High Voltage DC Transmission

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Module No # 02

Lecture No # 12

Let us start lecture number 12, and this will be the last lecture of this module that is a converter analysis, and this lecture will be addressed towards the Converter Chart. And in this chart we will see, the AC quantities of network site and also we will see, if we will change the axis like in the previous lecture, I discuss that if your axis or your voltage and current, then we draw the various quantities that is the DC quantities alpha, delta and u.

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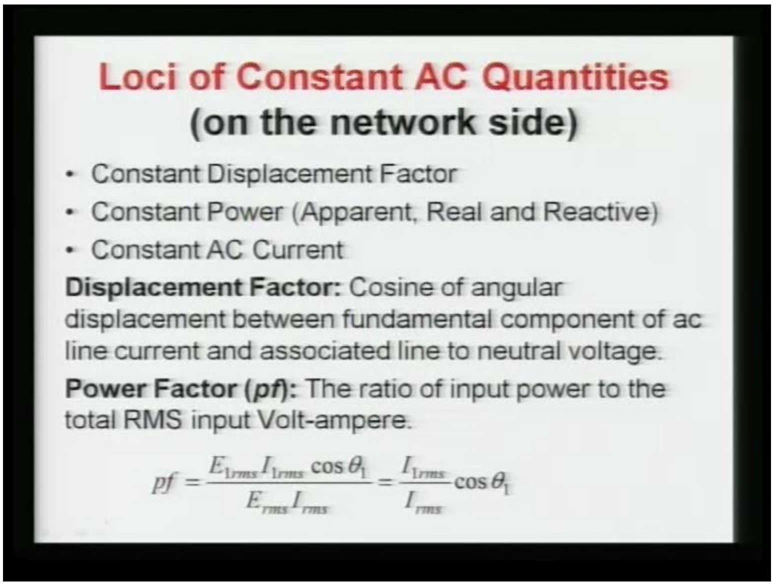

And today again on same axis, we will we will see the characteristic that is called the network site, means we are going for the AC quantities. AC quantities in the network site although so many are dependent to each other, but we can say that is, it is the three different, one is the displacement factor and another is your power, and another is your current that is a AC site. In the power, we are having the three different powers, apparent power, real power and active power, no doubt the two can give the third one, it means they are the dependent, so two are independent.

Here I m going to draw the displacement factor, not it is your simple power factor; to to know the difference between the power factor and the displacement factor as it is name the displacement, means it is the first we have to define what is the displacement angle. Displacement angle is the angle between the voltage phasor and the fundamental component of current that is angle is called the displacement angle. You know it is only the displacement factor is valid, if your loads are non-linear or your having some power electronics load, then means they are from harmonics are also appearing along with the fundamental.

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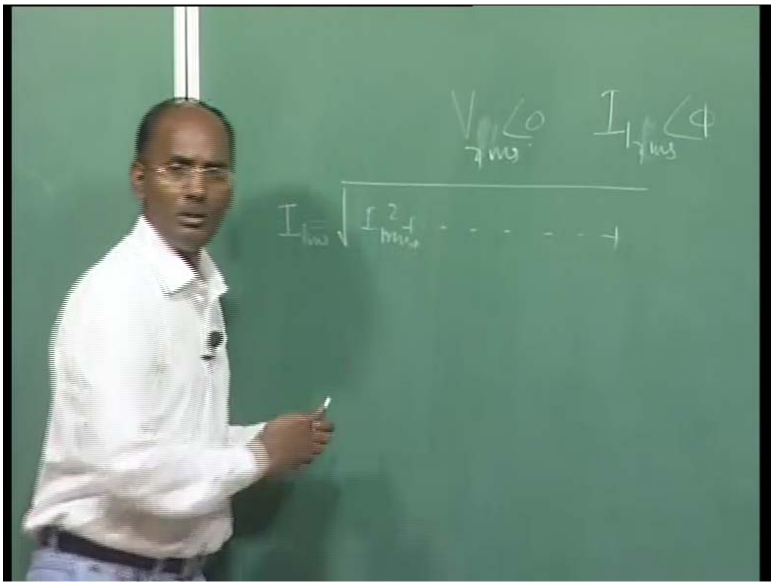

So, your displacement factor is basically angle between V that is you are applying the source in this case, this V is p and then you are having V 1 and it is a phase current. 1 is your fundamental component of the current, which is showing in that AC side. So, the angle between this basically, we are if it is angle is 0, what is angle here if it is phi and then cosine of this angle is known as the displacement factor.

We know. This is a another component here. I 1 if we remember it is the rms value here, I am not going to write 1 it is basically rms value of all the component that is added together. So, this is you know it is a define as this rms, the total rms I m talking which is suppose having a current having. So, many harmonics including fundamental or whatever you can say.

So, this one is your rms it is nothing but, you are I 1 square plus plus all the component of this but, here we are taking only this component. So, you know always this value is larger than your this value, it may be equal if other harmonics are 0, so we are going to have the same. So, it is your cosine of this angle between the voltage, because we are injecting the sinusoidal voltage there is no voltage harmonics in AC side.

AC side we are having the source is a balance three phase supply, only the current is having harmonics and that is why we are having the fundamental component for that phase current and the angle between these two is the displacement angle. And the cosine of this, so it is a define the cosine of angular displacement between the fundamental component of AC line current as well associated line to network voltage this a phase voltage. And now the power factor as I said if you are not having the harmonics, this will be the same and then it is define; so the power factor is basically the ratio of input power input power always, we are talking about the fundamental here power which is coming into this source.

So, the input power means that is your V 1 means (Refer Slide Time: 04:13) that is a already V p here is this case, because we do not have any harmonics on the voltage side. So, we are having the I 1 rms here, is basically we are talking here in terms of we can say simple rms here and this is your rms it is written in this expression and here, the displacement factor. So, this is your input power, that is the fundamental component power corresponding to that input taken from the AC AC side divided by the volt ampere; the total V rms here, divided by here I rms. So, this value is always you can say this value is always larger.

So, your the power factor is less than your displacement power factor, because this value here you can see I 1 rms divided by I rms, I 1 rms again that I said this is the first component here this case it is rms here. So, the ratio of this two you can say always here, this value is less than unity. So, the power factor refer the what side and this is called you displacement power factor.

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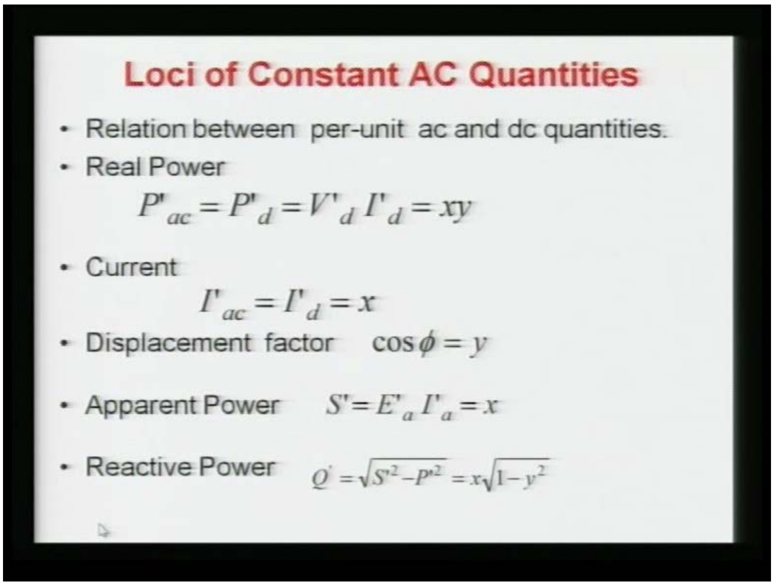

So, whatever we derive in our expression I am coming to that equation here, we are going to draw the AC side quantities. I will come here if you will see the displacement power factor here, that equation we derive in terms of cos phi is equal to y.

