Power Quality
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Lecture - 09
Active Shunt Compensation (contd.)

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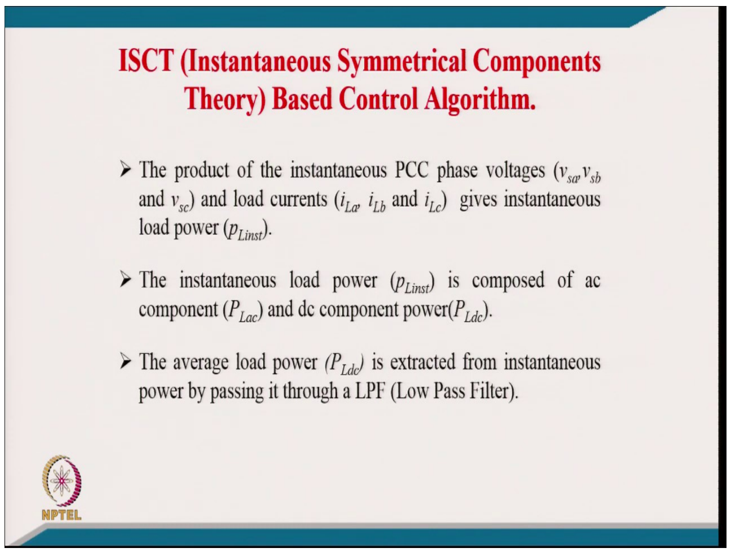

Welcome to the course on Power Quality. We will discuss today, the control techniques for DSTATCOM or Distribution some Static Compensator. I mean this is the first custom power device on which we are going to apply these control technique. Of course, we will not like to repeat the of course, most of the compensating devices as well as the you can call it the even other active devices, we like to use these control technique. I mean these can be modified and used for other compensators also.

[FL], that is the reason we thought of we will discuss first for this for DSTATCOM and then, we will discuss only in little modification. [FL] this is the another control technique, I mean which is used for this DSTATCOM. [FL], we call it like a Instantaneous Symmetrical Component Theory; in short, we call it ISCT Based Control Algorithm.

I mean in this control algorithm, the product of instantaneous phase voltage for all three-phase and the load currents of all the three give the instantaneous load power and this instantaneous load power of course, we consist that it consist of ac component that is responsible for harmonics or you can call it like a negative sequence and then we have a dc component which represents virtually, you can call it fundamental active power consumed by the load.

[FL] we can take it like a typically the average load power is accepted from the instantaneous power by passing through a low pass filter, [FL] we can get a fundamental active power consumed by the load.

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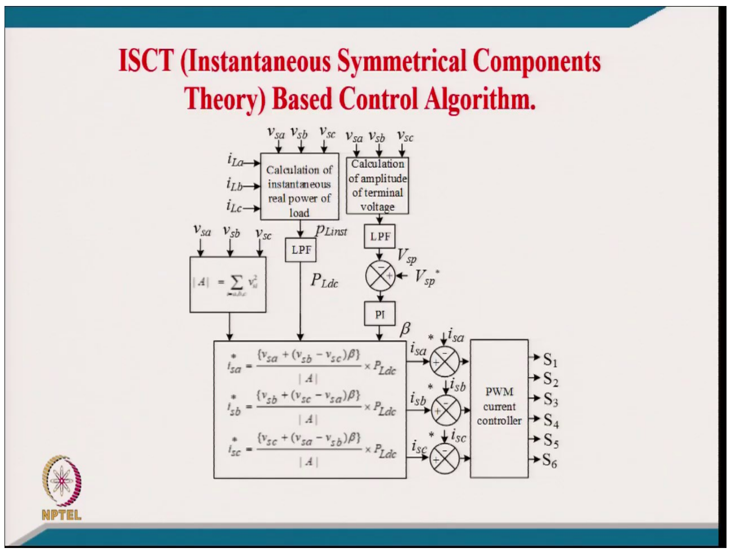

Well, this is the block diagram of this instantaneous symmetrical component theory based control. [FL] what we are doing as you can see here that we are taking a load current and the source voltage, I mean voltage at the point of common coupling which we already got it for if it is a three-wire system, three-phase three-wire system, [FL] we can sense only two line voltage and from these two line voltage, we can calculate the we can estimate the three-phase voltage and which are used here.

Of course, we already discussed earlier in some algorithm that those line voltage may be distorted or unbalanced, [FL] well, we have to for avoiding the distortion, we have to pass them for band pass filters so that only fundamental component of these voltage are achieved and after that, we convert them into the phase voltage. And these phase voltage we have to find out then, only the positive sequence voltage which are balanced set of voltage and these those we use on.

[FL], after from load current and these phase voltage, after multiplication of that we will give expression in that we will get instantaneous power and after low pass filter, we will get the load power. Of course, we have to maintain self-supporting DC bus, we have to add here again the output of PI controller on the DC bus I mean like [FL] that one can understand here.

And another block is responsible for here for typical for getting the voltage amplitude from this voltage and then, we that we consider after low pass filter the amplitude of voltage, we take the amplitude of the voltage and from passing through PI controller, we consider this is the angle; typically of the to be used in this typical control. [FL], this would be considered angle because this angle we need to do certainly this reactive power required for the reference current like.

And of course, we take estimate the another quantity like A here on which are calculated from v sa, v sb, v sc and once we know this, I mean then these three expression of i sa; I mean v sb v sa plus v sb minus v sc into the beta divided by A absolute and into P Ldc that give for really for a-phase reference current of the grid. Then, similarly, we calculate for b-phase reference current and c-phase reference current for the grid line.

And once we have a reference current, we have a sense current of the grids on the grid side and these these error I mean current error, we feed to PWM current controller which we discuss either you can use the instantaneous current controller or you can use the typically on off control or you can use the even PI controller with the comparing the carrier wave to get the typically the switching signal for voltage source converter which is used as a DSTATCOM; I mean in case of three-phase three-wire system like.

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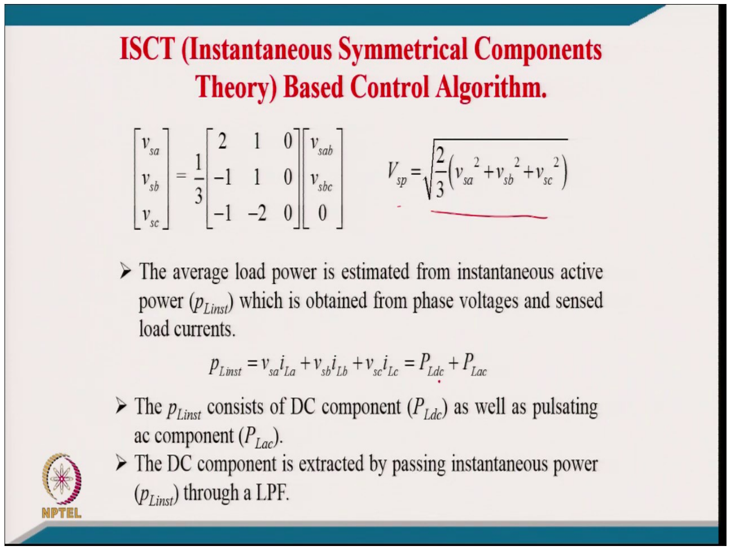

[FL], this is the typically the explanation through the block and these are the mathematical expression that we are formed. As I already discussed that we sense only two line voltage in three-phase three-wire system and from that, we calculate the three-phase voltage by using this transformation and once we got the phase voltage, we can calculate the amplitude here. Typically, from this expression, the amplitude of these point of common coupling voltage [FL] that is required of we will discuss how we will get it.

The then, we estimate the average load power from the instantaneous active power which is obtained from phase voltage and sense load current from this expression. This give the dc and the ac and the dc represents that consist of dc component as well as pulsating ac component. A dc component extracted by instantaneous power through low pass filter which represents the fundamental active power consumed by the load; the real power which normally used for the considering the typically for doing the work in the system like I mean or any load.

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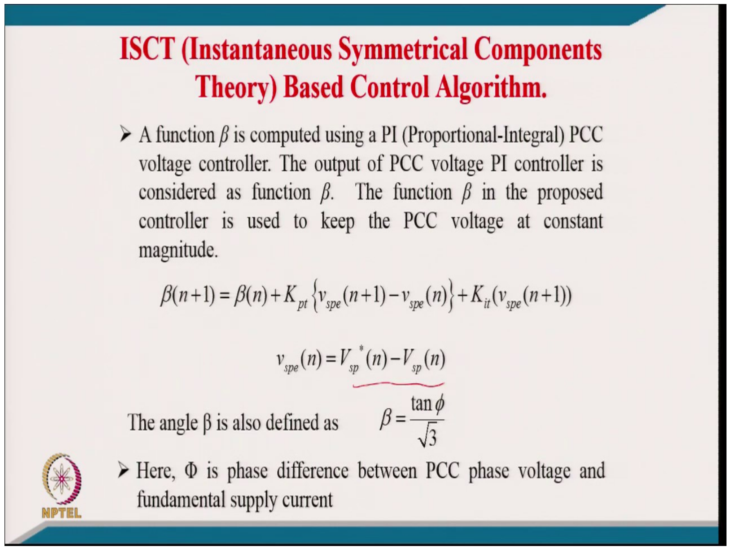

A function beta is computed using a Proportional-Integral controller on PCC voltage and output of PCC voltage PI controller considered as a function beta and this function beta is the proposed in the proposed controller is used to keep the PCC voltage at constant magnitude and this beta, I mean the we can call it which is on the voltage PI controller, where this is the point of common coupling voltage amplitude on which we put that and this beta represents an angle, we can call it from this expression. Beta tan phi upon root 3; where, phi is the phase difference between PCC voltage and fundamental voltage like.

[FL], we can called this function beta, I mean represents the how much phase shift you have to provide it, typically for these in these reference current for the purpose of regulating the PCC voltage. Because this may require you are leading reactive power or lagging reactive power, [FL] that also taken into account as we discussed in the previous block diagram and once, we know this beta from here for voltage regulation, we can find out these three reference grid current.

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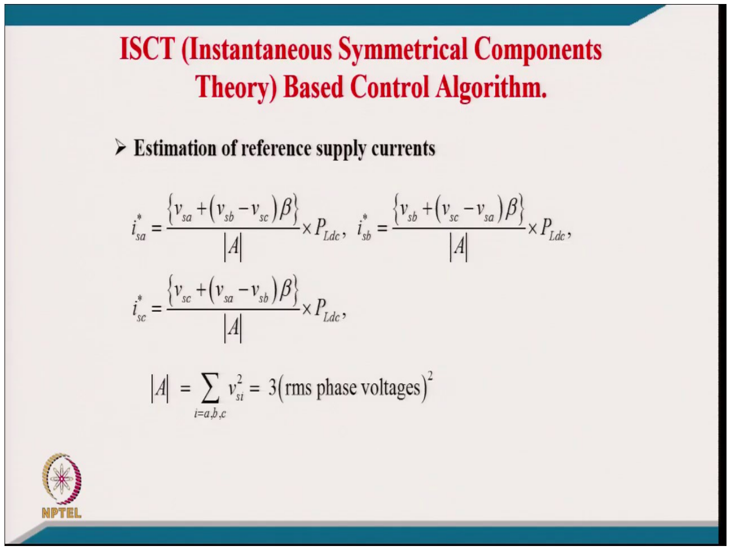

I mean i sa star as I already in the block diagram, we have discussed it about v sa plus v sa minus v sb into beta divided by A into P LDC. For similarly, for b-phase and similarly, for c-phase; where, A is defined as a you can call it the v sa square plus v cb square v sc square like I mean or so. [FL] this give us the three-phase reference current and comparing with the sense grid current, we have a indirect current control for this DSTATCOM.

