High Voltage DC Transmission
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Module No. # 05
Lecture No. # 03
HVDC Components Design

Let us start lecture number 3 of this module 5 in this last lecture there was some discrepancy means I wrote a wrong expression.

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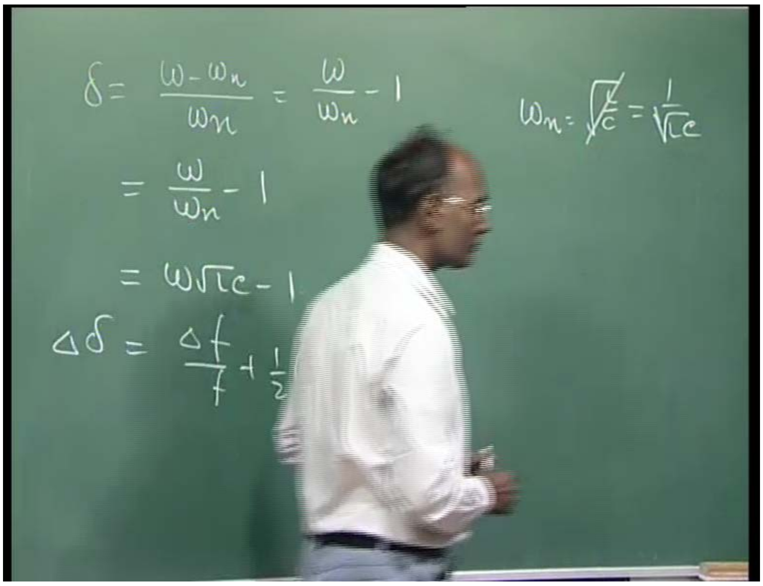

The delta which we wrote here, that is defined as omega and by omega n and it is nothing but your omega divided by omega n minus 1, and I wrote basically omega n is equal to L upon C which is incorrect. Nobody noticed it? This is wrong, it should be your one over LC. It was there, but later I think here if you will check your copy it was; we were getting somewhere minus c so, it should not happen. So, what we are going here omega L C minus 1 here, I think, at this point I wrote L by c so, that should not be there.

And here you know if they are going to change here, that we can write here, del f by f plus here, half delta L by L delta C by C. So, expression was same only here I think just I put under root L by C and that was wrong.

Now, today I am going to discuss basically here the minimum cost tuned filter we saw this tuned filter design here. Now, we have to see the minimum cost because the cost of the filter should not be more than 5 to 15 percent of the total terminal cost.

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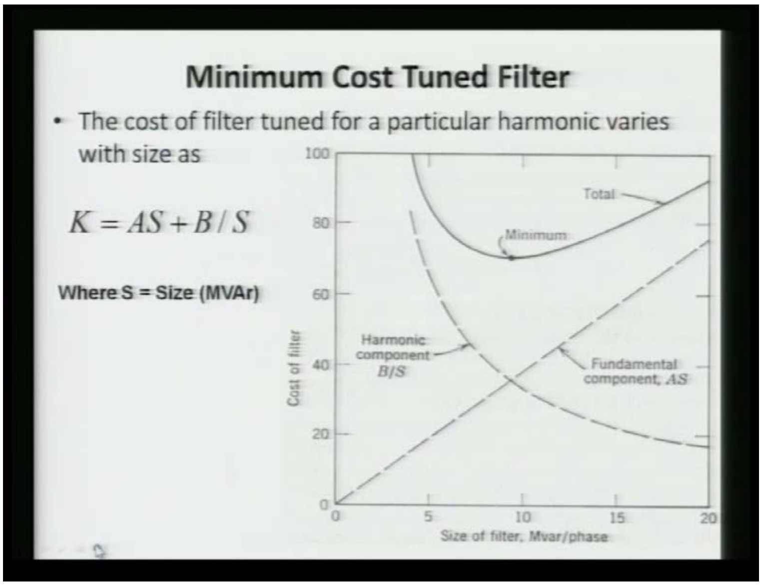

We will proove that the cost of filter. If we are taking k that is a submission of the two, that is a one is the linear quantity which is varying, with the size and size is just we are defining the size is in terms of MVAr and MVAr is basically defined in terms of the capacitor value. So, this is I will proof it also, this expression will derive. So, here you can say if the fundamental component here, the size of here is increasing, the cost of filter is increasing. But if you will see the harmonics component if this size is increasing, then the cost is decreasing. Means if you are adding both together we are having this curve almost means, at any particular point we will find the minimum value for which the cost will be the optimal for the given size.

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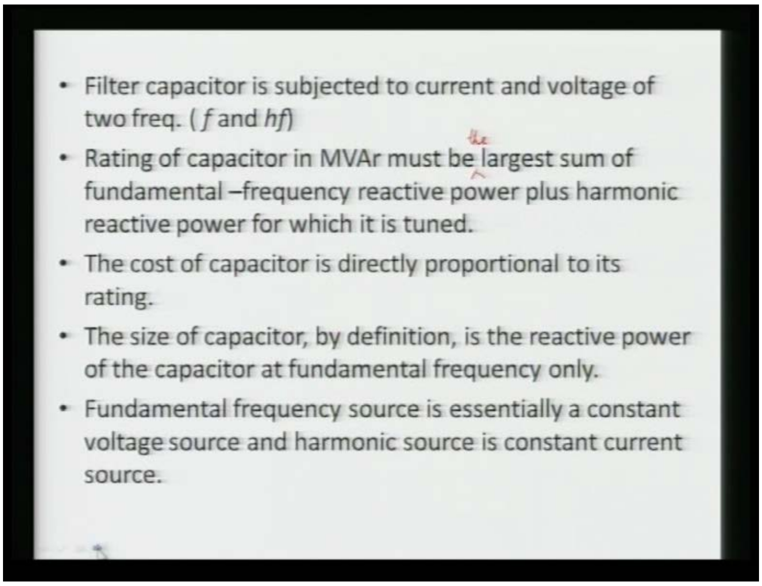

So, we will see that how we are going to get this a and b value? How we are going to calculate? This before deriving these are the fifth points that should be considered the filter capacitor is subjected to the current and the voltage of two frequencies. As we are talking here, a filter that is a resistance that is your R here C and then we are having inductance it is we are talking here the (( )) filter. So, we are having here capacitance here inductance so, in this branch no doubt we are having so many currents because this voltage is there harmonics currents are there. But this filter is fundamentally here your the fundamental component is there and then we are having that is one and then another is corresponding to h component.