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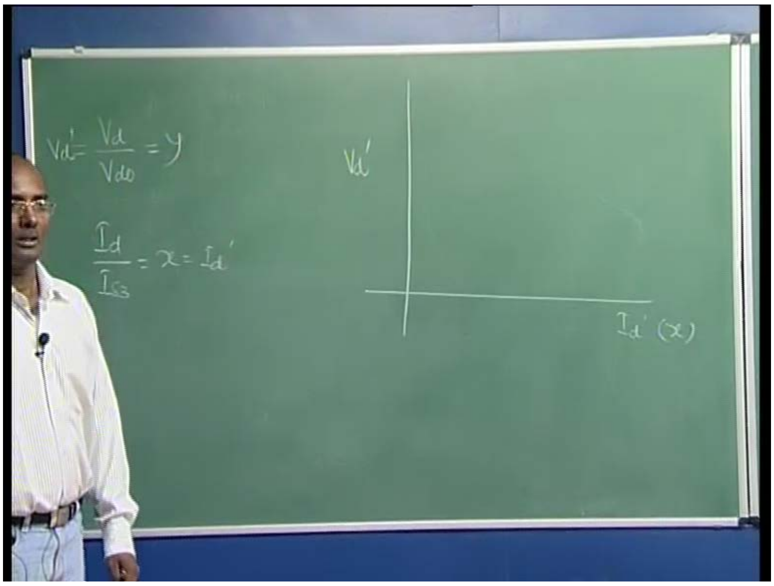

Another thing here again I just remind you here, V d upon V d o, we are taking is as y because we are drawing the voltage per unit voltage on your here y axis. So, this is your I can say V d prime, so this your V d prime means your this axis. And your x axis here your I d divided by I s 3 and it is your x or I can say I d prime means it is in per unit;

because you are dividing by here the base value and you are getting the per unit and this is your I d prime or you can say it is a x axis. So, already we draw for the DC quantities if you remember, we draw for our constant alpha, constant delta and the constant u already we saw the characteristic.

Now, in the AC side, we are going to draw this things real power current again it is the AC current here, displacement factor, apparent power and also we are going to draw the reactive power. Now see, how we are going to derive all these expression first one, let us say as I have written here, it is your real power.

We are believing the real power which is coming out the converter is equal to the AC site, because it is we are assuming your transformer as well as your converter is loss less, is ideal case there will be some loss no doubt. But, we are assuming here, that is why the per unit power in the DC site is equal to the per unit power in the AC side, that is ideal case and we are drawing here all the characteristics for ideal case.

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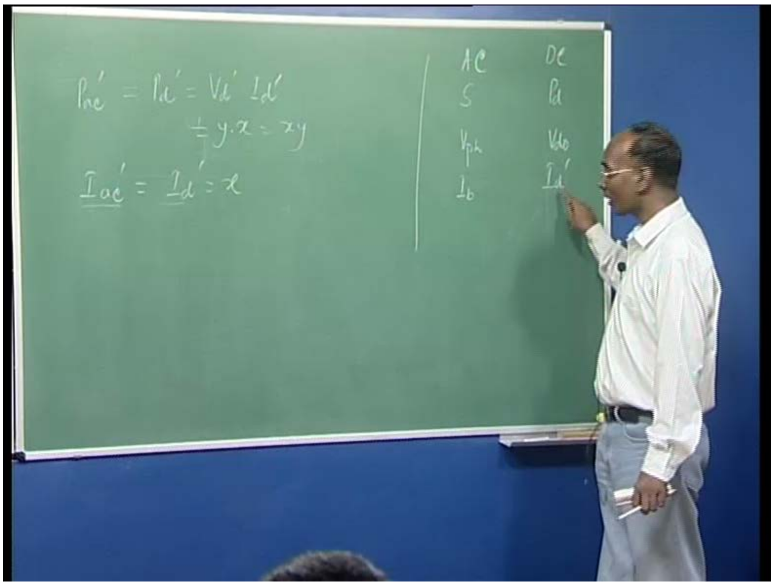

So, we know we are going to draw here, the P a c that is the AC site in per unit that is equal to your P d in per unit means it is your V d per unit multiply by your I d per unit. And already we know this is your nothing but, it is y here it is x means, we have having x into y characteristic. And that is why here it is written (Refer Slide Time: 07:52) the P a c is equal to x into y here, if your x varying it accordingly for the given AC, what will be the y value or x value that is we can draw.

Another is your current here, this is your current (Refer Slide Time: 08:06) here this your current I AC prime here, it is I am saying it is equal to your I d prime and it is your x. How it is true, how no current cannot be be both side it it is not guarantee, it is not necessary, because you know here, what we are taking the voltage on your primary side, what is the base value. If your AC site base it is your power here DC site we are having the same power here the p d the base value is same both side, power is the base both side.

Now we have to see what is the voltage different from the rectifier end and this end, so that will be the not same, because the base value this site it is your V phase base value, but this site it is your V d o just you see it. So, the base value, here this side, here this now, we have to calculate what will be your current base here based on these two AC side. Similarly, we can have here I d prime, we are taking the base that is here that is your your base value is I s 3.

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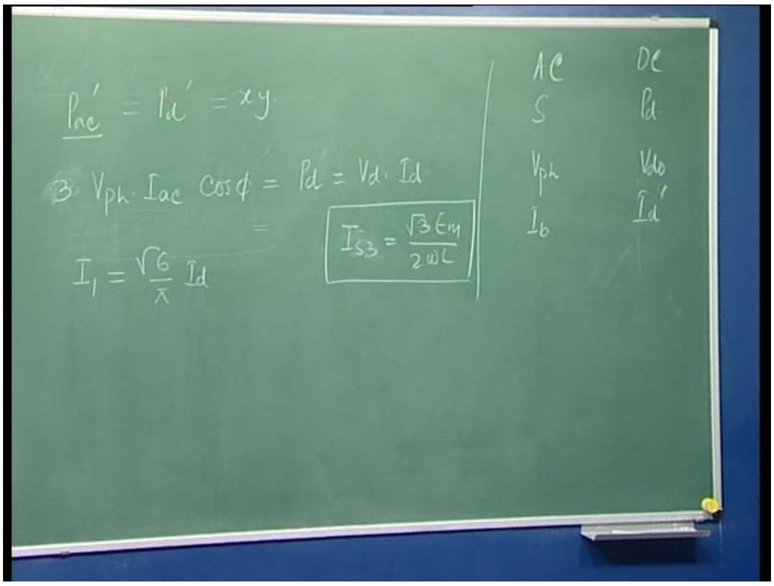

To calculate this value, we can go back to our, we can write what is this (Refer Slide Time: 09:42) this expression is valid and from here, we can derive it. Now, what is the P a c just we can this is true, here it is equal to your x y. So, now, what is the P a c? P a c we are taking here is under root 3. If you are talking three line to line or it is better to write 3 your V phase into your I a c is what we are talking the phase value that is your cosine phi, this is the power, three phase power is equal to your here P d.