[FL], that explain this instantaneous reactive power symmetrical component theory which has devised in 1957 and used extensively in power network either power system or other applications even for machine an electrical machine analysis that is also used in the same way as we already talked about, couple of theory for instantaneous reactive power theory as well as the dq theory. [FL] this is another theory which is used for a control of this typically of DSTATCOM.

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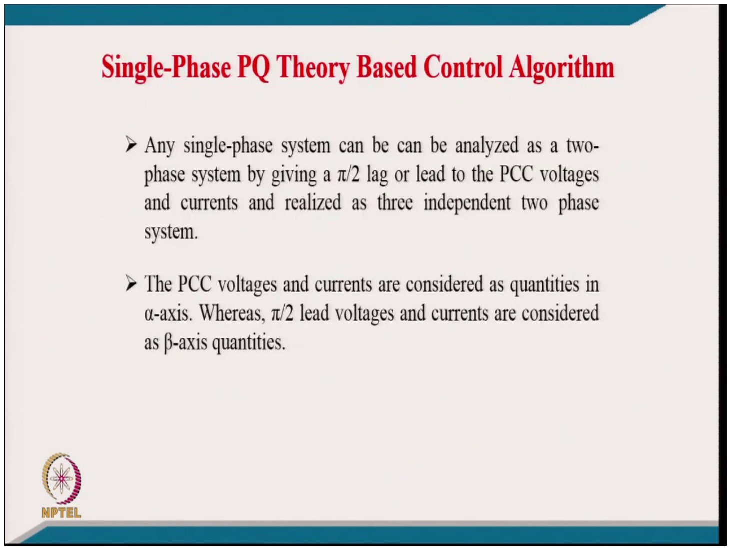

Well, the another you can call it control which is based on single-phase PQ theory based control algorithm. I mean like it is interesting, I mean it is a you can call it modification of your instantaneous reactive power theory used for normally typically single-phase how we can extend it to be used on three-phase.

For single-phase, you can use directly; but for three-phase, I mean we have to modify for every phase. [FL] we can say that any single-phase system can be analysed as a two-phase system by giving a an pi by 2 lag or lead to the PCC voltage of that particular phase and current and as realized as a three independent two-phase system and the PCC voltage and current are considered as a quantity in alpha axis, where the pi by 2 lead voltage and current are considered as a beta axis.

[FL] for each phase means let us say we have a three-phase system, [FL] for each phase we will considering I mean this alpha component as a original component and the beta which is phase shifted by a pi by 2 lead angle like or so.

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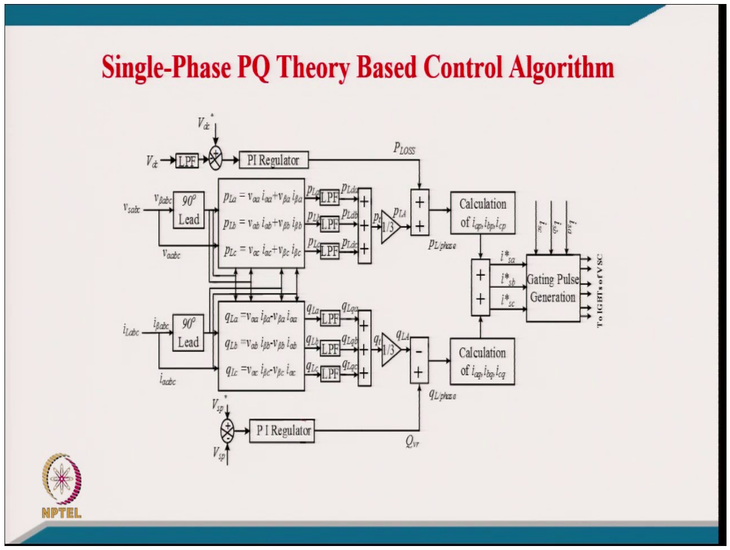

[FL], this is typically the block diagram of single-phase PQ theory based control algorithm for three-phase DSTATCOM. I mean here of course, we have a again both the PI controller, I mean we have a reference dc link voltage for the voltage source converter dc link and then, we have a feedback sense voltage on the dc link which have a ripple also.

[FL], that is why we have to use low pass filter to give a feedback and this error, we apply to PI controller, PI regulator; Proportional-Integral regulator and output of this we consider the P LOSS that is the power loss, we consider in the DSTATCOM and power loss consists virtually the in the interfacing inductor ripple filter. You can call a dielectric loss in the dc link capacitors and losses in the switching; you can call it devices like and diodes.

[FL], all the losses virtually, we equate it because with the when we want to maintain dc link voltage that much power have to be taken care by DSTATCOM with a loss, [FL] that is the reason we consider the loss. And now, here, what we consider it I mean this voltage here, we are transforming the three-phase voltage; one is the directly we are taking this I mean abc voltage, directly we call it alpha beta component of for abc three-phase and another all the three, we take a 90 degree lead of this, maybe by kind of some kind of compensator or some kind of filter which give 90 degree phase shift.

And similarly, for current, we take a directly alpha component; for beta component, we take the directly 90 degree lead I mean like here that is 90 degree lead and all these, we use in I mean calculating the instantaneous active power for all three phases; I mean which we are consider equivalent to two-phase alpha beta.

Similarly, for b-phase, similarly for c-phase and similarly, we take it for even a reactive power for all three-phases for from alpha beta by cross coupling; I mean using this expression [FL] this gives the reactive power for all three-phases a, b, c phase and similarly, reactive power for a, b, c phase.

And of course, it consists of ripple all these say let us say quantity consist the ripple and [FL] and a dc component; dc component is corresponding to the fundamental active power and reactive power which of course, we use the low pass filter. [FL] we get the dc component means, but I mean these can be different value because the reason being that you might have unbalanced load.

Similarly for quadrature, you can call it this even a reactive power also dc component can be also different. You might have a load unbalancing for all three phases. [FL] summing by all 3 and then, divide by 3, we try to balance as a per phase. [FL] here in this per phase equivalent, we add the loss and then, we get the total active power drawn from the supply for meeting the losses of the DSTATCOM as well as the active power for required for the load and here of course, we again have a another PI controller, I mean the we want to maintain PCC voltage.

This is the reference for amplitude of PCC voltage and this is the you can call it the estimated voltage from PCC the amplitude. And we again, pass on this error to PI regulator that is nothing but PI controller, Proportional-Integral regulator and output of this is a reactive power to be generated by DSTATCOM.

But out of this, the load reactive power have to be supply locally I mean by DSTATCOM to the load, [FL] we take a difference of this and this is the reactive power which have to certainly have to flow into the grid to maintain the you can call it constant regulated voltage at the point of common coupling at the load point. I mean that may require little leading reactive power in general or it may be lagging depends on the typically the reactive power drawn by the load.

And then, from this virtually from this active power and reactive power, we calculate the using the template which we already discussed in other technique, we get the instantaneous three-phase active power for all three-phases and for reactive power all three-phases and when we add the both active and reactive power, we get the three-phase reference for an for the grid.

And we have a sense grid current which we compare it and in the current controller and give the gating signal. [FL] we already discussed this is indirect current control and we get the gating signal for the inverter which is used voltage source inverter used for as a DSTATCOM, I mean like for the compensation.

[FL], this is the we call it single-phase PQ theory because we are using alpha-beta component for each phase, [FL] alpha beta transformation that called Clarke transformation is used only for instantaneous reactive power theory. [FL], this is modified for per phase basis and we apply for all three-phases independently and then of course, we take together and then get the compensation from this or so. Well, these are the typical expression for this PQ theory alpha-beta quantity of phase voltage and current.

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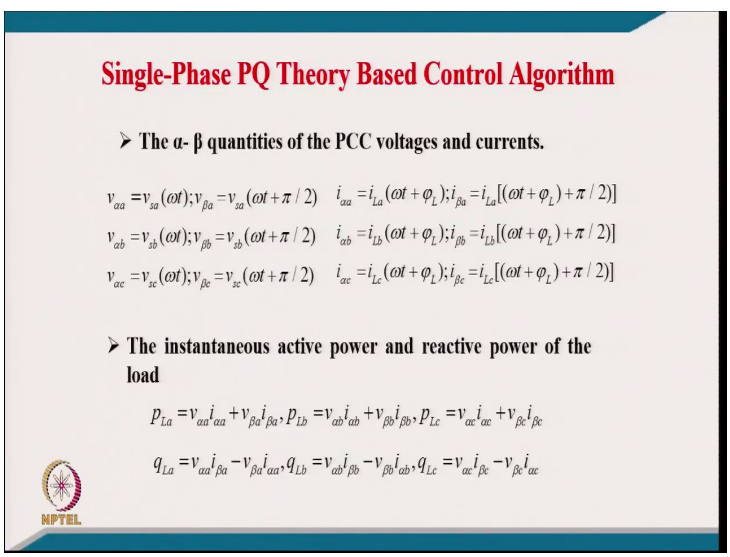

I mean, these are the alpha component and these are the beta component which are 90 degree phase shifted; similarly, alpha component of load current and beta component of load current.

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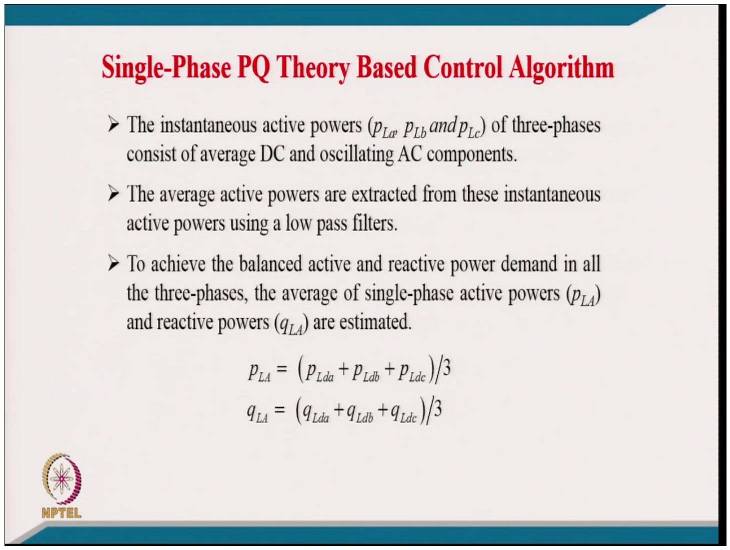

And once we have all six quantity, then we can calculate the power active power for instantaneous active power for all three-phases separately and reactive power also for three-phase separately. And once we have all these three, then we pass on these through low pass filter and instantaneous active power of three-phases consists of dc component and oscillating ac component.

And the average active power are extracted from instantaneous power using low pass filter which we discussed in the block diagram and to achieve the balance active and reactive power demand for all three-phases, the average of single-phase active power should taken as a four as well as four reactive power.

[FL], you can have a addition of this divided by this so that you got per phase basis this active power, typically for load balancing. Similarly, the reactive power, we take all sum divided by 3 because these 3 can be unequal depending on the unbalanced load as well as you can have a even the different reactive power in the different phases of the typically of the drawn by the load like.