Now, no doubt other component will be also, there because this resistance and capacitance will form some impedance for other currents as well, but this will be the significant, this will be more significant because this is designed it will be tuned here only r will be there. But other components will be there and for the other components this will offer huge impedance and finally, it will be not there that contribution will be very less. So, that is why it is said the capacitor here it is basically sustained for the two frequencies one is here, your f 1 that is a fundamental component and another is a harmonics component for which it is tuned it is designed and that is your f h.

So, you are nothing but f h, it is your h that component here that is a f 1. Similarly, it is true for inductance as well, it is inductance it is true for the resistance as well, the rating of capacitor now. It is a defined it not in terms of c value, it is not in terms of ferret we rate this in terms of MVAr. So, the rating of the capacitor in MVAr must be the largest sum of the fundamental component reactive power because, it is MVAr we are defining so, this two frequencies components are there.

So, this is if this fundamental components reactive power plus the harmonics components reactive power must be added so, that is the rating in MVAr the power reactive power it is q v. So, the cost of the here the capacitor is directly proportional to its rating means, if rating is increasing the cost will increase as obvious. The size of capacitor by definition is the reactive power of the capacitor at the fundamental component here. What we do? We say it is a 10 MVAr capacitor means, that how much reactive power it is giving at the fundamental component. We never count this because at fundamental reactive power, we are other frequency; we are not considering. Because this will tells it also provide the reactive power support at the fundamental frequency.

So, the rating here we are defining the reactive power based on this that is defined as s in that expression. So, it is only we are taking the fundamental component in terms of size of the capacitor, how but the; here, the rating here we are adding together. Now, the fundamental frequency source is essentially a constant voltage source because whatever it is connected here, we are having this v 1 but the harmonics component is the current, it is not voltage. AC side we are having harmonics what I said? This is your h that is n p plus minus 1, it is a AC side current harmonics, it is not voltage. However, the DC side we are getting the voltage harmonics and there is no current harmonics.

So, this harmonics component that is why it is written essentially here, the fundamental component is a constant voltage source here, the balance V 1 that is of that is supply voltage balance 1 and your the harmonic source is nothing but a current, that is normally it is given I h f .

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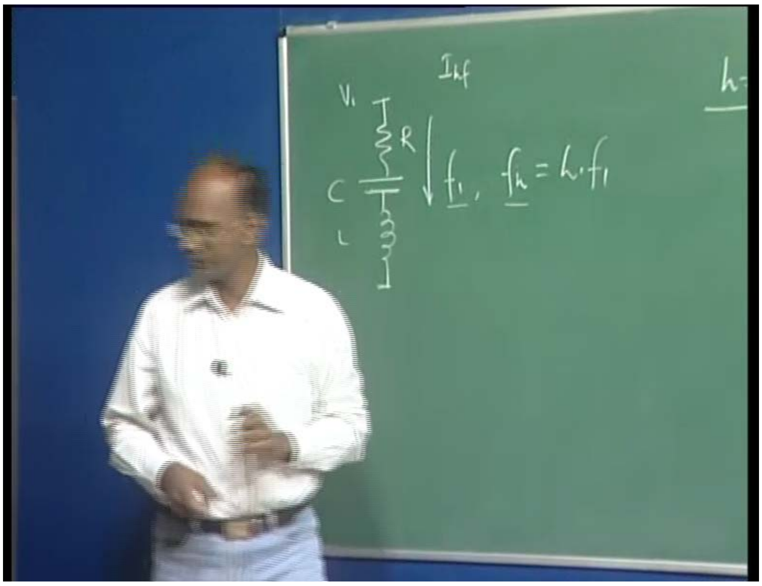

Why I h f? Because is a harmonics the particular harmonics current which is flowing so, this is a it is a defined that is a current which is coming. So, based on these two criteria voltage and frequency now, I will come to here you will see the rating of a capacitor. Size of the capacitor is S mind it. Rating is the total sum of the reactive power supplied by the capacitor at the fundamental component, plus the reactive power supplied by at harmonics component that is why here h f is there.

So, you know this is here V 1 is the fundamental component and this is your omega 1 C here, this value is there. Now, this is denoted at the S that is a size, that is in MVAr so, this is here replaced by S. Whole this equation this also we want to write now, in terms of S because in the previous the first graph I showed it was in terms of size and the cost. So, this is your S per phase and here it is your cost whatever the monetary value you are using and one was going like this, another was going like here means, your minimum total will be somewhere some value somewhere.

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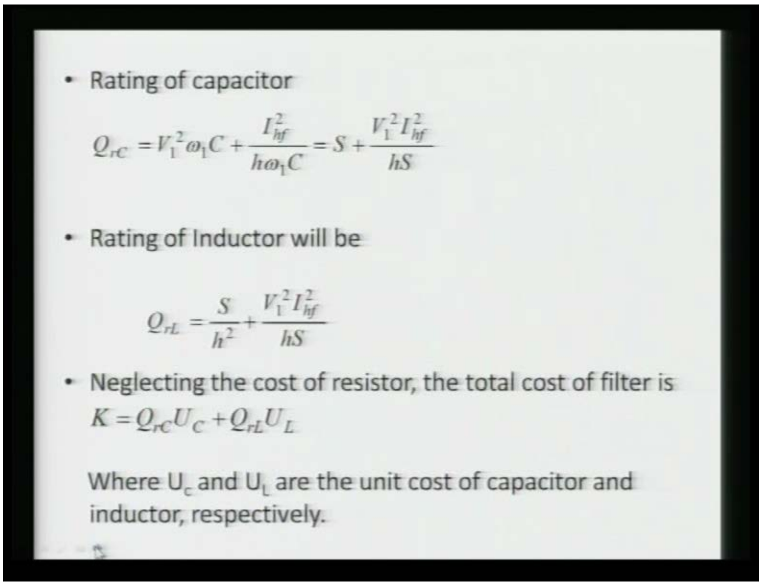

So, this is your size, this is the rating. So, total fundamental component here this component, this is nothing but you can see I square into x c. x c is your for this component here, it is a h omega 1 C h already here is there so, this is your harmonics component reactive power. Now, this component can be changed to this one, if you are multiplying here V 1 square here, V 1 square the V 1 square omega 1 and C is your S so, h is there and V 1 square is open.