But, here you could remember it is not the P d prime this is your P d, because the AC power is equal to your DC power. Once you are going to divide this this multiplied by this value, then that will be the P d this site, so this is I can write it is your V d into your I d.

Now, from here we can write this V d and your I d here, so what we are going to get here, the V d we can write in terms of, I think we can define here the displacement factor here first and then we can go for this one. First we can derive here, this expression because ultimately we are reaching here, because the cos phi here, then we will go back to I th early matter or we can go back again.

Now, you see this your I 1 rms is how much we can derive from here already I a c, I 1 we derive it is under root 6 by phi into I d. We have derived this this is the fundamental component of that is the 6 pulse converter current, here the DC current which is flowing (()).

Now, your I d prime this I s 3, what is this your I s 3, it means root 3 E m upon 2 omega L. So, to derive this (Refer Slide Time: 12:21), we can again, we can go back with this cos phi I think it is a better option.

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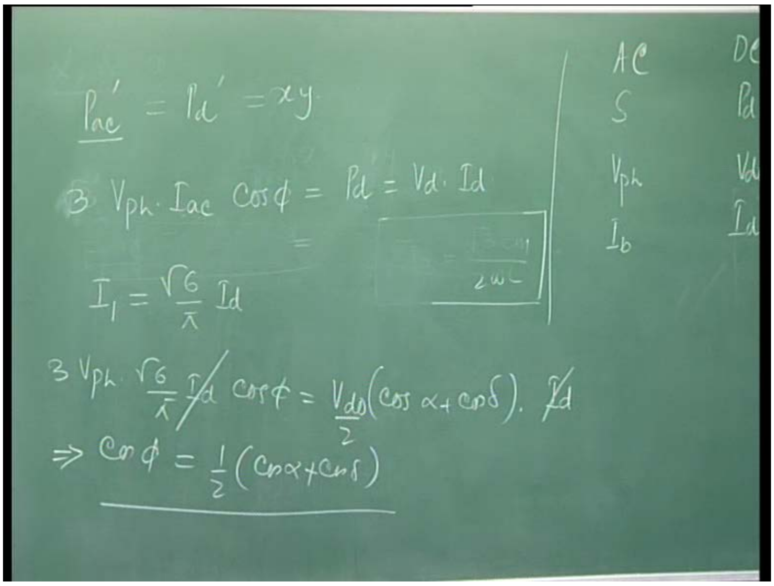

So, first what we can do, we can just define this value here in three phase form and just put this value here this, is I a c is nothing but, this value here. So, we can write here 3 V phase into your under root 6 by pie into I d cos phi, this value is your V d o cos alpha plus cos delta by 2 into your I d. Just from here I want to derive this first part displacement factor and then will come back here, in the current that is (()). Now this I d I d is cancel here.

Now, you see what this value, this value is equal to this value (Refer Slide Time: 13:26) only V d o, just put this value you can see how much you are getting this is 3 under root root 3, this is multiply by root this V p m divided by pie and this is your E m. And this your nothing but, your V d o, this 3 under root 3 I have taken this V phase, here is rms value, so thus under root 2 is multiply here is your peak value that is your V d o.

Now, what we are getting from here? Your cos phi is equal to 1 by 2 cos alpha plus cos delta; and this already we prove earlier also; in this case, only what will happen all this value, which we are taking here this is the case when it is the ideal case; this component was derived when there was no overlap. But due to overlap this value will be not equal to that value it will be slightly change that is why I can say this is approximately equal to this value.

Remember this value we derived in the ideal case, when the current was changing like this if you remember but, due to the overlap what happens this will be changing. And due to this change this current fundamental component will also change this will affect and that is error is very small and finally, we can get the expression that is very equal to this value. Now, this value, what is this this is related to your just remember, your V d expression equation here we derive here.

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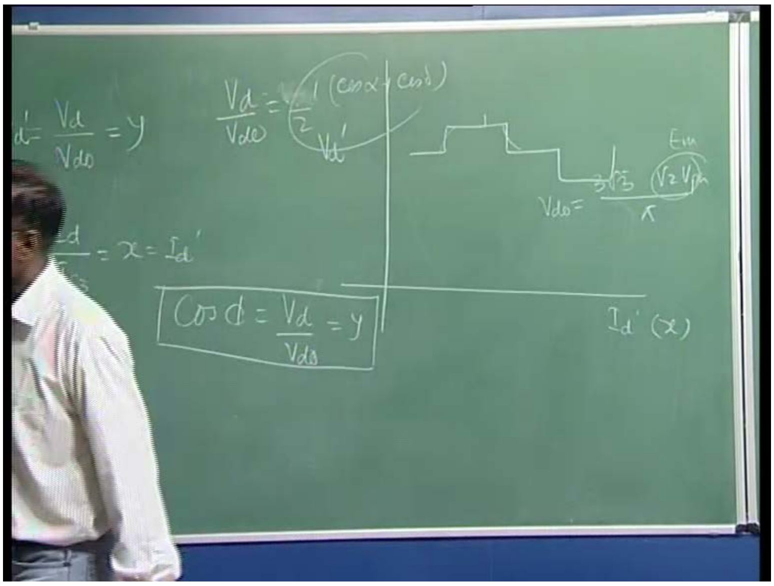

So, this value is nothing but, I can write this is a cosine phi, it is your V d prime simply, means this value is nothing but, your V d o here, because we wrote this expression if remember this V d is equal to V d o cos alpha plus cos here by 2. So, if this value is divided here V d o means your having this value and this is nothing but, V d prime and the V d prime is nothing but, your y.

So, the displacement (()) factor is just equal to your y in the per unit sense, again everything we are taking now in per unit. So, this is also, this value is always less than unity and this is per unit, so it is unity itself. So, this is your this factor already (Refer Slide Time: 16:20) I have written here for the displacement factor, now we have to come back here for I v.

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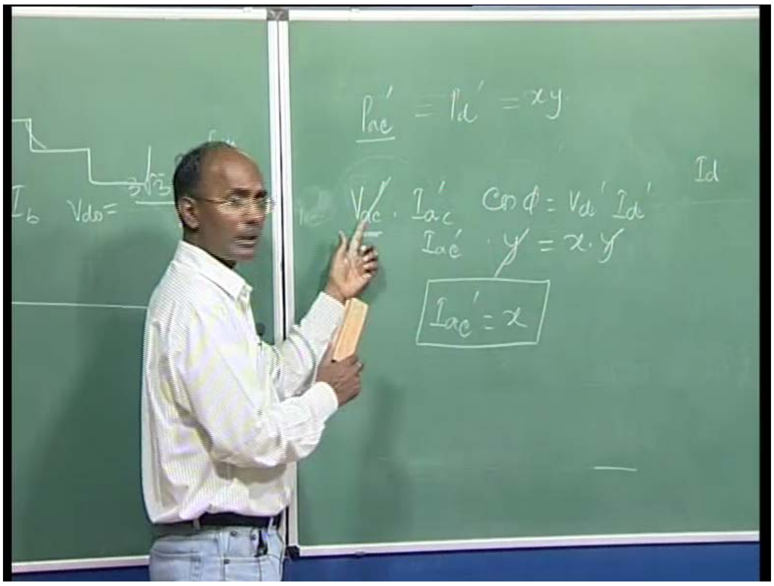

To equate this we have to use the same equation here, now this is the case when we are just writing if your writing here the V l r is something this is a three phase power, this is a total DC power. Now here, I what I m going to do in this case, the cos phi already we have define it is a y, so here if I can divide by V d o prime here, here also I can divide by V d o here. So, this is your y and this y is cancelled out, so I can say this is removed and this is I am also removing.

