, it will be minus delta PL 1 by 2 right; that means, when D 1 D 2 is equal to 0 and both are your what you call R 1 is equal to R 2 is equal to R. So, if we write and separately then what will happen.

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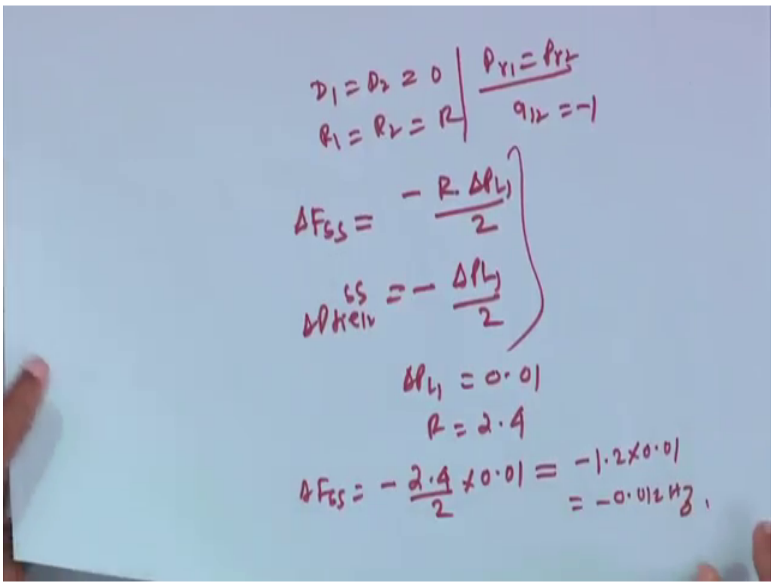

That steady state error delta F SS delta F SS is equal to you will get here minus minus sign is here right here it is minus r into delta PL 1 upon 2 and for tie line power delta P tie 12 steady state is equal to minus delta PL 1 upon 2 this is actually this will be very helpful for the numerical point of view. So, what we have done is conditioned here what we have taken we have taken D 1 is equal to D 2 is equal to 0. We have taken R 1 is equal to R 2 is equal to R in addition to that P r 1 is equal to P r 2.

Such that a 12 is equal to minus 1 right now for example, if delta PL 1 is equal to say 0.01 right and R is equal to 2.4 hertz per unit megawatt right therefore, your steady state value delta F SS will be minus 2.4 by 2 into 0.01 right. So, you will get it is your minus is equal to minus 1.2 into 0.01. So, minus 0.012 hertz right. So, this is the steady state value.

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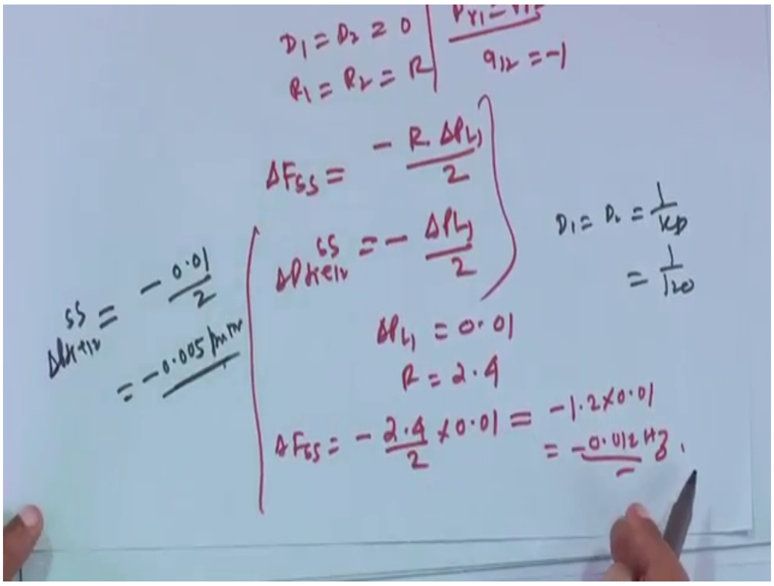

And for tie power making it here for tie power it will be delta P tie 12 steady state is equal to minus 0.01 by 2 per unit megawatt is equal to minus 0.005 per unit megawatt.

So, this will be very helpful for your numerical point of view just have a have some your this thing and if you consider that a D value D value I mean D 1 D 2 is equal to 1 upon your what you call K P is 121 upon K P. So, 1 upon 120 if you take D 1 is equal to D 2 is equal to 1 upon K P and K P is 120 means 1 upon 120 then you will get this value is slightly less. It will become minus 0.0117 hertz or if I recall correctly right, but this is a good approximation I mean very close actually and this is also.

Thank you very much, we will be back.