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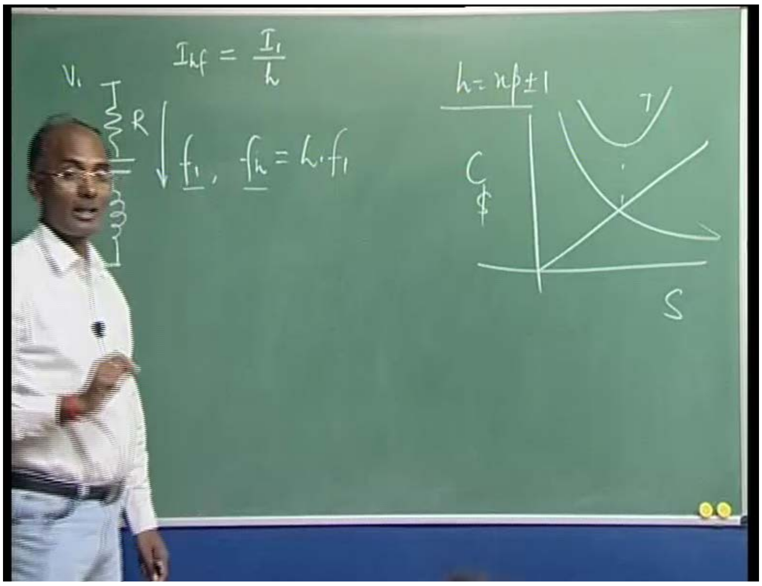

We want to express this because the V1 is your know it very well this current also you know because once you are analyzing the frequency components of any h th harmonics you can know what will be the current. This current this one, it is nothing but it is your I L by h ideally when there is no overlap we defined this already. But if there will be some overlap from factor here, will be coming into your picture. It will try to reduce some component already we summarize, that your overlap excreta will try to reduce the magnitudes. But this value which very small we can even though sometimes directly take this peak value and we can just work if u is very small.

So, this is your Q r C means, reactive power supplied by the capacitor. Similarly, to have the rating of inductor will be now I can write in this fashion. Now, how I can write? This is the final expression, we know this is I can write here Q r L now, the fundamental component I can write here it is your I 1 square omega 1 L. Because the current which will be flowing here inductor so, reactive power loss here it will be this value, plus whatever this current that is flowing h f square into omega 1 into here it will be h. Because this x L here for that that component so, here omega h will be there.

Now, we want to replace the L, we do not want the L at all. We know there is a some relation and also, we know this value your S it is your nothing but your V 1 square omega L C or I can write this in terms of I 1. I can write here, this is I 1 square, this x C your omega 1 into C. Now, we want to replace here this L and we know this your omega n it is your under root LC. Means, I can square it here so, this is square here LC 1 upon sorry is 1 upon just its current me it is LC. So means, your L is one over omega n, square into C or I can say, here is h omega 1 C. I can write this?

And then we can put this value here L means, we are getting your I 1 square omega 1 into here 1 divided by h square omega 1 square into C. Here, I can write your h f square h omega 1 here also, I want to replace this. So, your h square, omega 1 square here C or then we can cancel it means, this is a cancelled by this 1 here, your I 1 square into omega 1 C into 1 upon h square plus here this also cancelled with this. And this is the similar to this component of the first component here this component.

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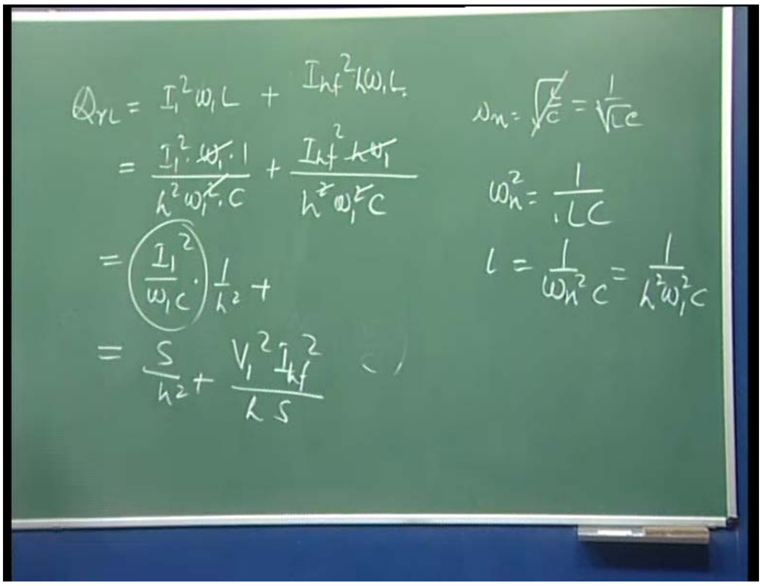

And it is also a valid, because the reactive power supplied at the resonance by the two will be equal because you know omega L here, will be equal to 1 upon omega C means x L is equal to x c. So, whatever it will give, it will be equal to that at the harmonics components, whatever it is giving it will be for the inductor as well at that particular harmonic. So, this value is now your S so, I can write S upon h square plus here V 1 I h f square, h into S this value we are getting the same value here. So, this expression is written.

Now, we can conclude you can see, this component at the fundamental component, the reactive power consumption if it is designed for the tuned filters for any h th harmonic here, this is giving S so, this is going to give a less amount this h which is a fifth harmonics. Means, reactive power it is generating, reactive power absorption it is of that value. So, that is why if it is a designed for any let us suppose fifth or seventh harmonics the reactive power generation is more compared to its absorption and that is why it works as a completely as a capacitor in terms of your fundamental component. So, here and that is a h square means huge amount it is varying so this is your q r l that is a rating of inductor is defined this is one way to define in terms of reactive power output.

So, from these two expressions, if the unit cost of the inductor is defined that is here I can say dollar per MVAr for the capacitor. That is, it is you see here it is the unit cost of capacitor means, it is the dollar per MVAr here we are talking MVAr. And U L is your unit cost for your inductors means that is, a dollar per MVAr reactive power support. By this one than your total cost will be this subjected to if you are ignoring this cost. This cost of course, is very very small, compare to these two costs it is no doubt about it because the resistor cost is very very small.

And in the tuning basically, this is independent term the tuning frequency because these two are the varies to tune this. This is only how much energy it is going to dissipated and how much damping it is providing basically for the transient disturbance. So, your k will be this one so, from this you can just put this value together for you are here, you can put the value for this from here. And you can put this value from here, you will find this expression here, just it is put it here and now you can combine together. And finally, you can see, we are getting the similar expression which we derive in the beginning here this b upon s it expression this curve.

Because the fundamental component is was rising here that is AS and your is your the harmonics component. So, one is decreasing and another is increasing means, we will get some optimal value somewhere at particular size the cost will be the minimum. So, we have to find what will be this minimum value and it is obvious that you can differentiate this K with respect to S and equate it zero, you will get the value of S optimal value of S and then finally, you can get the K minimum for that value, you can put it there.