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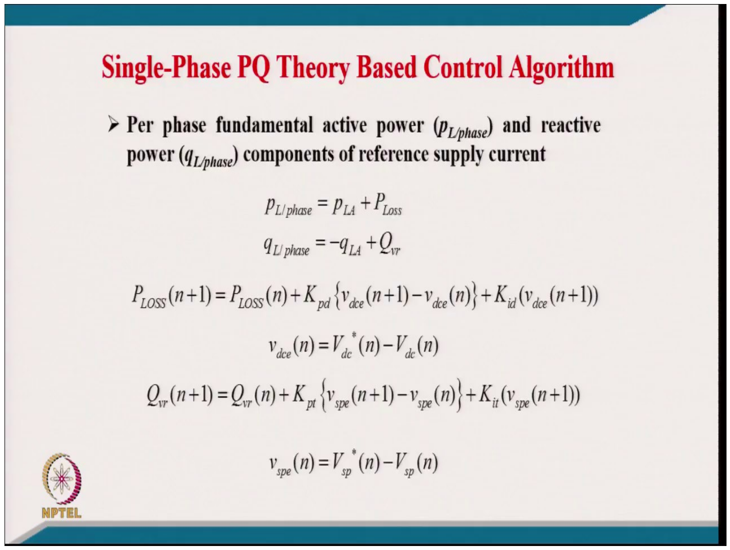

[FL], that explain and you can have a per phase, you can have a again here the power plus the loss which is on dc link voltage controller and this is the reactive power of the load and this is the output of PI controller for regulating the reactive power generated by the DSTATCOM, which we calculate from voltage PI controller and this is the voltage error and this is dc link voltage or this is the loss power component which we add here.

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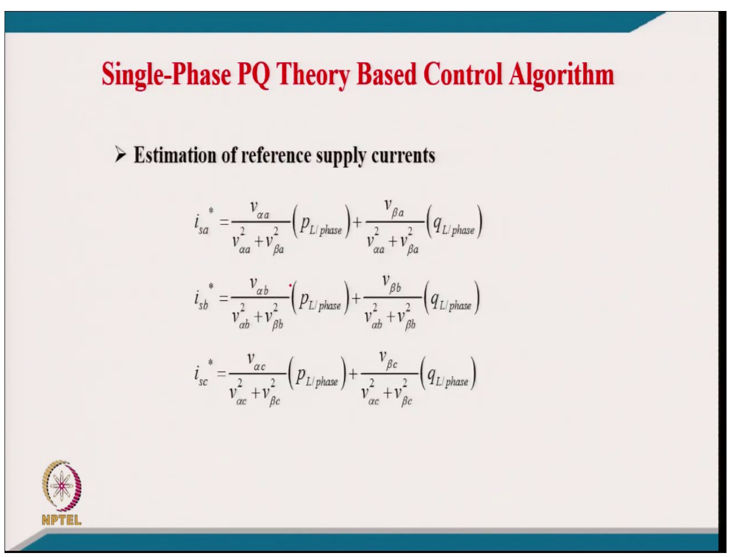

[FL] once, we know these of course, we can find out from these relation of p and q, we can find out the instantaneous active power, instantaneous reference grid current by both power and active power and reactive power by using this expression and this expression is the same as the instantaneous symmetrical component theory, we discussed already earlier.

We call it IRPT. [FL] this give us three-phase reference current which we compare it with the sense grid current for indirect current control and we give the I mean through those current errors depending upon, whether we use instantaneous current controller or we use typically the you can call it like a even any other PI, I mean current controller, we get the get general form, those reference and feedback current like or so. [FL], that is about single-phase PQ theory.

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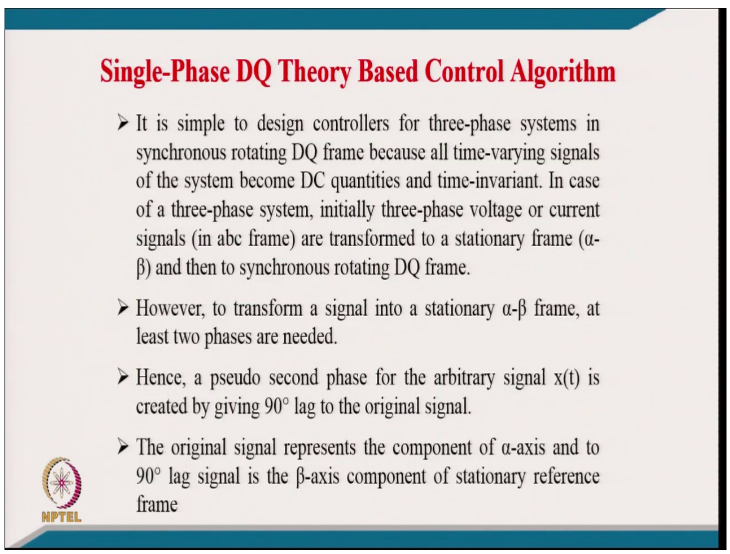

Similarly, I mean a DQ theory is also modified to apply I mean single-phase DQ theory also modified to be apply for three-phase DSTATCOM and this is about the typical explanation for that. [FL] it is simple to design controller for three-phase systems in synchronously rotating DQ frame because all the varying signal of system become dc quantity and time invariant, that is the one advantage of this DQ theory and in case of three-phase system, initially three-phase voltage and current signal in a b c are transformed is stationary alpha beta and then, to synchronously rotating DQ reference frame.

However, to transform a signal into stationery alpha beta frame, at least two-phases are needed. Hence, a pseudo second phase for the arbitrary signal is created by giving a 90 degree lag to the original signal and the original signal represents alpha axis and 90 degree signal typically beta axis component of stationary reference frame.

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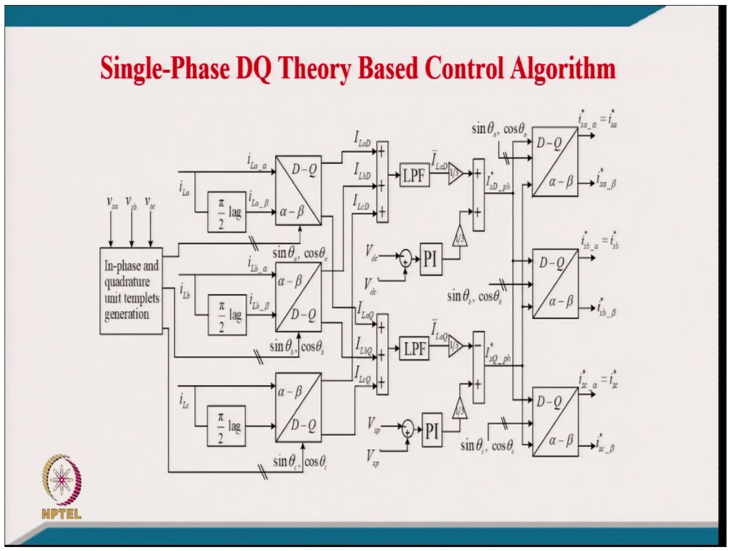

[FL] here of course, we use this both the transformation and this is the typically, the block diagram of this. You can call it single-phase DQ theory. [FL] here what of course, here also we have a what we discuss already the typically the whole dc link voltage control of through PI and of course, we give one-third here because we divide for all three-phases, the losses have to and similarly, the voltage regulation for the point of common coupling, this also we divide by 3.

Now, what we are doing here? If you look into carefully and we are having a typically the three-phase sines voltage and from these sines voltage, we are getting a sin theta cosine because that is required for typically you can call it for either you get PLL form or through from template, the sine theta cosine theta required for DQ transformation.

[FL] we get from this voltage only and now in current, we are having a original current for a phase and 90 degrees shifted current and that give us alpha beta and using sin theta cosine theta which are generated from the voltage of point of common coupling, we get the typically you can call it I LaD and I LaQ.

Similarly, we do for b-phase, we have a b-phase current as alpha originally I mean and then, the 90 degree shifted another for b-phase as a beta component and again DQ transformation. Similarly, for c-phase DQ transformation and all three D axis current, we add here and Q axis current, we add here and after adding this, we use the low pass filter so that we get the dc component or fundamental component of it and then, we divide by 3 because we have to convert per phase basis add with the loss here, [FL] we get the amplitude of active component current.

And here, we get the we have again we subtract here because these have to be met from DSTATCOM locally the reactive power and the remaining self-flow only the current, [FL] we get the amplitude of reactive current of the grid and we have again sine theta cosine theta because these are the dc quantity or you can call it in you can call it DQ reference frame and using cosine theta sin theta, we convert into typically you can call it in I mean again back into DQ 2 alpha beta or you can call it all three a-phase, b-phase and c-phase current.

[FL] we have a three-phase current, you can call it here reference current and by sensing the load typically the grid current, we can just compare and use the current controller for generating the gating signal for DSTATCOM. [FL] this we call it the single-phase DQ theory like on or so.

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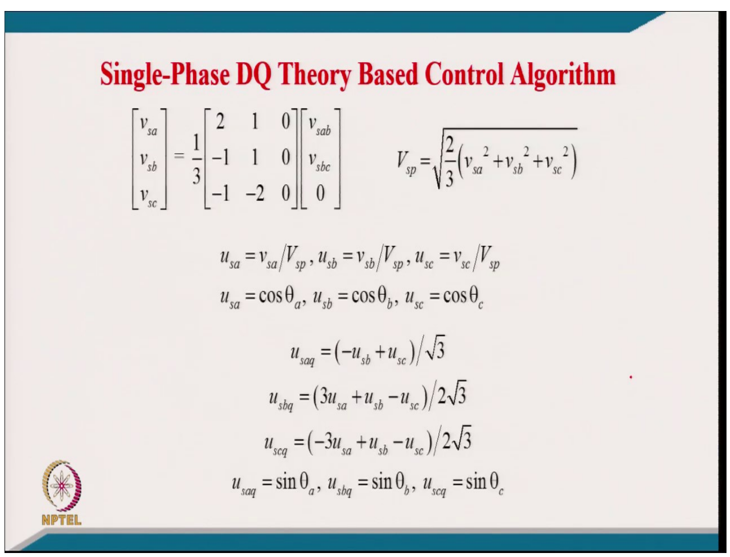

Well, single-phase, I mean the as far as mathematical formulation of single-phase DQ theory based control algorithm, I mean we have a again we are sensing for three-wire system the two line voltage and we are estimating three-phase voltage from here, from this expression as we did in other control algorithm and we have amplitude calculation of the phase voltage.

And we calculate then typically the template which we are considering and from these template, virtually, we are considering these are the cosine function and from this quadratic temperature, we are getting sine function that I mean does not require any PLL and very sophisticated. [FL] we get very straightforward, the simple calculation from that like I mean or so; for cosine theta sine theta.