Now, here if your going to make this this value and now here this is I 1, basically I a prime in the per unit value, we have to now take the base here and it will be nothing but, your I d prime and it will be your x.

(())

Look if your writing in the per unit here, the same expression we can write here the V a c prime the per per unit value voltage per base into your current base here, we are taking about the current base here; everything is based here cosine phi is your V d prime it will be more easier to understand this. The per unit power in the AC side will be equal to per unit power in the DC side

(())

Listen listen now now it is here I have change that equation, here it is I am talking prime means per unit value. So, per unit voltage, per unit current multiplied by power factor because this is V a per unit, multiply by power factor here it is your active power in the per unit and that AC P a c prime here, basically now I can say P a c prime here.

So, in per unit to three phase concept has gone it never appears, because this simple is the per unit here, if your taking line to line, the base will be the line to line. If your taking the three phase power as a base, then the voltage will be your line to line base. So, that ratio the under root 3 and three terms appear in the per unit system; simply if your base is 100 m b a base you multiply this and multiplied by 100 it will be actual power that is three phase power.

So, here now I am writing in this value, so there is no question, now this value is your x and y, this is also your y I a c prime here and this value is the voltage base and this voltage base is basically given your power base and the voltage base are assigned, then your current bases are calculated. In any per unit quantities you required basically there are three quantities power, voltage and current the two are the dependent, one is automatically calculated.

So, in any per unit system normally this power, this is basically apparent power whole transmission system, the active power and the m b a almost same. So, this power and this power voltage is base value defined, I base is calculated. So, in this case voltage base here is your unity, because the divide by the same actual value with your base value, this becomes unity at all.

So, this is your cancel here, this is cancel this is cancel (Refer Slide Time: 20:39) and your I a c in per unit it will be your x. So, it is easier to define, otherwise we have to go for the calculation of here the base quantities, we will see this whole base quantity conversion, when we will talk about AC, DC load flow. Because once you are going to deal with AC, DC load flow you have some problem yes.

(())

Here

(())

No, no it is unity this is and tell me what is the V a c? V a c means actual voltage divided by your the base voltage and that is your base voltage, so it is unity. So, this is unity I am not saying it is cancel, so it is unity. So, here we are getting this value means I can say 1 and then we can write this x.

(())

In the per unit x we define we define at that time I did not use per unit, here also I am talking about the fundamental component here, we are not taking this we are here we still talking your this fundamental component. Because here other components are very less they are the filter out, so many components fifth and seventh that is not coming to the network site, another components are very, very less.

So, this chart is approximate here, we are talking one only but, the fundamental component, because this is also true for fundamental component only, here we are using the displacement factor it is not even the power factor that is why here use y. Otherwise I cannot use y, because that would be the different value we depends upon the power factor. So, we are taking about the AC side, what happens all the components basically gone down they are filtered out.

So, we are having this AC current, here that is equal to your x, now this apparent power here (Refer Slide Time: 22:48), apparent power in the per unit again here is a prime as we using. So, this will be equal to your E at this voltage prime per unit into current prime E a again is unity and I a derive x, so it would be x, so apparent power is also x. Now the reactive power, we know this per in per unit this apparent power square minus your real power square of under root. And then you have to put this value here x, here x y square you are going to get here x outside under root 1 minus y square. So, these are our five quantities, that we can draw on this axis.

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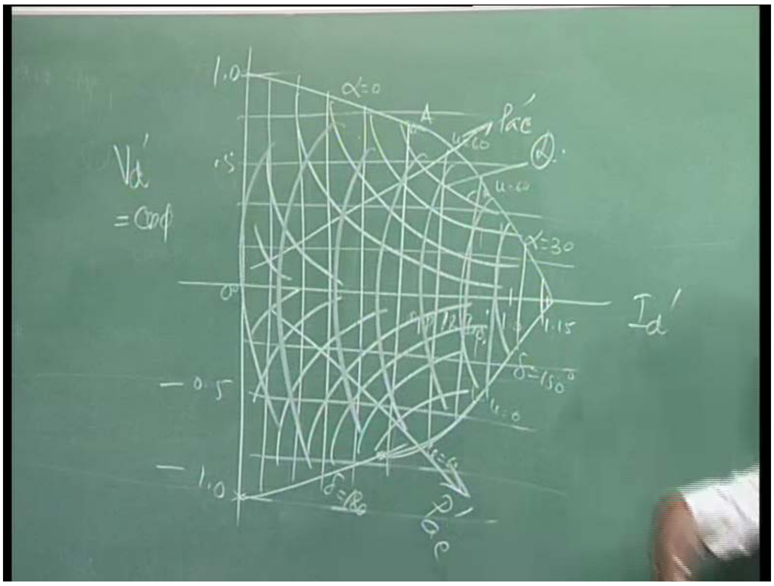

And this chart is now note as the AC side quantities on your voltage and current axis. So, here again we are having here this I d prime here, we are having V d prime or y. Now we can draw the first one, leave the first one (Refer Slide Time: 23:54) first we can draw first the displacement here. Here the displacement you can say is equal to your y means for a given displacement here, phi value here the y is constant means at that axis this is a constant throughout.

So, it will be all this here, both side of the voltages this is negative side here, I can say 0.5 here, unity, here minus 0.5 here minus 1. Before drawing this we know what is the actual operating range of this converter, we had the various boundaries here, if it is the 1, if you remember then we 1.15 per more than u is 60. Then we had the characteristic here that is your alpha is equal to 0, we had a characteristics here that is delta is equal to 0, no delta equal to 180, then we found there is the another slope here, that is your alpha is equal to 30 and here delta is equal to 150.

So, here if you remember, we found one point here where u are 60, here another point was there there u are 60 and between these two points, it was your u is equal to 60 cos. So, whole this converter chart on voltage as well as the current axis, we are having the three zone and the first half it is alpha is equal to 0, certain value here it was A, here it was C, then we are having the u is equal to 60 operation; and then we are having this operation alpha is equal to 30 in this zone.

So, our characteristics here will be confine only in this zone we, because we cannot operate our converter beyond this zone. So, this is the boundary of our operation means it cannot here alpha is 0, here is 80, then if you are going u will 60, then you can go here this is the limiting factor. And the finally, if you are exceeding 60, then your this is zone counts.

So, this line which is horizontal line and all both rectifier operation here as well as inverter operation it is the parallel to your x axis and that is your displacement factor going there. Now question arise, what is the value here and what is value here? This value here this is nothing but, your cos phi means here the power factor is 0, here the power factor is unity is obvious.

If you are operating alpha is equal to 0 your power factor becomes unity, because already we define where you is 0, here you use 0 and then it is gets the actual operation ideal condition. So, this is your positive side and this is negative side of y as upper differential here we are getting this.