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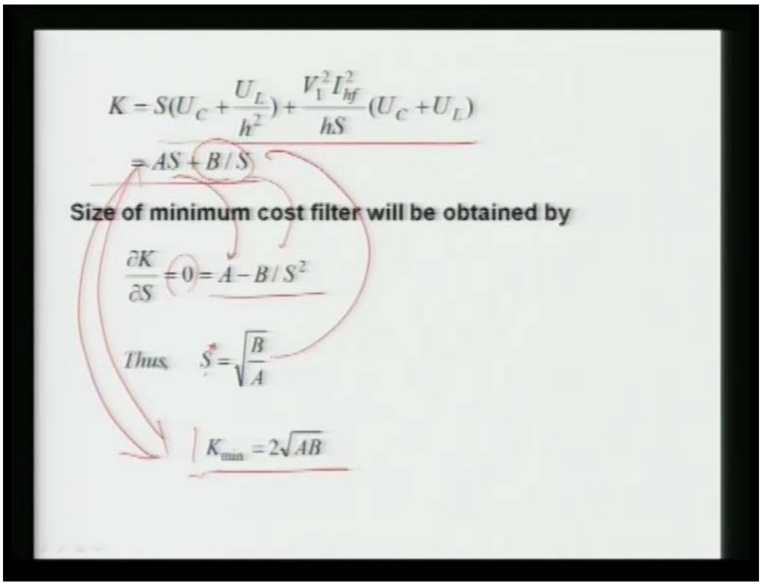

So, here it is basically, differentiated with us so, your this component if you are differentiating with the (( )) then it becomes only A. And if you are differentiating this you are going to get B upon S square and if you are equating 0 you are getting this S here that is optimal value here, you are getting B upon 8 under root. And if you are putting this value in the equation here, you can put this value in this equation you are going to get this K minimum value that is the cost will be under root 2 A B.

So, this is basically the optimal design of the capacitor. So, basically based on your A and B values, these values are calculated, these values are basically defined you can say what is the A? A is basically the unit costs of the capacitor and inductor in terms of some harmonics components for arising. Here also you can say the B component this is S is down here and this is A V 1 this is a supplied voltage this harmonics current what is magnitude of this and these cost and h component is coming into the B.

So these values are known to you this cost is you know the, what is the cost of inductor? What is cost of capacitor in terms of MVAr per unit? Harmonics component you know for which this is a tuned filter. And V 1 is your supply voltage that is a given the fundamental supply voltage and I h f is the current just you have to calculate based on the fundamental component. For example, let us see 1 example, how to calculate this?

Let us suppose, you have been given a 1 example here, just I can take it, that is a it is said that is a plus minus 300 k v bipolar system is there and it is consisting of 4 bridges. So, it is the 4 bridge of twelve pulse converters, then we have to see twelve pulse means here, the 4 bridge means, it is a 1 bridge here, here 1 bridge. Then it is simply you can say, it is your transformer here, that is your star, star here another transformer this is your star delta. So, two bridge basically forming twelve pulse. Then remaining here, it is forming 4 negative side of this so, these are the 4 bridges means, it having completely 4 bridge one side. It is not said the 4 bridge per pole, it is said 4 bridge in total so, the 4 bridge here means the two bridge per pole.

This is your DC here it is going and this side also we are having. Now, in this What we have to do? What is the voltage across this? We require the fundamental component that is coming here the V f. So, the AC side voltage is given to you, this is AC side voltage is given 235 K V this is line to line voltage. So, here this mind it the expression just we used here this the V 1 is the phase voltage, because we are talking whole calculation the per phase the cost here is the per phase not for the total. So, here the whatever it is given by under root 3 will be there. Now, you can calculate the current also here this total power is given of this link, total power it is given it is your the current is given 1 kilo ampere.

Now, you can calculate the power, because this is 300 this is 300. So, it is 600 voltage multiplied by this power, this power basically is coming here divide by 4 means, all are sharing the same current power. So, power you can get from this side I L 1 means this is your AC voltage. This total power means, P dC it is your 600 multiplied by one, this is in k V, this is in k V so, we are having 600 megawatt. Now, the 600 divided by 4, it will be the power coming in one. And then you can require this p AC here in terms of power factor you can calculate and the power factor is also given here for this the power factor is given 2.88 6. Means for this it is given power factor is this value is already given to you so, what happens just you can see this a DC power.

This is your 600 I can say this is your under root 3, this is your V 1 into your I we want to calculate this I L here I L 1 into cos fie. Here what we can do? If we are taking the V 1 as a per phase, then it will be 3 times if you are taking line to line, if you are taking this value directly what happens only this you are getting confuse if it is nothing said it is always line to line. And whatever this expression, we are using the per phase value. So, if you are taking this here V 1 in that V, then it will be 3 times here. So, what we can do? We can; and this will be your equal to your p DC.

So, this is your 600 megawatt again always you should be very careful about the megawatt means, now this should be in kilo, this should be in kilo then kilo, kilo will be megawatt and we are not going to here multiplied by 10 power 6. Otherwise we have to put here 10 power 6, we have to put here 10 power plus there and here also the same value you can get it. So, this is equal to your 3 here 235 divided by under root there this is a K V and into your I L 1 and your cos fie is given 0.886.

Now, this will be by 4 of course, because if you are talking only current here the total current you again divide by 4. So, it will be this here the AC will be at multiplied by here divided by no this total power will be total AC but this current which is we are taking now it should be multiplied by 4 here. So, this current is one current we are talking here so, this will be basically multiplied by your 4. Same here divide by 4 of course, so your I L 1 will be your 117 means 1700 by 4 ampere, this will come this value.

Now, this is your r m s value, there also h 1 f we are using the r m s value because in reactive power this value is not peak value here. This value is the r m s value is not the peak value, we are talking it is r m s value, here also this is r m s value so, there is no peak value concept here. So whatever if you are analyzing the furious in this, you are getting the cosine and sin component those are the peak value. The components that is a n b x components are the peak values are coming so, you have to convert back to again back to you r m s value.

But here already this value is your r m s value, this is r m s value because this is r m s, the r m s everything is r m s so, it is r m s value. Now, I want to calculate what will be your h f? It is ask for your fifth harmonics so, h is 5. So, it is your I L1 divided by 5 and the total value it is coming to be 85 ampere because this divide by again further five so, that will be 85. Now, if you consider the factors, of your u and the delay angle as I said some factor is going to multiplied by some k factor.