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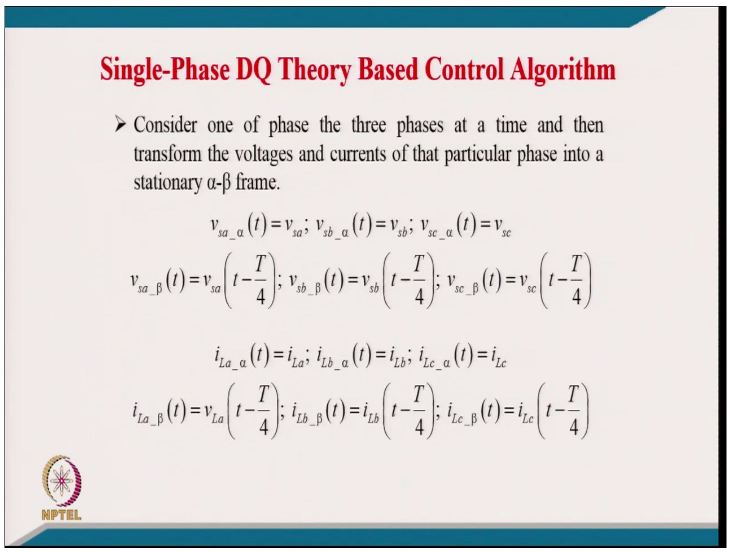

[FL] considering the one of the phases of three-phase at a time and then, transform the voltage and current to that particular phase into alpha beta reference frame, [FL] we have a three typically the three voltage and then, we are transforming the these three voltage 90 degree phase shifted; similarly, we have a three-phase load current and we transform the three-phase load current to 90 degree phase shifted as we already discussed in the block diagram.

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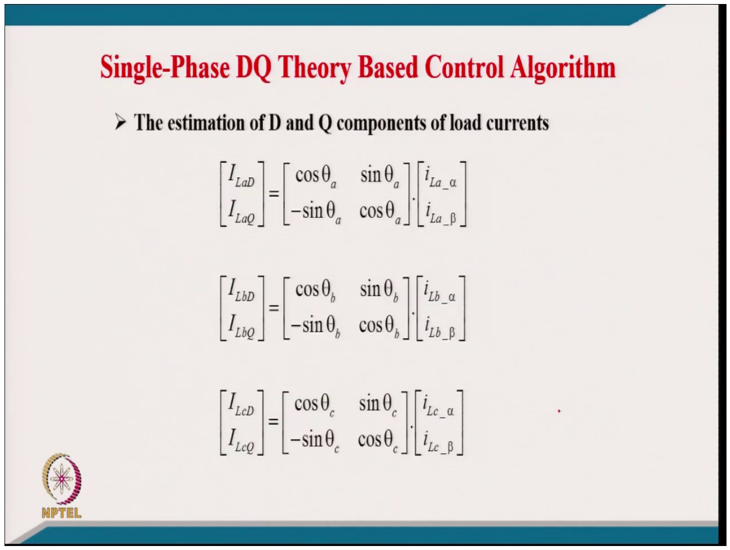

[FL] once we have these two sets of current for all three-phases, I mean by using this cos theta sin theta transformation for a-phase, b-phase separately and c-phase separately, we get the DQ component. You can call it for load a-phase current, b-phase current and c-phase current like.

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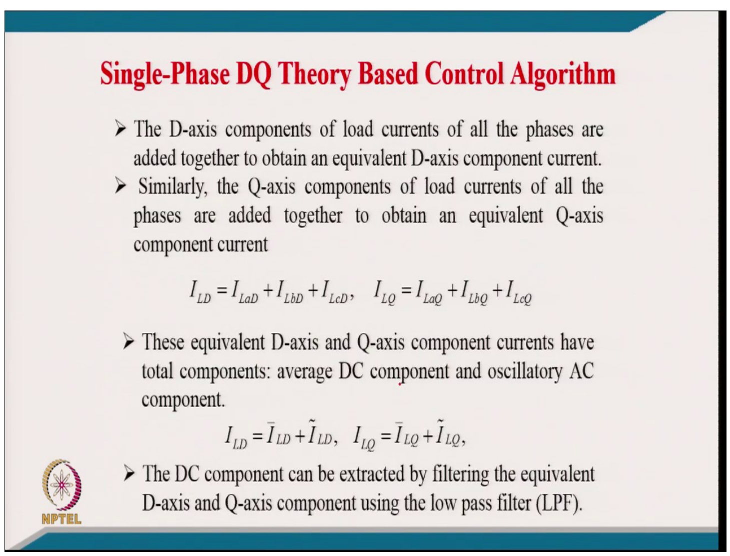

And then, I mean from that D-axis component of load current of all phases are added together to obtain the equivalent D-axis current. And similarly, Q-axis component of load current of all three-phases are added equivalent to, [FL] we have a here all three we are adding and even a quadrature component of load current or reactive current also we are adding.

And from this of course, I mean once we add, it has a dc component, ac component. Here dc component in for active power of the load and ac component is corresponding to we can call it like a ripple leads corresponding to either negative sequence or harmonics and other thing, I mean like components.

Similarly, for Q-axis, this is fundamental reactive current of the load equivalent and the dc component can be actually by filtering the equivalent D and Q-axis component using the low pass filter here as we have discussed in the block diagram.

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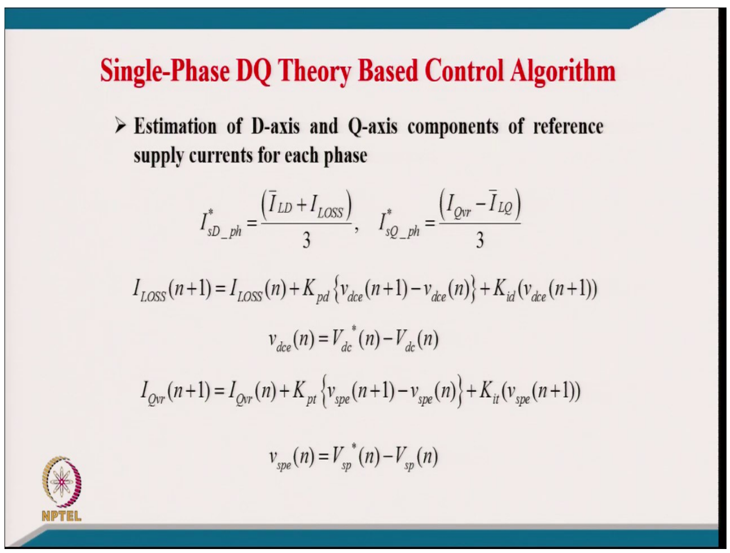

[FL] after getting this dc component, we can get a amplitude or per phase basis of your active component that is the load component plus the loss component for the DSTATCOM and we divide by 3 because this loss also have to be supplied by all three-phases.

Similarly, we take a typically for Q, I mean like quadrature also; the reactive power generated by DSTATCOM by PI controller as we are calculating here by PI controller on the voltage PCC voltage amplitude, [FL] that minus the we are taking like the reactive power required by the load and then, because that have to be supplied locally by DSTATCOM.

[FL] divided by 3 means we are getting per phase and this is certainly, the active power loss equivalent component by losses in the DSTATCOM, which are only dc link I mean achieved by putting a PI controller on dc link voltage. [FL] these are the two amplitude for active power and reactive power component of current form drawn from the supply system.

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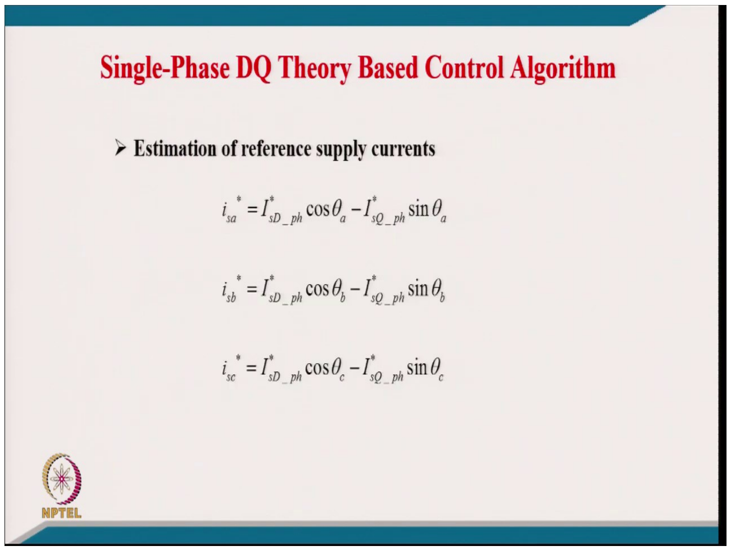

Now, from getting this D and Q component, I mean using this transformation for, we can get it typically for a-phase, b-phase and c-phase; three-phase reference current for the supply or grid current or we can call it source current and we have a sense source current. [FL], we compare them and get the current controller on that and we get the switching signal corresponding to that like on or so. [FL] this give the typically this control algorithm.

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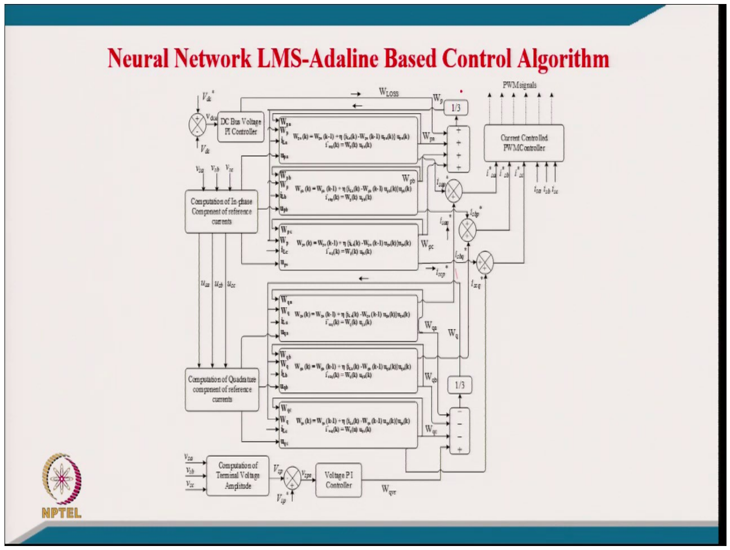

Well, typically another algorithm just to give you an idea like a neural network, I mean people are using this neural network concept typically in many applications, [FL] here also, we also given the simplest neural network algorithm. We call it least mean; LMS means Least Mean Square at Adaline Based Control Algorithm for the control of DSTATCOM and I consider this is one of the simplest among the all control algorithm which we have discussed so far.

[FL] just here, you can just see even a single even a single expression is responsible for extracting the fundamental active component from the load current. [FL] we have here again the dc bus voltage controller, PI controller which we are estimating. We have a reference dc link voltage, we have a feedback dc link voltage and we are using the PI controller Proportional-Integral controller regulating the dc link voltage. Of course, this is the after the low pass filter after sensing this and this give us the loss component which we just take into this block.

And then of course, we given a weight back to the input to this and we are giving here as a input as a load current and you can see as a input as a load current, we are giving a I mean for typically for a-phase and we are giving a template which we are calculating template form point of common coupling voltage; phase voltage, we are calculating phase template and we are taking a quadrature template. [FL] from phase template also we give it; the previous weight, the total weight and we take a load current and the template.

And from using the single expression, we are able to extract the weight corresponding to you can call it the active component of for a-phase current and we are able to estimate virtually a-phase even a typical current here also. Similarly, for b-phase, active component; similarly, c-phase active component and this is reactive component for only one expression for you can call it extracting and this is for b-phase reactive power and c-phase reactive power.

[FL] we have a reactive power component, we have active component and this active power component, we add by one-third and here also we take all three. [FL] we get this weight and once we get the this total weight, we get the reference current here and this we take here for a-phase.