Now, second characteristics (Refer Slide Time: 27:24), we can draw here this I a c, I a c here is a x for constant value of I a c x is set means if it is one per unit here, we can say 0.2, means x is 0.2 all the time, so we are having this vertical axis (No audio from 27:38 to 27:48). So, this axis I mean these line that is vertical lines parallel to y axis that correspond to your, this apparent power and the current. So, here these lines are apparent power, I can say apparent power and your I a c prime 1, here again it is I a c 1.

Now, we can drop this P a c it is a equation of hyperbola inverse characteristic, we can get and we will find here it is like this characteristic (No audio from 28:25 to 28:40), means once your P is here at this point. Once your P is 0, we are here, means P is 0 (Refer Slide Time: 28:47), means your either x are x is 0 or y is 0. So, P is 0 means either you are here or you are here for other than that value it is your increasing means your P is increasing; in this way means from 0 it is 0.1 0.2 and so on. So, for you are increasing here also your P that is the P prime, what we are taking P a c here, P a c.

Now, what will be the characteristic of this see, this characteristics you can just means here it is x 1 minus, here y square it is a, it will be the characteristic of similar to this one. And the I can draw from here and it is nothing but, we are going to get this value here, this is your Q, means Q is 0 this side and you are moving this side. So, this is your Q characteristics on the same current; now to see it, you can just see in here in this graph.

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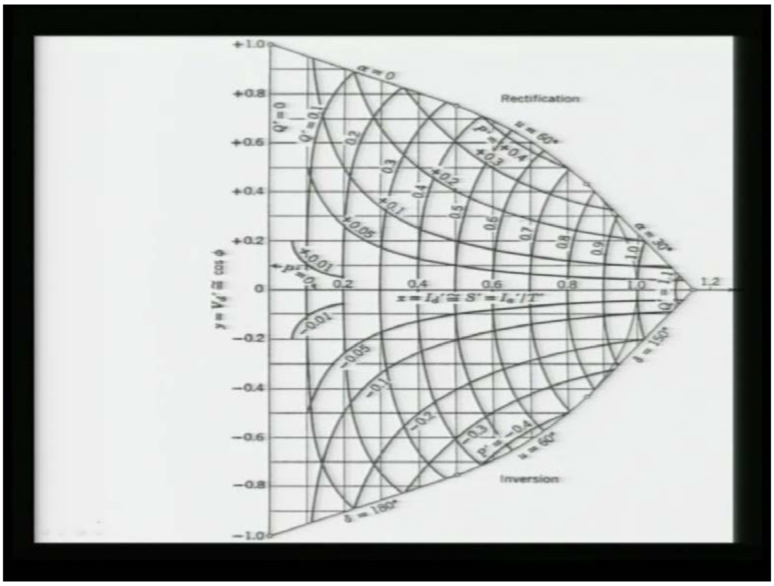

We can see from here we are having this is a Q characteristics here Q, Q more Q and here you require less Q and that is also true if your operating here, your power factor is in this here it is a better. So, it is Q is point 0 on this axis, then you are going keep on increasing, if your operating here in this as I said if your alpha is increasing, because alpha is changing here, if you are coming this side alpha is more power factor is (()) as. So, this side is the Q this is your P axis, P curves on this axis and these are vertical lines are your apparent power and the current AC side and this is your cos phi that is the displacement factor.

So, this is related to your AC side quantity and now will move to your another quantity that is called another chart here. Instead of voltage and current sometimes we require our axis should be in the power, because it is not always possible that we can see whole things on the voltage and current axis, it is also better to have the power axis. So, we have to reverse this curve, because here you know P and Q are there. So, we can have Q on y axis and P on your x axis and then, we can draw all these quantity again further but, that chart become very, very complex.

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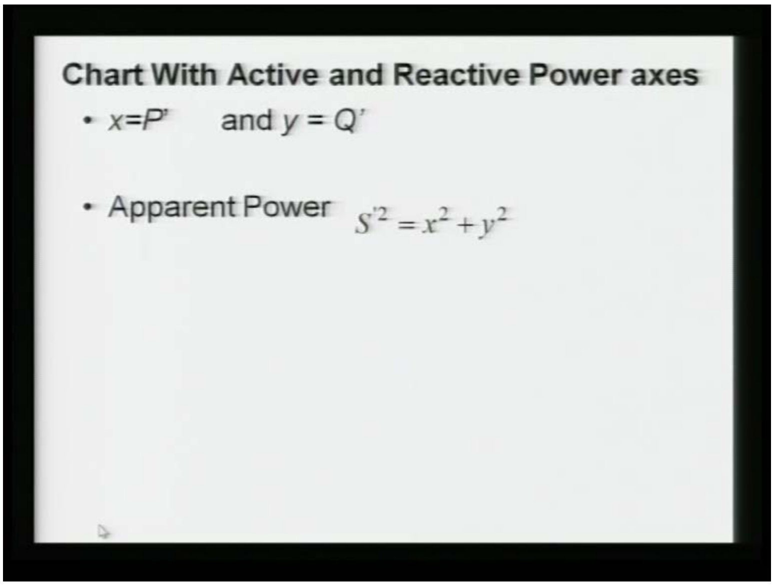

So, let us see what are those quantities and then we can define it here, means in this chart what I am going to do it is, we are taking x is equal to P prime here, again prime in the per unit sense. And then we can have the apparent power, then we can have the displacement, then we can have the constant mu, constant alpha, constant delta, current all the cos, we can draw in this axis. And to draw it here, the apparent power is very clear, this is x square plus y square because p and q square but, for others it is as difficult and as complex, because to go for the mu term or even the alpha term and delta term it is very very complex. But, we have to go for first the displacement and then other thing, just I will derive and I will show some other things.

So, now I am going to draw this active and reactive power and as well as other parameters, other quantities and your this chart, before this even though the last term, we were discussing about this this angle is alpha here delta is 150 degree (Refer Slide Time: 32:55). This constant basically is the similar to this constant, because alpha is I said it is not less than 30 degree here it is your delta cannot be greater than 150 degree the reason is same because if you will see, this in three, four wall conduction mode here.

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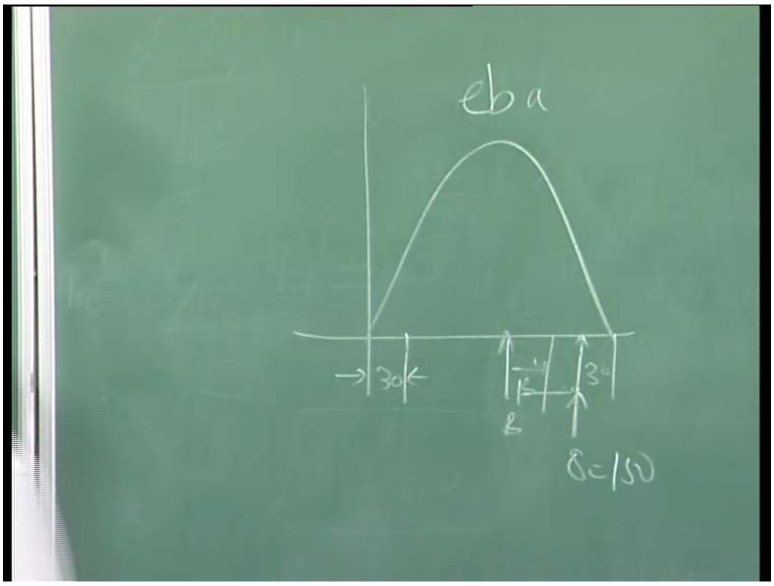

I said if is your e b a, is your commutation voltage of wall three, it was not powerful only after 30 degree this voltage was positive across wall three and that was your e b a. So, this was 30 degree; similarly here this side, this must be over before the 30 degree, because the voltage is going to reverse. And once it is voltage going to reverse means here you have to fire your beta and then there will be some u, so that it should not here go beyond 150 degree.