Since, we did not analyze for how to calculate this k factor? We are not going in the detail also, because otherwise for the different u and alpha, you will get the different factors again it is a very difficult to calculate. So, if it is given this factor, then it should multiply that factor, if not given take as a unity means that is ideal means u is zero means it is nothing said. Then put this value there, for other here calculation of the cost you require U L, you require U C. You can see, in this expression, now we have the h value, now we have this value. This value is 235 k v divided by under root, there you have this value only we require these 2 values, this is given to you what is the cost and the cost in this example.

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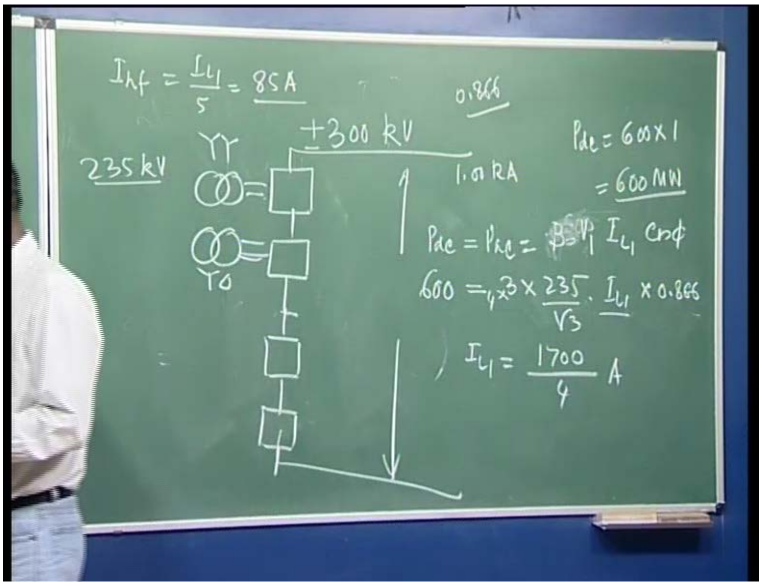

It is given this is your cost of capacitor it is given 3.5 dollar per K V A r and this value is given 8 dollar per K V A r. So, here if you are multiplying, this value now S if you are not changing in the MVAr this your cost will be in the K V A r. Means how you are taking? This is AS value f we are taking here, this your values are if you are taking in the k here k excreta then you have to go in the k v a r otherwise this k v a r you have to convert in the MVAr or then you can put directly no problem.

So, what happens if we are going to put this value, your a value we can take here this a value it is U C here it is a 3.5 plus your U L that is 8 by 5 square here, this will be basically coming 3.82 basically dollar per k V A r. So, here a we are using in the per

KVA r now size you are going to use in the K V A r also. Here, this value which we are going to use it is should be also in the K V A r. It is not in MVAr if you are using this k So, this should be in a, if you are using here k and k then it is becomes MVAr mind it. So, we can go for your B value or you can simply because we are taking in the M V r s here, you just simply convert this value (( )) per MVAr into the 10 power 3.

So, it is your dollar 3 8 2 0, because here again create confusion. So, always if it is defined and derived in the same unit convert and then begin itself. So, here will be your 3 A, 3820. Now, your B value here this will be we can take from here the V value, V is your V 1 square into your I h f square, U C plus U L divided by your h. Now, this value we can put 235 by root 3 of square, into your I h f if you can take 85, you can take otherwise factor so, it can take 85 so, it is 85 into. Why I am writing minus 3? Because I am making in kilo so, this kilo, this kilo now it becomes m v a into this should be added together in the per M V A r.

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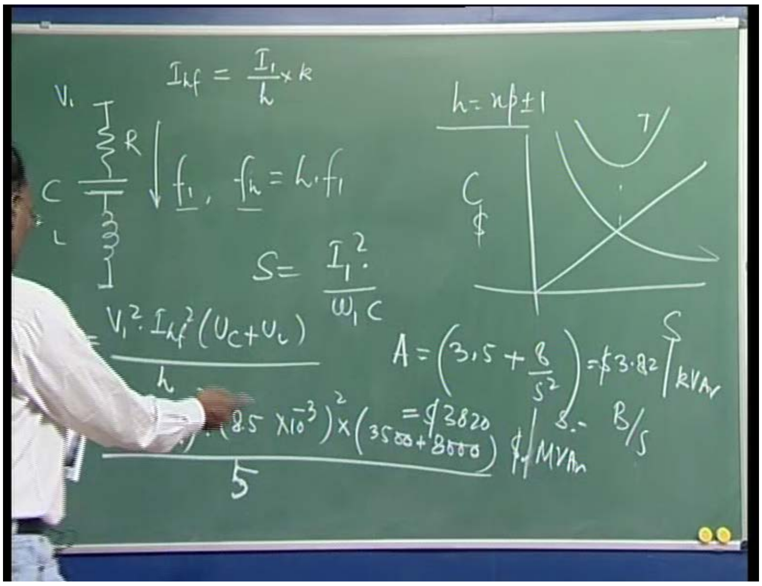

So it is your 3 5 0 0plus 8 0 0 0 divided by 5. What I did? Here 3.5 this value means 35500 per MVAr, this is 8000 per MVAr. We put it here because everything now it is in MVAr. So, this value is not in MVAr actually in 2 MVAr because already it is B by S. So, it is in dollar so, this value is going to be divided so, into a MVAr here means dollar MVAr I can say. A was the dollar per MVAr here this is dollar MVAr because divided by S here. And this value if you will calculate you are going to get something basically, we require here for the minimum value of the size of the S can be determined just put A and B you will get this value, now it is in MVAr.

Because this is also in the here this is the per MVAr it is here into the dollar MVAr so, this is going up back and a square root means, we are getting in MVAr. So S value is coming around 9.32 MVAr per phase, this calculation hole is for one phase. So, if you are having there phases means, you require the 3 different tuned filters for the different phases. Then you can again put this value, you can get the cost. What will be the total cost? And the cost is approximately coming to with the 71000 US dollar per phase. So, that similarly, you can calculate.

So, this is one illustrative problem how to calculate? Basic problem only happens this formula excreta is very simple. Only here you have to mind about your unit conversion here, you have to be careful about you the bridges excreta. Because here the how the bridges are formed, once this picture is clear than you can calculate it. Once it is not clear, once your simply your I L is not correct, everything is wrong.