Reactive component, we take from this phase, [FL] here and we get the total component for grid for voltage regulation as well as for power factor correction. Of course, if you do not want typically the you want only power factor correction, then typically I mean you can just keep this component here the 0, I mean the reactive component and that can give you power factor correction.

[FL] similarly, for b-phase and c-phase and you are getting three-phase grid reference grid current, you have a sense grid current and you have a PWM current controller here current controlled for the voltage source converter operating as a VSI. [FL] this is one of the simplest you can call it the single expression is able to take the fundamental component of the load current of a-phase, b-phase and c-phase very effectively and we are able to balance per phase basis also by calculating from this like.

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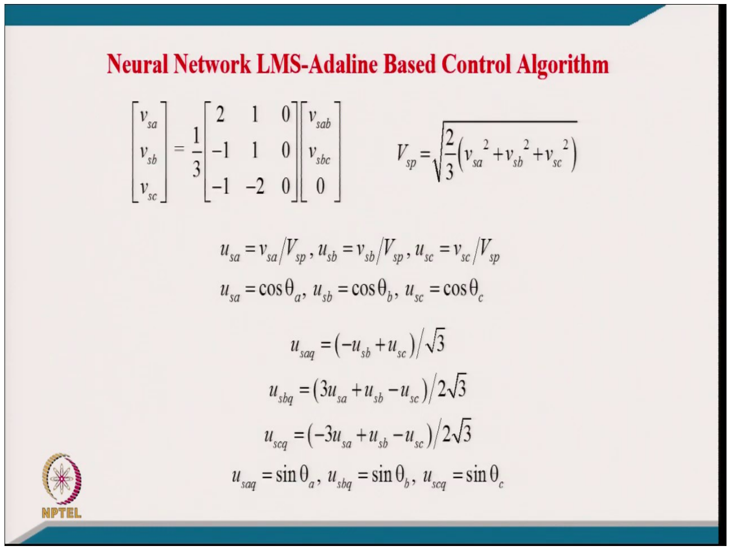

And this is the mathematical of course, equations correspond to that. [FL] from line voltage, we get the phase voltage, we get the amplitude of voltage and we get template here as a cosine theta for all three-phases from this amplitude and instantaneous and we get the quadrature component and then, we get typically here even the quadrature sine theta cosine theta.

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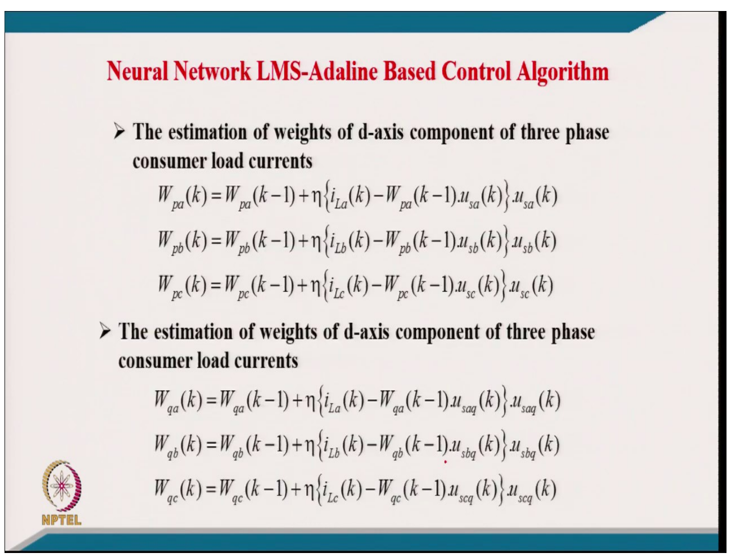

And then, we get this active weight, I mean which we have already given expression for a-phase, I mean this is a-phase load current, we have a template here and the template there. [FL] using just this simple expression, I mean here it is a one convergence factor this is becomes very important. This eta convergence factor, I mean if you keep very high, filting will be poor; if you keep a smaller, then it will be slower convergence.

[FL] you have to make a compromise and we found point two I mean typically point two value of this convergence factor have been quite good, a compromise; but of course, depends on I mean this can be for the look into as a adaptive also, even some of our student have used this as a adaptive manner also.

[FL] during dynamics and during in steady state, you can modify also and similarly, we get the weight corresponding to quadrature component of all three-phase load current from using this expression. [FL] all these three six-weight for active and reactive component of load current, we are able to extract the fundamental active and reactive current from the load current like.

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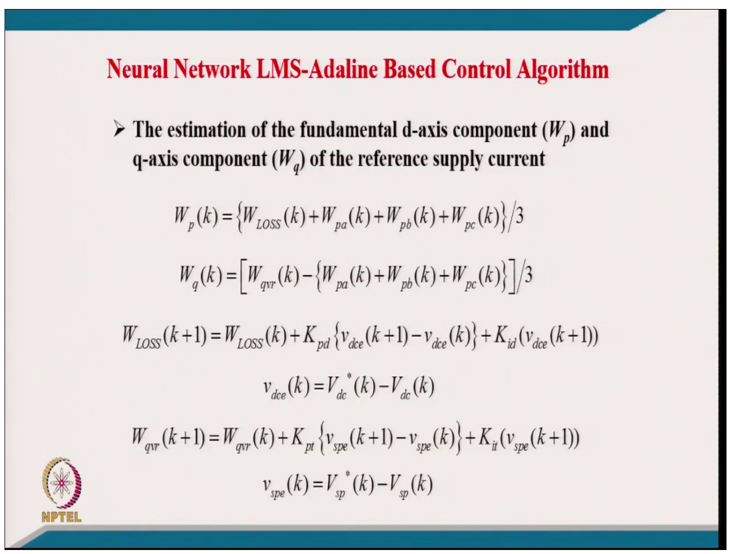

And that of course, I mean we have a loss again from PI controller here and we have a typically the all three active component of current, fundamental active component of current. They may be unequal because of unbalanced load; but here by taking three, we are calculating per phase basis.

Similarly, reactive power generated by DSTATCOM minus the reactive power consumed by the load for all three-phases and then, per phase basis that the loss component we calculate from PI controller again on dc link voltage as we did in another control algorithm. And similarly, the voltage regulation at the point of common coupling regulating the amplitude of the voltage like I mean. [FL] that give the basically the amplitude of active component and reactive component of the supply current.

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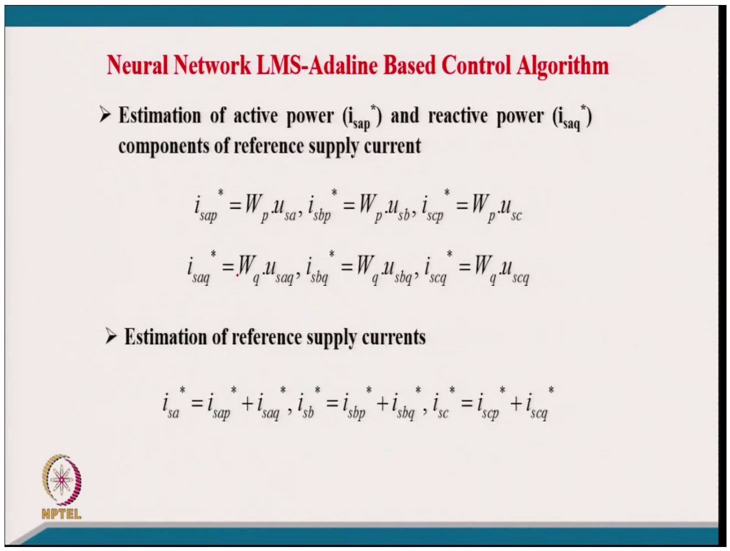

And then, from this, we can calculate for all three-phases using this weight multiplied the template for a-phase, b-phase, c-phase the you can call it the active component of all three-phase grid current; similarly, reactive component of the grid current which is required for voltage regulation.

But you can keep this as a 0, then W q 0, then you will get a power factor correction only by this and then, you can add all both the component of for a-phase, b-phase, c-phase getting a you can call it the reference total reference grid current and by comparing it with the sines grid current, I mean you can generate the getting signal for the three-phase voltage source converter operating as a DSTATCOM like I mean or so.

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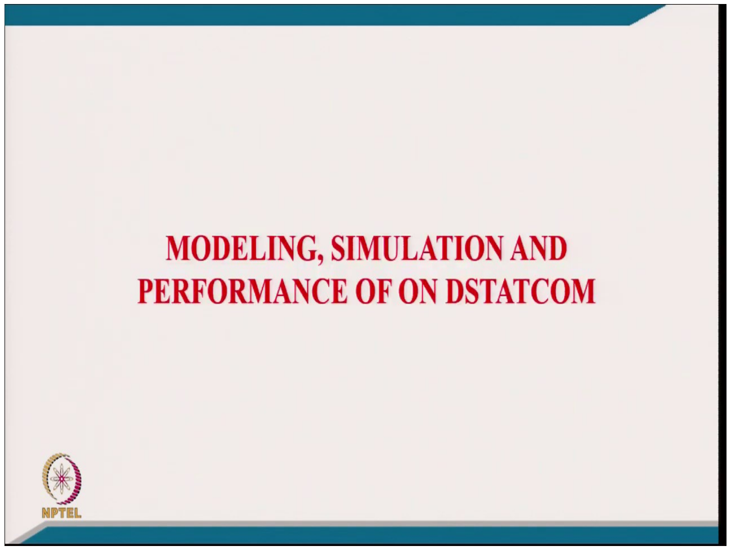

[FL] that control I mean these we have discuss enough number of control algorithm for DSTATCOM and this control algorithm of course, we will be covering in the lot of active compensator. This was the (Refer Time: 28:07), then we will talk about the even a series compensator, then hybrid compensator, then we will go even later on other cases also like a active filters.

[FL] we will not discuss it again, we will just discuss the modification. [FL] at one place, we wanted; this will discuss all these control algorithm in a one form so that you understand and then, the little modification, we will discuss it. Now, we like to of course, discuss that these control I mean after this control algorithm, we look into a case study of these DSTATCOM three-phase three-wire by modelling the complete system.

[FL] including a control and power circuit and in and load modelling also and even the different kind of disturbances which you can think about demonstrating like a load unbalancing other thing, [FL] and then simulated through that MATLAB modelling. Of course, you can model in any other form; earlier, we were modelling through MATLAB, we were just making our you can call it the program code and then, simulating the performance

But now such software like MATLAB are available, [FL] you can develop the total model itself from the block for this complete system including a control algorithm and then, we are able to get a performance of this DSTATCOM like.