So, your delta basically is 150 degree means alpha plus beta here. So, this case you can say this is alpha 30 (Refer Slide Time: 33:56), here it is not alpha 150 degree, it is a delta 150 degree, because we are concern here because here going to change from here. So, it is your beta then there will be u degree. So, beta plus mu is basically your delta. So, here basically this is the concern is 30 degree, means one eighty minus 150 degree.

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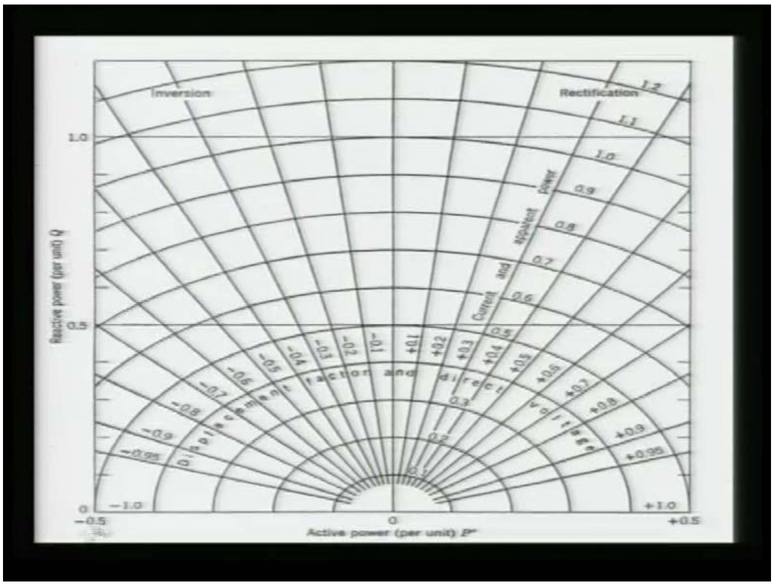

Now, let us draw the AC side quantities here this one and first I will draw what will be the displacement power factor you see the displacement power factor here, this curve now this circle, so your apparent power.

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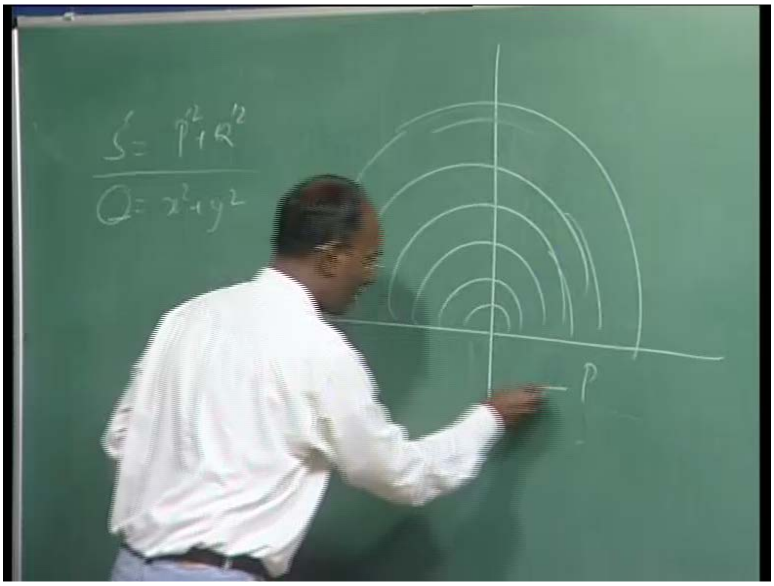

Because here in this axis we are drawing your P prime here here it is your Q prime means this is your x this is your y. And in this case, what is done it is both side of the here the we are going for this, now the P positive and negative and Q we are talking here only this is positive side but, it can be also 0 down as well. So, it is drawn in such a fashion, I can say it is your P, because P negative means the P positive means it is a rectifier, that is the flowing inside to DC link and negative means it is a inverter operation.

So, your S is nothing but, your P square plus Q square, so it is a equation of a circuit that is your x square plus your y square and the radius is the value of apparent power. So, your apparent power if it is changing here, it is your circle. Of course, if it is going in Q side negative, so it will be going this side as well but, always your operates the requires the reactive power support, whether it is a rectifier, so it is a lagging power factor. So, this is your apparent power characteristic, this is the circuit, this is your P, this is your 0 is the positive side, here negative and this is your Q.

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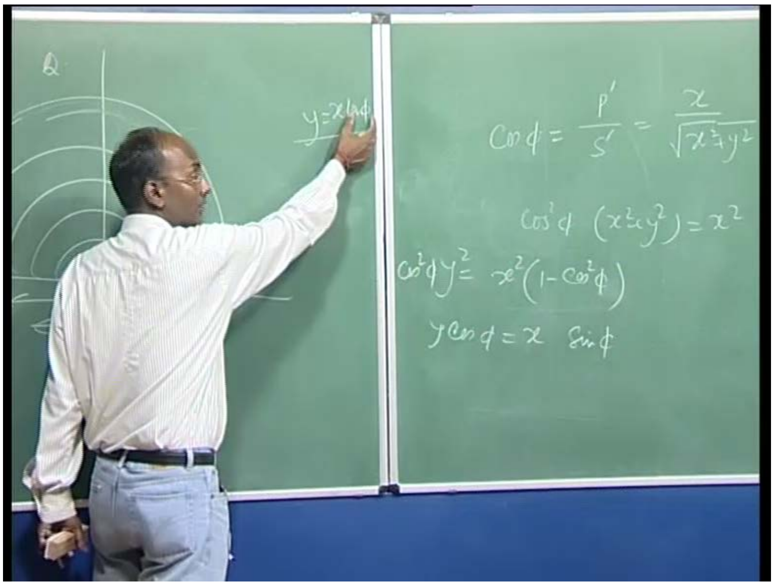

Now, the displacement factor, you see this is a straight line. Now how to calculate displacement factor, here it is displacement factor that is your cos phi it is nothing but, is a define as active power if you are talking per unit, so this your per unit value divided by your apparent power per unit. And this value is your x, this is your under root x square plus y square. Now from here just simplify it and I want a expression in terms of x and y, so here if I am going to multiply here, simply square it. So, we are getting here cos square phi, here x square plus y square is equal to your x square just I squared it here, so I can write your y square will be your x square 1 minus cos square phi.

And no, here I am missing something here cos square phi, so if will taking this under root, means y cos phi is equal to your x sine phi means, we are having y is equal to your x phi. So, for a given phi angle means power factor, we are having a straight line of y and x here, this is the fix and then we are varying, means if your power factor is, now we can draw for the different value.