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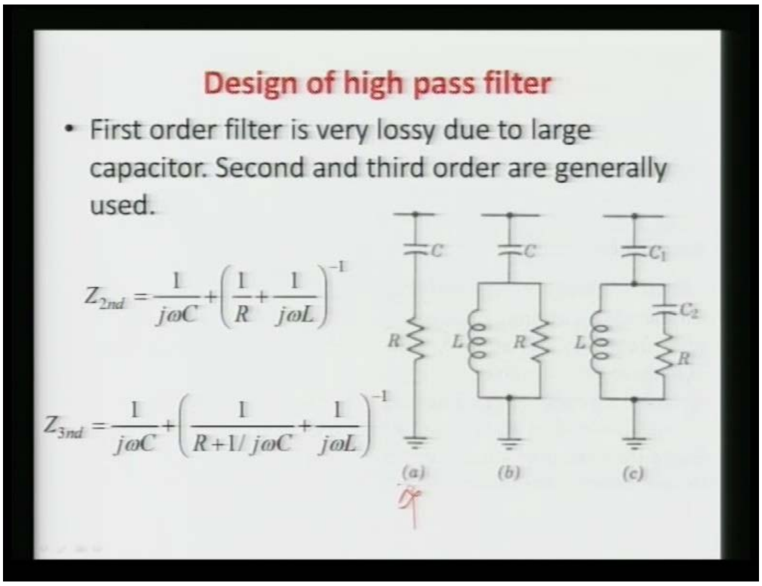

So, this is your one of the illustrative problem that is I just tried to explain now we have to go for here the design of high pass filters. So, till now we just saw your tuned filters, but for other harmonics component if they are significant, we normally use the band pass filters. So, that the filters of particular harmonics onwards should not enter in the AC system, whatever characteristics or uncharacteristic harmonies are there we have to take care So, normally you can see this a filters here the diagram, this is a it is basically first order filter.

In the first order filter it is nothing but r c filter we can you know the band pass filter or simple bed pass filter is a r c filter. And here you can say, this capacitor here is only one capacitor is here, which is large capacitor is require to sustain this voltage. And thereby what happens? This is a very lossy and it is normally not used. So, we go for this higher order band pass filters and the B is your second order here, it is your third order you can say if you are keep on adding the elements the order is keep on increasing. Means, you have to make a combination of LC, if you are having one c r L it is a first order if you are having 1 L1 c it is second order.

Now, you are adding here the 2 c 1 L means is a third order. So, normally second and third order are preferred and now you can say based on its impedance here, the r LC here, we can write the impedances here. Impedance here, it is this one over omega C plus the parallel combination of this which is written upon r plus 1 upon omega L inverse of this is added. Similarly, here now we are having this series, with the parallel of this L this series now, parallel of L and then C is here it is added. Here, only the mistake I have done here the C 1 and C 2 are there so, both C is a written here. So, I can say it is your C 1 here it is your C 2 in this case, it is simple C.

So, this is your impedance now our idea is not to know only the impedance, now our idea is not to know only the impedance, because these impedance r LC are designed in a such way fashion so that we can know what is the quality of this? And then we can tune so that we can have a very good characteristic and the characteristic here. Now, you can see for the second order onwards here you can see this is your characteristics. For the varying value of your quality affecter you can say if your quality factor is increasing now just see it is going to be a tuned filter q just increasing.

You can see now, here the q is very less now it is just coming here, it is a just flat. We require this is of component, where this should be passed and this is blocked, again how you are designing means it is a it is a providing the minimum impedance for higher order. High impedance for the lower orders means, it will only allow to pass the higher order onwards. So, once you are increasing here, you see this quality factor this component is keep on rising and normally it is becomes A your say tuned filter.

So, we will see how these expressions are drawn? Means, we can derive expression here in terms of frequency and also in terms of impedance like we draw for our tuned filters here, and the final expression will come here. So, let us here derive this expression so that we can know how this q is going to affect your.

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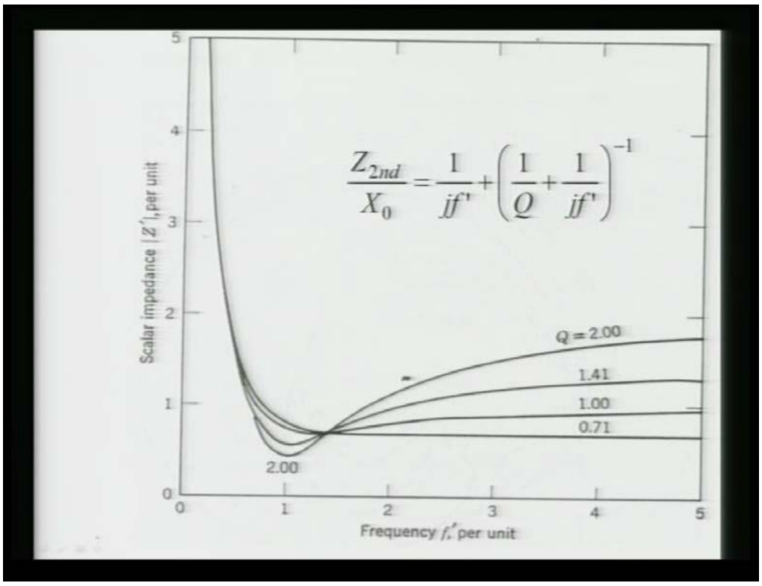

This impedance this impedance basically written as z 2 prime means we are just diving by x naught. X naught is nothing but in terms of L n C here if you remember earlier we define here your L upon C. We can have the omega n it is defined over one over LC whatever the value of this there will be some tuned frequency omega L for given one and C values. So, this is defined in this term and we can write this quality factor in terms of x naught. What will be this value? R by X naught or X naught by R? It will be X naught by R. So, I want to go back the impedance which I wrote here.

So, z second means I can write z second it is your, I wrote it is one over j omega C plus here one over R plus 1 over j omega L here it is inverse. Here this Z the prime we are going to get Z upon X naught value means. We are talking the per unit value so, and another term here f naught prime it is you f upon f n or I can say omega upon omega n. Now, here see this value we want to let us multiply and divide here I think this can you remember this value is correct? Its correct. So, here I can just multiply here x naught here in whole and then I can divide so, it is one over j omega X naught C. I just multiplied and divide here so, it is cancelled out here plus here I can write X naught by R because this is the inverse mind it.