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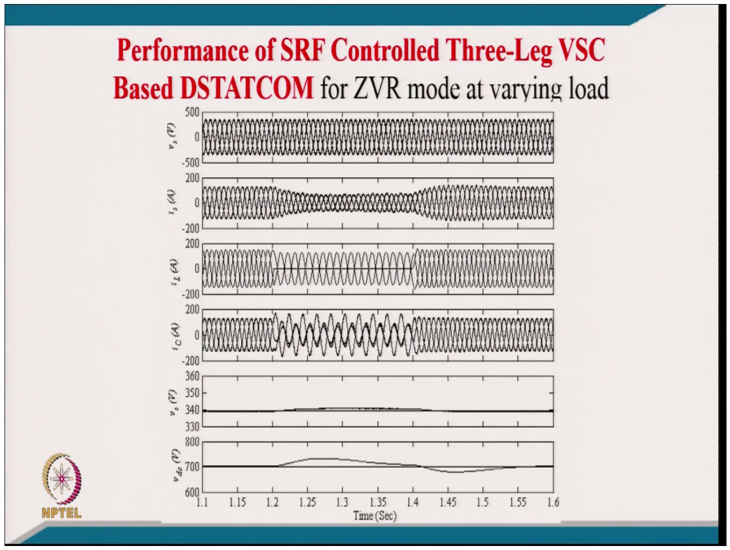

[FL] this is the typical case study, I mean performance of you can call it Synchronous Reference Frame Controlled Three-Leg Voltage Source Converter based DSTATCOM for Zero Voltage Regulation mode at varying load. [FL] you can just see it is a three-phase PCC voltage; it is three-phase grid current, which are balanced current. But of course, they may not be in phase because you are using for voltage regulation ok; maybe slightly leading and this is the load current.

You can see the load current; here, we have a three-phase load current, lagging power factor load current, but here we have removed one-phase in three-wire system [FL] two current one return is like a single-phase; one current is going and returning, [FL] this is load unbalancing to demonstrate and again back putting the that load current back, I mean so that I mean you look into how the dynamic response is there and this is are the compositor or DSTATCOM current.

[FL] DSTATCOM current, if load is unbalanced, the DSTATCOM current also become unbalanced; otherwise here, it was the only compensating the reactive power because these were lagging load and you have to maintain the voltage.

[FL] these are compensator current for all three-phases and this is the voltage you can see the regulated voltage across the point of common coupling. Of course, during dynamics, it takes time because of X and PI control, but it remains regulated and this is the dc link voltage because when you remove the load, certainly there will be slight overshoot in the dc link voltage.

But with the time, it gets settled down and again, when you apply the load, there will be some undershoot; I mean, but that comes within the design limit and you are able to get a quite satisfactory performance as far as the grid current are concerned. Even the load is unbalanced, but grid current are balanced and sinusoidal throughout the operation in this zero voltage regulation mode.

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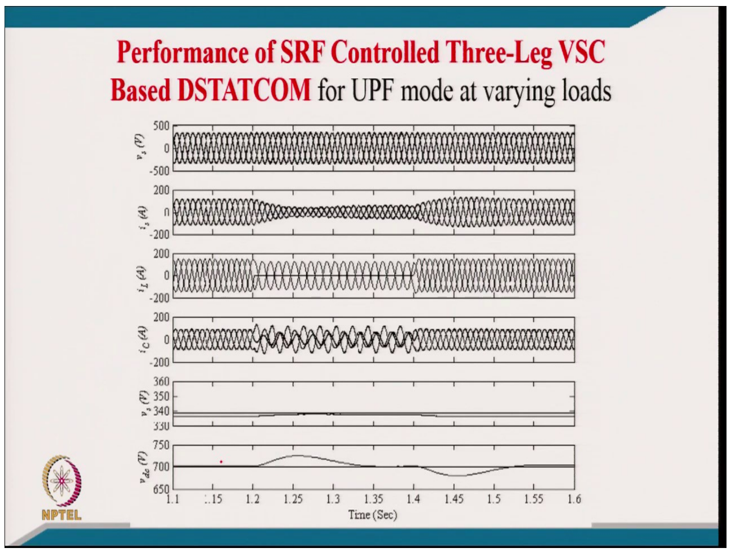

Then, the next mode is of course, it is Unity Power Factor mode. I mean unity power factor mode, we discuss it earlier, [FL] these are the point of common coupling voltage and these are the unity power factor current, balance current, sinusoidal current, current in phase with the PCC voltage and when load is removed, you can just see how the current are modify, one phase load is removed, [FL] load it is a load balancing; it provides the reactive power compensation as well as the load balancing.

And you can see the compensator current, [FL] these are the some current because it is the lagging power factor load. [FL] it provide the leading current I mean by the compensator so that power factor is unity of the grid current and here, you can see the unbalanced current because the load is unbalanced, [FL] compensator have to generate unbalanced current so that the grid current are balanced current and again back putting the load, it comes that and you can see, here we are not regulating the voltage of typically a point of common coupling.

[FL] when you have a load, certainly the voltage at the point of coupling reduces from the supply voltage and of course, when you remove the load, it comes closer to that; but it is still some small difference.

Similarly, when you apply the load back, it goes little down. But you can see the dc link voltage, when you remove the part of the load, where you are drawing the more energy even forfeiting the load now, same energy gone coming for some period and that give the overshoot in dc link voltage for short period. But after the controller action, it comes back to the same and similarly, when you apply the load back it go to undershoot and after the action of PI controller, it recover back.

You can just see this overshoot undershoot is hardly I mean go typically 4 to 5 percent, it depends on your controller parameters on PI controller regulator parameter, how it can be made fast. But if you want to really avoid this, you can use another you can call it the control like a slide remote controller also which may give better than PI controller, but here we are just discussing kind of a one of the benchmark as a case study like.

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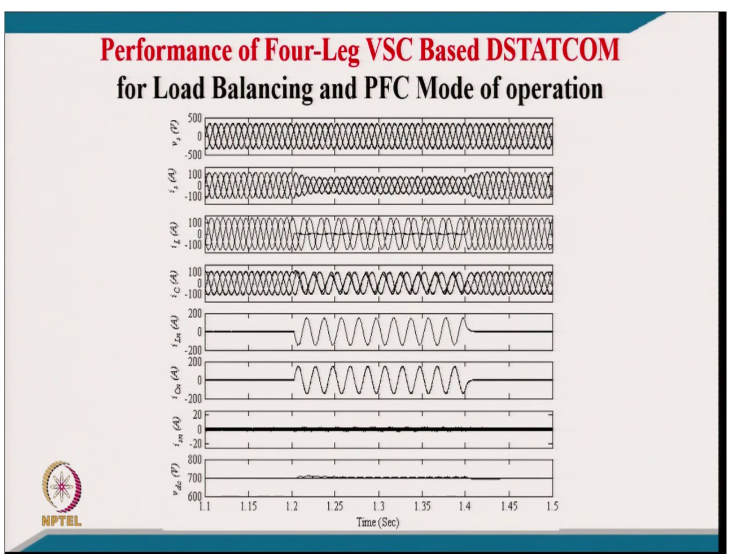

Well, that was the typically four three-wire system. Here we have a four-wire system. I mean we are using a performance of four-leg four-wire system voltage source converter

DSTATCOM for load balancing and power factor correction mode. [FL] you can clearly see here it is a three-phase supply current, three-phase supply voltage, three-phase grid current and here it is the load current.

[FL] you can say load is connected between line to neutral for all three-phases and in during this duration, two-phase loads are there, but third phase load is removed. I mean here and because of this you will find there will be a kind of load neutral current and when there was a balanced load current, there was no neutral current was there.

But load is unbalanced, it means now two-phase line to two line to I mean neutral there is a load connected, [FL] one-phase is not there that is why you have a load neutral current appearing there and again, you recover back, [FL] again neutral current goes 0. But in during this period, when you have a load unbalancing, of course one-phase load is less, [FL] power drawn is less.

That is why the total balance current drawn from the supply is also reducing here and you and the compensator, of course three legs are generating the current for balancing this and so their supply current are balanced and the fourth leg is compensating the neutral current so that grid neutral current is maintained 0.

[FL] these are two opposite; I mean whatever the load current is there, the compensator neutral current is just exactly opposite and same magnitude so that the neutral current is kept 0 and the dc link voltage remains regulated here because it is a power factor correction. [FL] we are not shown the voltage waveform, [FL] that is demonstrative in three-phase four wire system; I mean typically neutral current compensation also along with the reactive power and load balancing like.

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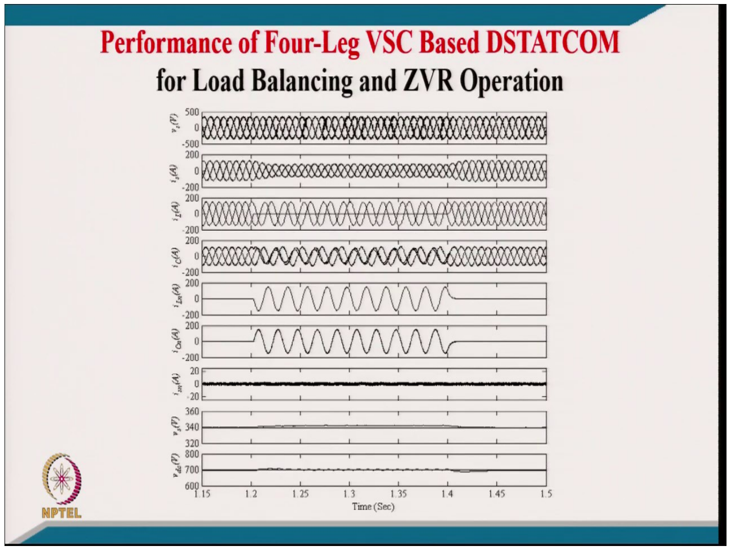

This is the another case study, again of you can call it like a four-wire four-leg voltage source converter phase DSTATCOM for load balancing and zero voltage regulation. [FL] you can clearly see here it is typically the voltage at the point common coupling which is regulated which we will see in PI controller and these are the grid current which are balanced; but of course, maybe slightly leading because you have a lagging power factor load and here we remove the load of one phase and apply back. [FL], you will see neutral current, here it is 0 and once the load unbalancing, then neutral current appears.

And the compensator three-phase current and neutral current of the fourth leg of compensator, they are able to I mean compensate for neutral current as well as the reactive power as well as you can call it even for regulating the voltage and you can see here neutral current is 0 throughout, I mean like and point of common coupling voltage is also regulated and dc link voltage also remain regulated like I mean or so. [FL] it depends on controller parameter or so. [FL] that is another typical case study what we have looked into.

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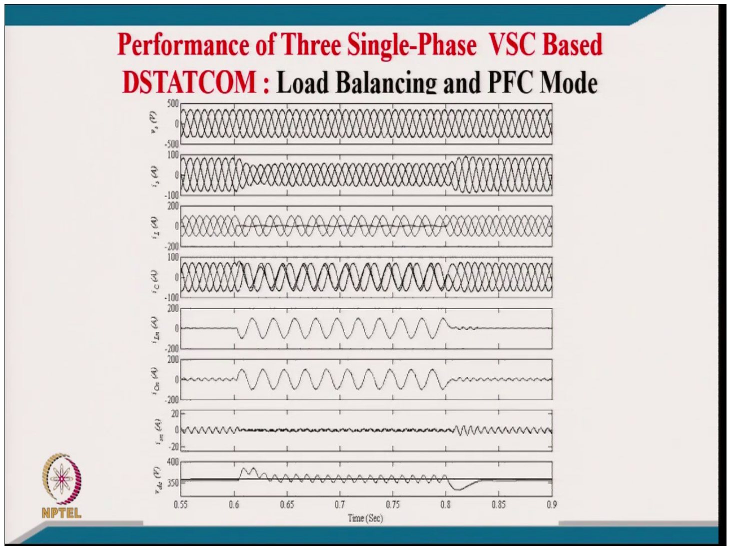

The another case study for three single-phase, I mean four-wire system, you can use the thing three single-phase voltage source converter also, DSTATCOM for load balancing and voltage regulation and here you can say the three-phase PCC voltage, then the you have a three-phase grid current and which are balanced and sinusoidal at unity power factor and here, you can say load is unbalanced and having a load unbalance from three single-phase, you are providing the compensating current here and you are providing the load neutral current here.