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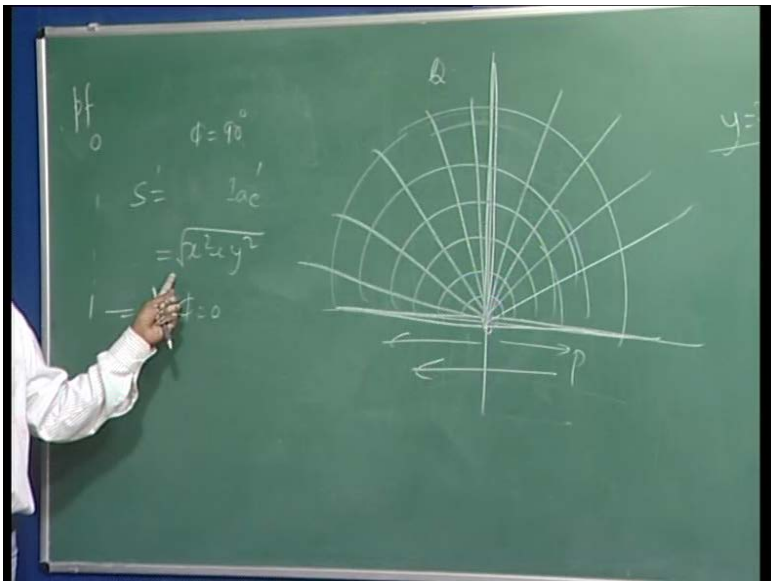

If your p of displacement factor is your, we start with the 0, then your phi is your 90 degree and here if your going back, back here we are getting the power factor unity your phi is equal to 0. Now, if your power factor is unity here, now what will be the value if tan phi, here it will be 0 and 0 means your y is 0.

So, you are here somewhere, the power factor 0 here means it is a infinite are reverse in your x is 0, here you are here; for the any other values it is the straight line, because this is a slope any value of phi here that is calculated here, your having this is the straight line starting with the origin. And this characteristics here that is strong you can see here the power factor is unity and the power factor is P prime (()) till here 0 and then it is going the different lagging side depending upon the power reversal is there but, reactive power requirement is still there. This will here, we are taking in whole displacement factor, because power factor is very difficult to calculate because so many harmonics are there.

So, here still we are taking this phi is the displacement factor, here in whole this converter circuit I did not talk about the power factor, although I use the power factor because it is very close to that. So, this is your apparent power and your this value displacement factor, we also know this apparent power S is very equal to I a that if we remember it was x in the per unit sense.

The apparent power per unit is your the V per unity a c into here, a c per unit and this is unity, so this was this already x we define means here it is also x square into y square in the per unit. So, your apparent power as well as your current AC current will be the circuit that is why it is written here apparent power and the current is equal, because both will have the same type of characteristic; no doubt the value here will change for a given value of I a and this value will be decided. So, here the current and apparent power can we draw for the displacement factor. So, we have draw all the quantities all the five quantities except our V d and I d on this plane, because we want to draw our V d as well that is V d prime and your I d prime.

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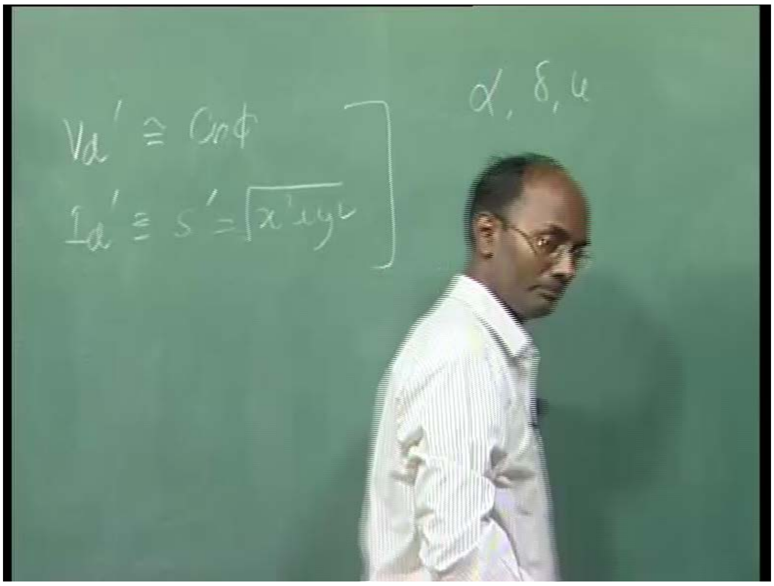

Now, what will be your V d prime, we did this and this it is approximately, this V d prime and this is V d prime will be approximately here, your cosine side. To remember cosine phi is equal to I wrote y when it was the V d prime, when I was trying on the V d current and voltage axis this was y here. So, means that was equal to your V d prime, so V d prime is approximately equal to here the displacement here, again because the overlap angle we are not considering that is why I am writing here.

So, you can see this is a cos phi here and this is nothing but, a characteristics similar to your displacement factor, means that is why here you can see written on these scales, here the displacement factor and the direct voltage. So, these straight line are showing your these slopes are showing your the displacement factor as well as the direct voltage in per unit, these circles are showing your apparent power and your current on this one.

Now, another quantity here it is your I d prime, I d prime it was nothing but, it is also related to your S, because again we define here S is I d power here and this is your x square plus y square here, means this is again apparent power. So, here it is written current apparent power and the power factor displacement factor all this here this straight line is apparent power basically and you can see we have just derived. The major problem in this one, if you are going for alpha, delta and u characteristic, because converting u in terms of power and apparent power is very, very tremendous, very complex let us see here.

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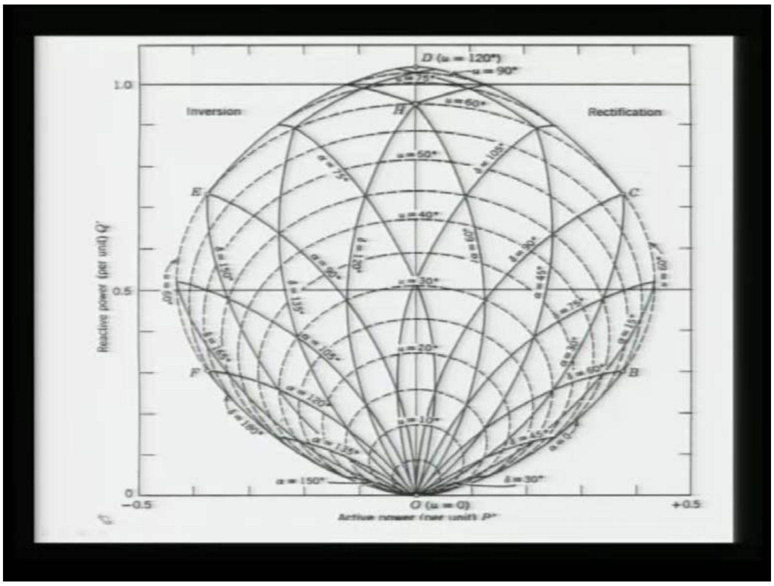

See this now, mathematically we can derive equation first very simple for constant u, because for the constant u, if you are going to derive from all these basic equation you will find you are getting expression. Similar, to a circle equation which basically is which here the diameter are this distance is your radius is keep on changing and it is touching your the 0 axis it is passing from here; means all these are the circles here this is a stress slightly it is not looking circle but, it is circle because here I think this graph is stretch if you are going to this it is circle.