So, here if outside if multiplied here divide by here means it will go up here plus your X naught by j omega L inverse. I can write this now see, what is this value X naught C this is X naught it is your under root l upon C it will be omega n 1 by omega n. So what happens this it is your X naught 1 over j omega divided by omega n. Now I should be very careful because last time we did not notice and I did some mistake. So here it will be omega n now plus this value, it is Q now, what will be this value? It will be your one over j omega divided by omega n I think this will be also the same. Because this is similar fashion, here it was combine together here is omega L upon this and this.

We are going to have this is x naught 1 over j f prime as per our definition here plus, here Q plus, here j f prime, here that is a inverse. Basically here this is a complete bracket now, this will be divided this side so, we are going to if we remove this, we are going to have z second prime. But I think our expression is coming something here one upon Q should be there the final expression I think why it is so?

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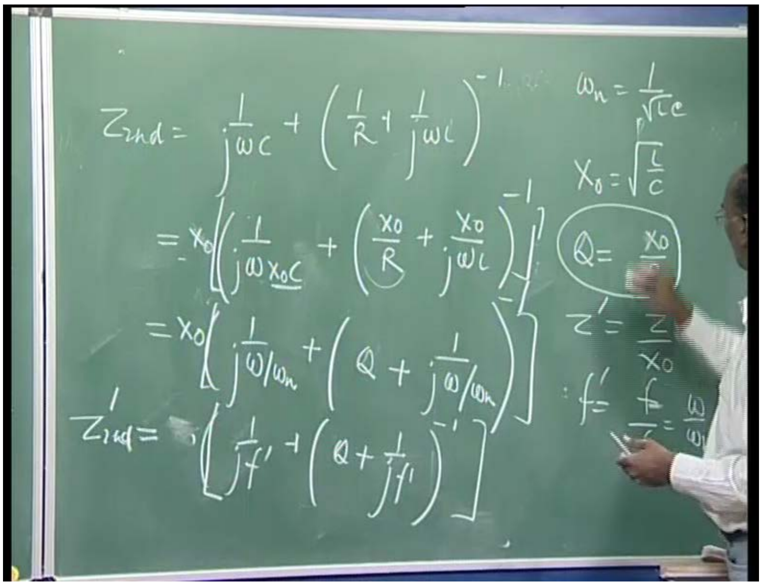

This Q is, that is why I am just doubt here your this is X naught if you will see just the last term what we got? This it was your under root L upon C. Then it is I can say omega n L upon R so, this is your nothing but under root L 1 upon LC so, this is going to come this omega n is 1 over under root LC into L divided by R mean it is your L upon C divided by R means X naught upon R. This is correct, its correct, it means the expression which I wrote is not correct. So, here this is your Q is not 1 upon q it is q so, we are doing correct. So, there is no problem, but here since this value is coming 1 upon Q but it will be always inversely proportional it will come because already this inverse is there.
So, if you are keep on changing this value this magnitude here will vary in this fashion.

Similarly, we can derive here for this whole this scenario we can get in this form what happens? You can say this is j omega C 1 here your l part here another C part 1 upon f is coming here this is a coming 1 upon this it is true. And you can see here it is having the different scenario if you are changing Q it is going very fast here you can say 0.77. It is this and we are having since second order so, there is a 1 here the peak will be keep on coming is a third order because 2 C and 1 L l is there. So, normally the second order filters are very permanent because it gives complete bypass. Because you saw this previous figure it is a very perfect compare to this.

Here you can see this is just like your straight line if you are having low quality so, whatever the frequency component f here beyond that is you can just pass it. Means it will provide the minimum impedance for higher component here and this it is nothing but your f upon f n this is f prime. So, this is the basically the band pass filters.

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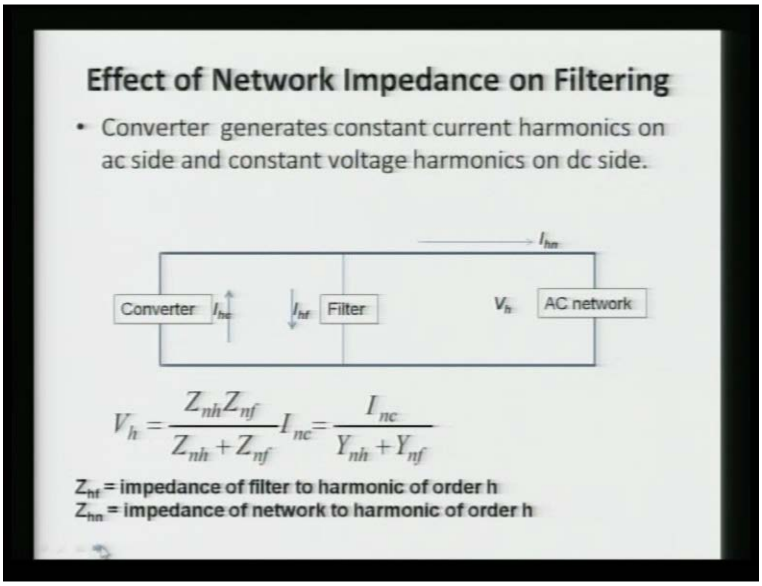

Now, we have to see another aspect of this, that is you know this is the k th when the filters are there is no parallel impedance excreta. This is analyzed in isolation but it is not so. Because we are having the filter impedance, we have the network impedance, as well and then we are our harmonics current generation. This is basically converter which generate your the harmonics component and that is a current source it is not a voltage source means, the harmonics currents are generated.

So this current which is flowing now it is going to be through this filter and through the network this is a AC network. While, analyzing all this we assume this side we do not have anything here. So, everything is going through this but it is not so, because your network is having some impedance and that is it is called if this impedance is called your the network impedance at the fundamental component. So, Zhn here this a impedance of network harmonics of h th order, no doubt this impedance here the network impedance is having the impedance for the fundamental component this is a AC and that is required because this should be there the network the fundamental component.

But it will also offer some impedance for your harmonics order if it is designed for fifth. So, for fifth if you will see at the filter terminal it will be having some impedance so this h n here. It is written means for order h impedance fundamental is there which is hardly matter we want this fundamental component should go there or should come from the network hardly matter. But this filter which is a designed for h th harmonics so, this current which is flowing here, remaining it is going to the network, if this network is offering the infinite impedance. Than total current will come here means this is a open circuit. But it is not possible another option that if it is offering the short circuit means zero minimum impedance than the filter is having no use. Because the total current will pass here whatever the filter you are designing it has no meaning, because that current will go to the network as well.