[FL] you are putting the compositor current through typically I mean throughout the neutral just exactly opposite out of phase so that neutral current in the grid is 0, almost negligible and this is the dc link voltage of this. Why dc link voltage? I mean you can see a little and that because this is lower voltage, you are able to see the second harmonics, when there is unbalancing of the load. That is the nature, I mean because we are using three single-phase I mean here.

[FL] you have a slight overshoot, when you remove the load because energy is coming and when you apply again back the same load and slightly undershoot is there, but I mean second harmonic certainly will be there which I have discussed many time, when we were using low pass filter for regulating the dc link voltage of the DSTATCOM.

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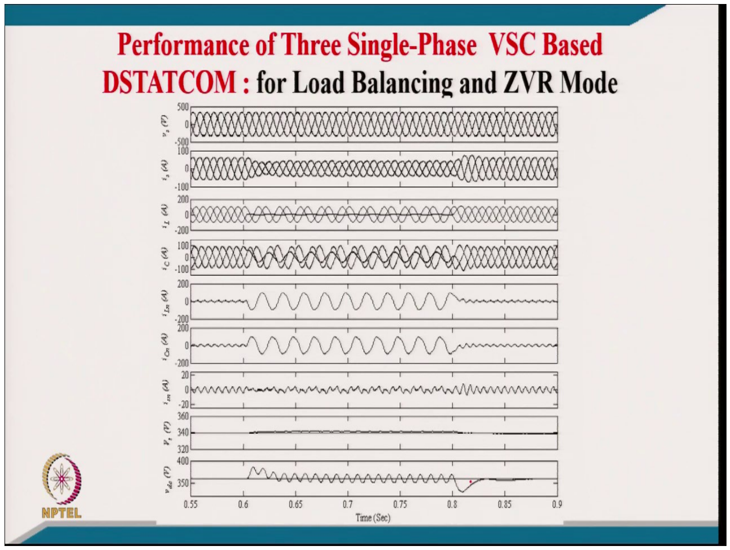

And then, the same the compensator of three single-phase voltage based DSTATCOM for four-wire compensation for load balancing and zero voltage regulation. [FL] here what we are having like a three-phase PCC voltage, then we have a grid current which are balanced and sinusoidal and here is a load is made unbalanced and compensate accordingly compensate so that grid current are balanced.

It is a neutral current of the load and compensate a neutral current which compensate this exactly out of the phase and same magnitude so that neutral current is almost source neutral current is almost negligible and the point of common coupling voltage, you can see clearly remains regulated throughout the operation.

I mean like whether load is less or load is unbalanced and here you can see the dc link voltage again have apart from that your second harmonic during load unbalancing; I mean and then slight overshoot undershoot and a removal of the load and application of the load like I mean or so. Because it give a instantaneous energy comes back to the dc link and here, it takes instantaneous energy from the dc link capacitors of the DSTATCOM.

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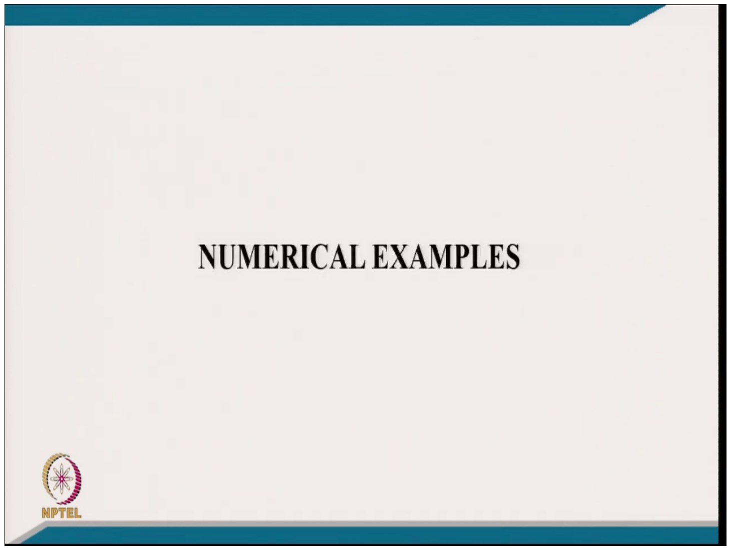

[FL] with this, these are the case studies we discuss it; typically, the for voltage regulation power factor correction for three-wire system and four-wire system. Now, we like to discuss typically some of the you can call it numerical examples, I mean on these DSTATCOM starting from single-phase, three-phase three-wire, three-phase four-wire DSTATCOM system for used for compensation.

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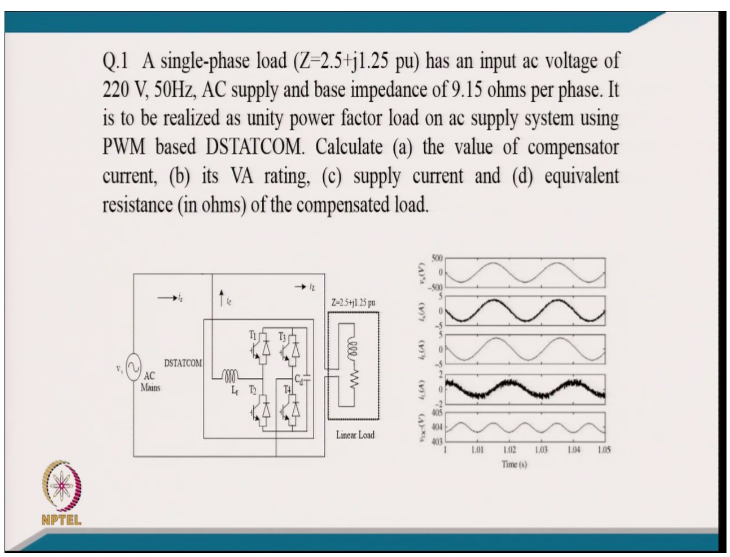

So, this is the first example. a single-phase load Z equal to 2.5 per unit plus j 1.25 per unit has an input ac voltage of 220 Volt, 50 Hertz, AC supply and base impedance of

9.15 Ohm per phase and it to be realized as a unity power factor load on ac supply system using PWM based DSTATCOM. Calculate the value of compensator current, its VA rating, supply current, equivalent resistance of compensated load.

[FL] we can clearly see here we have a supply and we have a load which is a inductive load and we have a DSTATCOM typically, I mean circuit here, [FL] what we have to find out and for given load, we have to find out this compensator current so that I mean we have a unity power factor on the supply side.

[FL] after getting typically the design and we just simulated with power factor control, you can clearly see the grid current is in phase with the grid voltage and this is the load current which is I mean little lagging power factor.

And this is the you can call it like a compensator current and this is a dc link voltage. It is slightly enlarged; but you can see in single-phase, this will be second harmonics that is the nature of the system second harmonics will be there. [FL] over this voltage of your whatever you are regulating I mean the you have a this second harmonics reflected on the dc link of this like.

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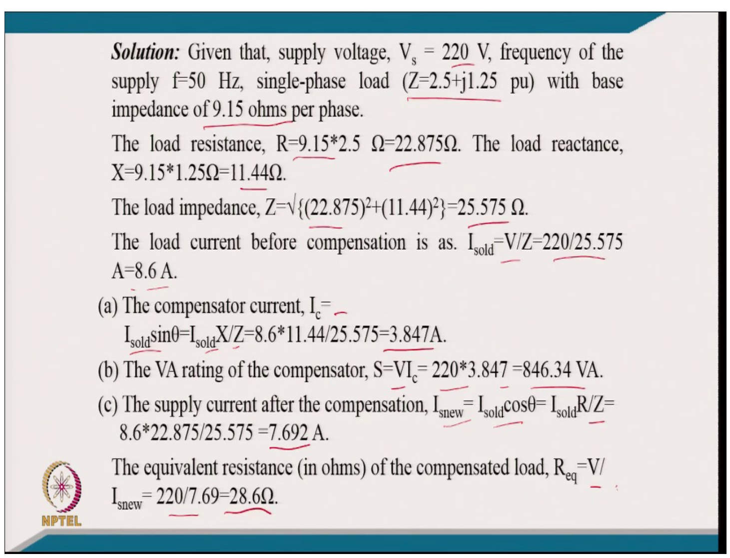

Coming to the solution part of this. Given that, the supply voltage is 220 Volt. You can say supply 50 Volt and single-phase load equal to Z equal to 2.5 plus j 1.25 per unit with a base impedance of 9.15 Ohm per phase. [FL] load resistance comes to be after calculating, it comes 22.875 Ohm and load reactance comes for 11.44 Ohm and the load impedance, I mean comes 25.575 Ohm and the load current before the compensation comes V upon Z, it comes typically 8.6 Ampere.

And compensator current which is for reactive current I sold into sine theta; I sold X upon Z, putting the value, it come 3.847 Ampere and the VA rating of the compensator with V into I c that come 220 in to 3.847 that comes 846.34 VA and supply current after the compensation is typically I snew equal to I sold cos theta that is I sold into R upon Z, [FL] it comes typically 7.692 Ampere and equivalent resistance of compensator load is R equal to V upon typically V upon I, [FL] it become 220 upon 7.69, [FL] it come 28.6 Ohm.

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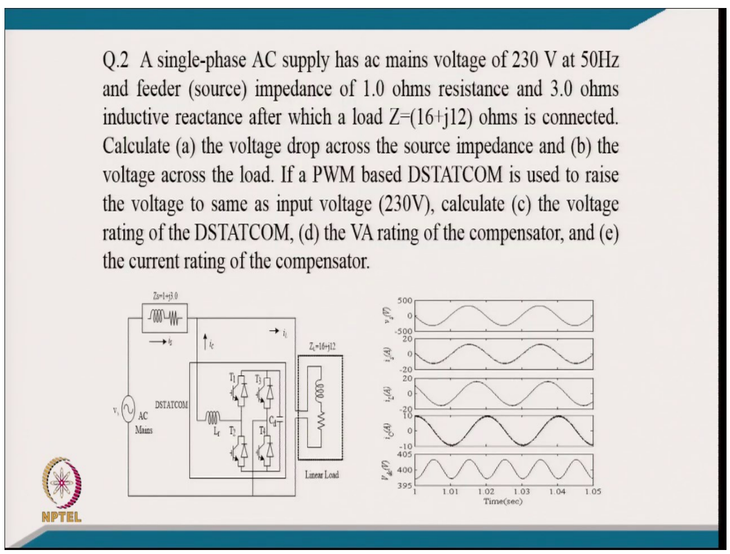

[FL] taking another example a single-phase AC supply has ac mains voltage of 230 at 50 Hertz and a feeder source impedance of 1 Ohm resistance here and the 3 Ohm inductive reactance after which a load of 16 point j 12 Ohm is connected. [FL] calculate the voltage drop across the source impedance and the voltage across the load. If PWM based DSTATCOM is used to raise the voltage same as 230 which was the grid voltage, calculate the voltage rating of the DSTATCOM, VA rating of compensator and current rating of the compensator.