So, the equation for this for the constant u, if we derive it is very complex it is your nothing but, which is coming out to be your x square plus your y minus your u by 2 square and here your sine u by 2 square. Now, we see here is not sign, it is actual value and this derivation is of course, very complex and that is I do not want to derive it again.

Here only I can show you this is a characteristic here for the given u, u is here less 5 degree, 10 degree, 20 degree, 30 degree and here up to 60 degree. If your going for more than that this characteristic again becomes a different. Now if you will see, the scenario becomes very verse for the alphas and the deltas, it has a different characteristic again we can derive it is very, very complex for the different plane.

That is why normally charts are used for the voltage and your current axis or if your going for the AC side, normally if what we need if your analyzing the your converter from the DC side always it is beneficial to use your current and voltage axis chart. If you are deriving in this AC side it is better to have the P and Q, because we talk about whole system in the real and reactive power and voltages, so this is better in that side. But if you are going for the DC side there just you can see it here, what complex even the drawing the chart is very, very complex.

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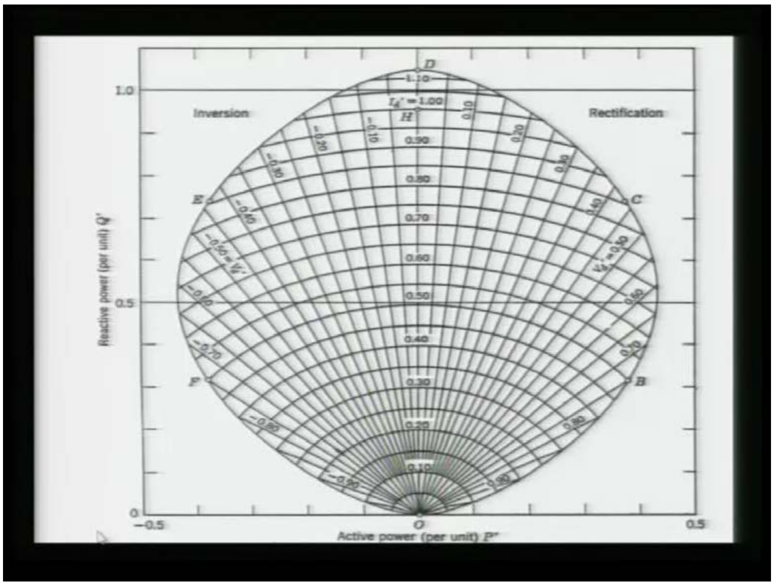

Now if you will go further here now this is basically it is another curve for the you know I d another values it is going to very, very complex, here here slightly in this case what we have done this axis here basically your is a exact compared to the previous one. Here we are drawing the V I d prime and the V d prime but, here we have taken very care here this you know the V d's are changing with the axis here, V d and the currents are this one. So, this chart again it is very complex, that is why I said if you are going for this DC side quantity, the alpha, u and delta these value on the P Q axis is a complex.

So, if your going for the DC because the P and Q is AC side Q always comes in AC then DC there is no Q. So, I can say the DC variables on AC axis is not good and the same time if your having the DC a AC variables on that side is also not good. So, it is better to use this P Q chart for the AC quantities and the DC, you can use your voltage and current.

So, in this, so this chart is over but, now I have to summarize what we did in the twelve lectures here, in the summary if you will see in I devoted, so many lectures here first lecture was, basically for the single phase rectifier circuit. It was started with the half wave rectifier, then we went for the full wave rectifier, again the centered transformer then, we use the bridge circuit, then we introduced the commutation value, this commutation group Q.

And then in the second lecture I started with the three phase rectifier circuits and we use the grouping, how the Q the commutation group was decided the Q value, we also introduced r and s that is the series and the parallel; we derive the voltage equation for those three phase simple circuits, rectifier circuits.

Then in the lecture number 3, I started to go for what should be the exact or better configuration of converter circuit. In that we say the various features, we derive the four feature that we should have the highest the DC voltage, harmonics are highest repel we should go for the transformer relation should be better and also the peak inverse divided by your DC peak inverse I can say in per unit it should be the less as minimize as possible.

Based on that we decided that for the six pulse converter and I gave assignment for the twelve pulse converter to you and that is we decided which configuration is better. And the final doing some modification in that optimal selection, we if you the same winding for the twice. So, the winding factor was improved and the transformer (( )) is improved and that is why we use the bridge circuit that is a gate circuits.

Once after deciding this, we went for the in the lecture number 4, it was a converter circuit analysis, then I use the very ideal conditions for the bridge circuit inversion, it I use your rectification as well as the inverter operation. In the ideal case when the always the two walls were conducting, one from upper limb, one from lower limb. Then in lecture number 5, I just introduce if there is some overlap as a practical circuit we also define the various voltages at that time, what will the phase voltages line to line voltages. And then I went for this u less than 60 degree, what will be the conduction mode and then we saw our rectification operation in the two three valve conduction mode that was in lecture number 6.

In your lecture number 7, I introduce the I just show the graphs output voltage for the inverter operation of two, three valve conduction and then we also introduce about three four valve conduction mode. In lecture number 8, we derive the various voltage and the equations corresponding to the change over from valve one to valve three or from three to five and then we derive the various instantaneous for the currents, etcetera; and in that was in also in the lecture number 8.

In lecture number 9, I introduce another that is called already this gamma was coming out all the way till our three, four valve conduction mode. Then I introduced another variable that is the zeta and this was your commutation margin angle was define and the for various ways that is we say in inverter operation how this angle both are changing.

So, it depends upon the dents in lecture 9, also I discuss about the twelve pulse operation we saw how this and we also draw the valve voltage corresponding to the delta winding of the transformer, if the delta winding is there then how we can draw the output voltages, we define clearly. In lecture number 10, I just give you five problems, I explain those five problem those related to the quest as well as it was related your mid sem one examination.

And lecture number 12 11 and 12 were diverted to your chart it was related to your first I went for the DC side variables; I define the chart for the DC variables that is your alpha u delta V d. And I d and in this 12, I just went for the AC side and also we saw this we are changing the axis means, we are going to draw whole chart on the real and reactive power axis then how would this becomes very complex and just I define for you only AC side quantity exactly.

For the DC side I showed it is very complex and that is not require at all at this level if your doing some research or something here then again this huge mathematics is involved. And then with this I can disclose this module 2, lecture number 12, in the next module with now, will use our voltage equations. And then will go for the control objectives how we can control our HVDC link what should be the various options.

We will also see, what is the role of OLTC transformer? OLTC means, on line tap changing transformers; as I said this HVDC links are always collected with the OLTC it is not a normal transformer. They are having the tap changers; they are keep on changing the voltages that is require by the DC here. First we try to control the voltage by your converter circuit, if this converter limit is heating then the tap changer start changing.

So, we will see how this control philosophy is done, and what will be the control characteristics for both rectifier and inverter side, one will be trying to maintain your current, then will still will go for even though this value minimum value, alpha minimum value, so many characteristic will find, and then we will see, what are the various control schemes or philosophies are being used, that we will see very clearly in that your control operation. So with this, I should end it; and if you have any doubt of course, if there is no doubt, then we can end it here, thank you.