So, that is why here it is written if the impedance of the filter is your h f this is your h h f and this is your h n impedance. So, this current which is flowing here that is your harmonics component of any harmonics component it is divided into the 2 part 1 is through the filter another through your network. No doubt we are dividing the here network that it should provide the minimum impedance. 1 option the minimum impedance here, is going for the tuned filter here, let us suppose, you are having this is your resistance this is your inductance, this is your capacitance here if this R is 0. This is a short circuit at the that h f means your here this h f here it is zero, if R is zero.

Because this we are talking the impedance of this filter at the h th harmonic for which it is designed. So, this will be zero if R is zero but we never keep zero because we want some energy should be dissipated that harmonic component and also, me damping otherwise there is a some oscillation here the sustain oscillation will be there energy charge and discharge. So, that may create problem so, we should have a some circuit here some resistance R and once you are putting R here now it may be comparable to your network impedance. So, that is why here the voltage that is a we can write whatever the component here.

There we can calculate this what will be this voltage now what will be the component. Now, this is nothing but your v h I can write here it is your I h n into your Zhn and I write this voltage whatever this current? Multiplied by its impedance. For that harmonics component so here I have written now your this h n in terms of I c will be your I can say

I h I basically all this h it is looking like n, this h we are talking here hopefully this is slightly, this h n are here this is a this is a h n and here it is say h n here.

It is basically change here h n here it is a h f here it is a h f h means we have particular harmonics order f for filter n for network. So, here just why here this h f is written h f means for filter and h th harmonics similarly, the network here this is your for that harmonics so then it is required that is we should write here. So, from this figure we can write simply if it is your V h it is nothing but it is your I h n into your Zhn here is a network of that component, and this value we can write this I h c into what will be the current here, this current it will be in this current the impedance which is multiplied by the current.

We want this current this impedance multiplied divided by the total impedance its true so here we can write this z h f divided by your Zhn into z h f into I can write Zhn which is written here in this expression R in terms of admittances.

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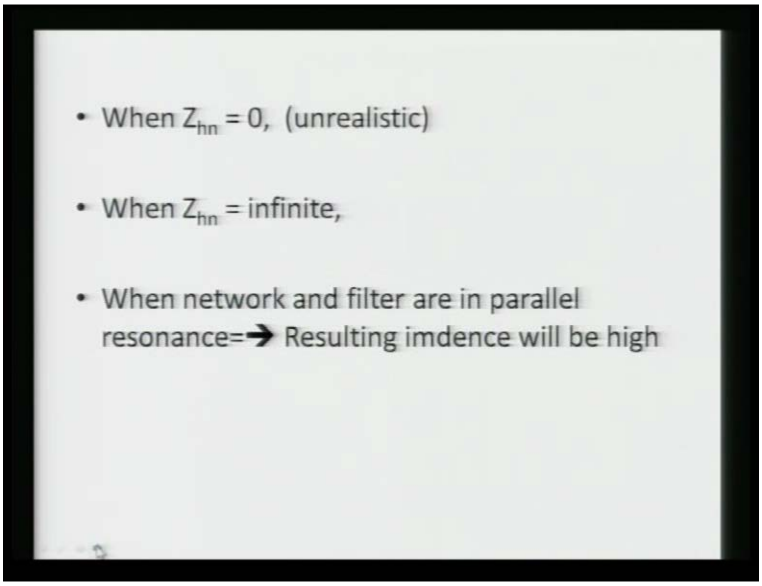

We can just divide here we can write in this fashion now, you can see what will be the voltage and what is the impact here? As I said if h n is there is a possibility that your network impedance is zero for that harmonics component. Although it is unrealistic, but it means, that it is the filter is of no use and whole current the harmonics current is a going through your network rather than filter so, whatever you are designing filter has no meaning.

But it is no doubt it is a unrealistic so it is your filter I can say filter effect is nil, another here this h n this network one that is infinite. Now, it a behaving open circuit whatever this is now, it is the pure condition when the harmonics generated is passing through the filter it is not going to the network and this we require this condition. If this is there, it is basically the ideal condition I can say, but it is not possible neither we can have the infinite nor we can have zero means, it is in between and therefore, the network basically and filters are in parallel and sometimes they may form the resonance .And even though if it is a forming resonance in the network here.

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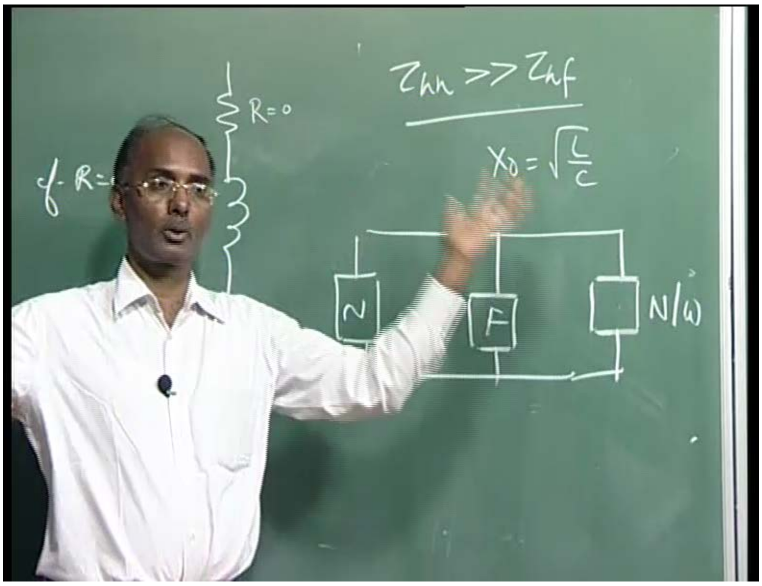

This is your source converter, this is your filter, this is your network, this is I can say network this is your filter, this is your I can say source of harmonics. So, there is a possibility here if impedances are resonating each other than huge voltage arises across this and that is also, not yet desirable. But in the most cases what we want that your Zhn should be large enough than your h f means, that is the case when we are having this condition so, that it should not enter to the network and it should go down one.

So, we design the filter to make this, what we do this one, it is in our control this is not in our control because the network as a whole you cannot control. This component you can have and here you have the parameters. So, the option here, that you have to decide the impedance for that 1, for the impedance you know this is already at that frequency it is zero at the tuned frequency these are the impedance here zero only this is contributing you make as minimum as possible.

But at same time you have to see, there should not be any resonance and also this should have a some should not have a not the oscillation circuit. It should the damped properly damped so, this is basically impact of your network on your the filter design so, whether you are going for the tuned sfilter or whether you are going for band pass filter these impact will be always there. So with this I can end this lecture of your filter design and the harmonic analysis part is over next we will see the grounding and the your DC line in this 1 and then this module will be over. Thank you.