[FL] after getting proper design and control and these are the waveform after the simulation with power factor control here and you can see clearly I mean supply voltage and supply current, they are typically here and supply current typically supposed to be slightly leading than and this is the load current and this is the typical compensator current or you can call it like the current draw I mean put from this and this is the dc link voltage which certainly takes a second harmonic chain into it like or so.

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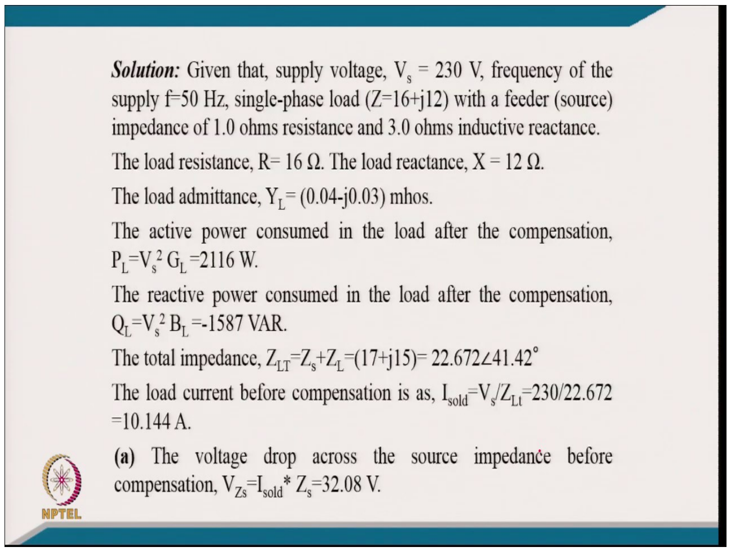

Well, [FL] given the that the supply voltage V s 230 Volt, frequency of supply 50 Volt and single-phase load of 16 point 12 Ohm and feeder impedance of 1 Ohm resistance and 3 Ohm reactance; [FL] total I mean load resistance of 16 Ohm and load reactance 12 Ohm, [FL] admittance of load admittance and we can get the active power form conductance V square G L.

[FL] this is active power consumed by the load and this is the reactive power consumed by the load and the total impedance, we can find out including the source impedance here with this relation and we can find out the load current before the compensation V s by total load or total impedance of the circuit and then, we can find out the voltage drop across the from that source impedance multiplied the current that is the voltage drop across the source impedance before the compensation.

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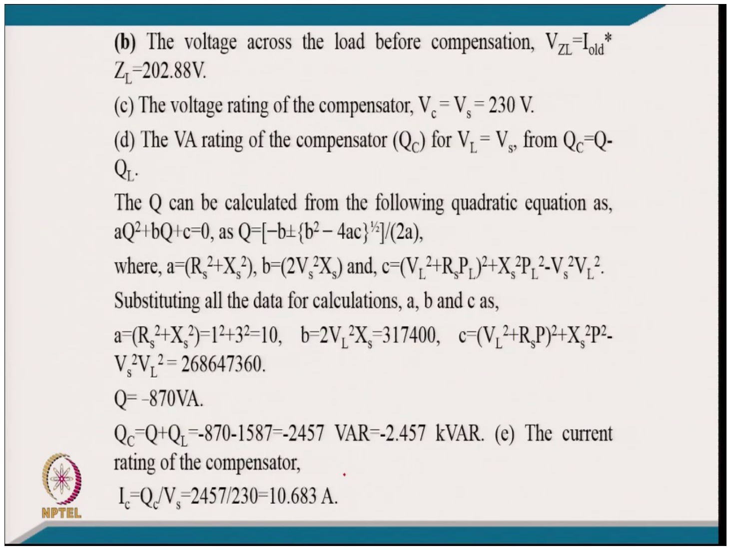

And the voltage across the load, we can find out. [FL] that is the or your you can call it the current drawn from the source multiplied the load impedance, [FL] it comes to 202.88 in place of your typically you have 230 Volt. [FL] that voltage you can say it reduces because of source impedance and lagging power factor load which give you worst voltage regulation.

Now, we want that the compensators should regulate the Volt same voltage at the point of common coupling at the source voltage that is 230 Volt, [FL] VA rating of compensator we can call it for V L equal to V s that will QCc equal to Q minus Q L. [FL] Q L can be calculated from the following equation. I mean we have a here the equation quadratic equation for this aQ square plus bQ plus c, where you can call it Q is calculated from this relation, where a is here, b is here and c is here.

And once, we are calculating the a, b, c and we get the Q equal to typically 870 VA and total compensator current that is for voltage regulation only and we can get typically here Q, Q C equal to Q plus Q L and both are of course, of you can call it leading nature. [FL] we get I mean minus 2457 that lead minus means it is a leading reactive power and it becomes 2.457 kVAR and the equivalent current rating of the compensator will be the VA rating I mean VAR rating divided by voltage, [FL] this is the current rating of the compensator like or so.

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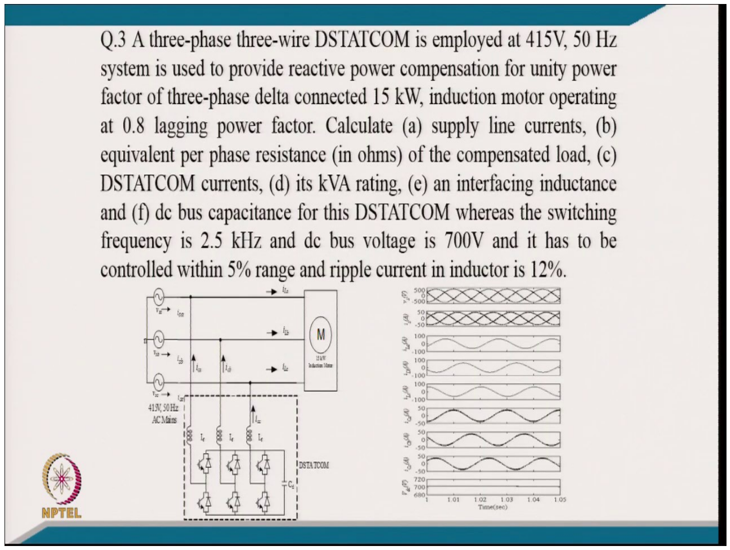

I mean like to discuss on this distribution a static compensator, virtually on the applications and then typically related to the problem. [FL] a three-phase three-wire DSTATCOM is employed at 415 Volt, 50 Hertz system is used to provide reactive power compensation at for unity power factor of three-phase delta connected 15 kilo Watt, induction motor operating at 0.8 lagging power factor.

[FL] calculate the line current equivalent per phase resistance the compensated load DSTATCOM current, its kVA rating, an interfacing inductance, dc bus capacitance for this DSTATCOM whereas, the switching frequency is 2.5 kilo Hertz and dc link voltage is 700 Volt and it has to be controlled within 5 percent range and the ripple current in the inductor is 12 percent like.

[FL] this the typical circuit like, the I mean like some motor is connected to the grid; but with this DSTATCOM, we want to have a power factor on the grid side, it means all the reactive power which is required by the induction motor load is to be supplied by DSTATCOM and these are the typical cons you can call it the all the currents voltage and current of this circuit including the dc link voltage or so.

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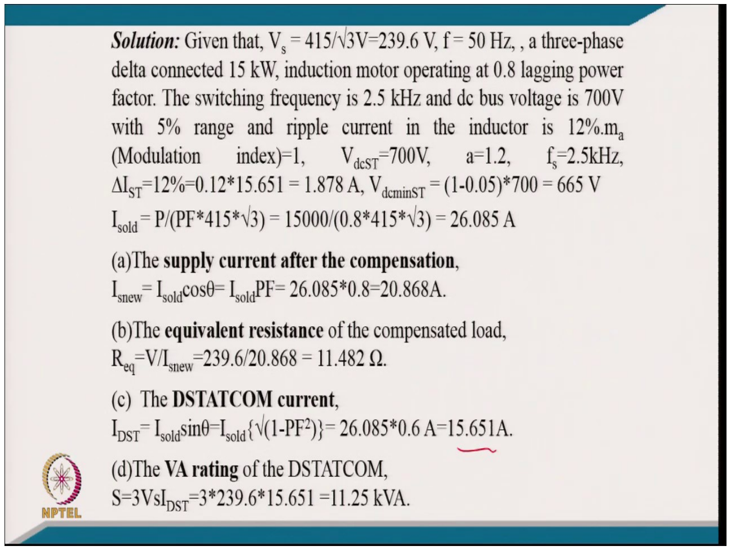

[FL] coming to the solution that given that V s equal to 415 by root 3 per phase voltage 239.6, frequency 50 Hertz, a three-phase delta connected 15 kilo Watt. Induction motor operating at 0.8 lagging power factor, the switching frequency 2.5 kilo Hertz and dc bus voltage is 700 Volt with a 5 percent range and ripple current in the inductor is 12 percent, modulation index is 1 and V dc of DSTATCOM is 700 Volt, a equal to 1.2 and frequency of switching voltage 2.5 kilo Hertz.

[FL] we can calculate the ripple current, I mean 12 percent that is 0.12 into the current of the typically of how much is the DSTATCOM? [FL], 15.61, [FL] it comes 1.87 and we know minimum dc link voltage is provided 5 percent less than 700, [FL] it becomes 665 and we can find out the current virtually for I mean like typically corresponding to the load that is 15 kilo Watt divided by power factor 0.8 415 root 3, [FL] it comes 26.085. [FL] the supply current after the compensation is I snew equal to I sold cos theta and that is 26.08 into 0.8, [FL] the load current active component current is 20.868 Ampere.

And the equivalent resistance of the compensator load is V upon I, [FL] that is per phase voltage 239.6 divided by per phase current 20.868, [FL] it comes 11.482 Ohm and the DSTATCOM rating is corresponding to the reactive power required for the load that is the I DST, [FL] I sold sin theta, I sold under root 1 PF is equal to it comes like 26.08 into 0.6 and it comes 15.651 Ampere and the VA rating will be 3 into phase voltage into the current of the DSTATCOM, [FL] it come 3 into 239.6 and 15.61 that comes 11.25, that [FL] that is the kVA rating of the DSTATCOM.

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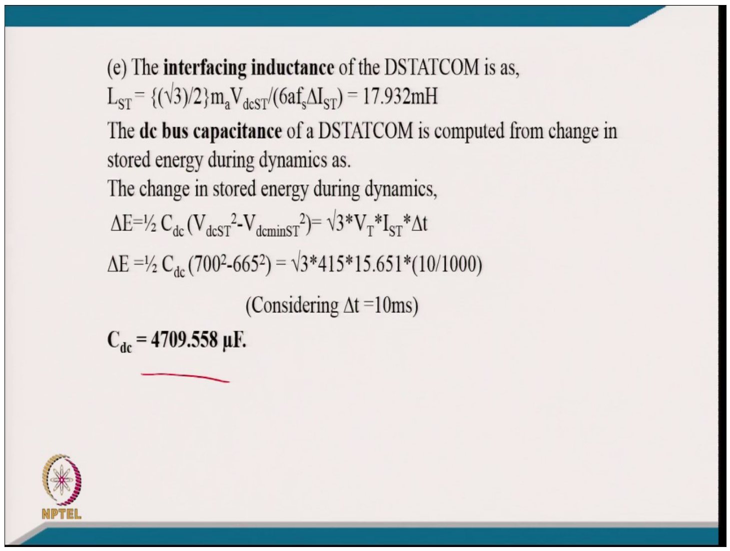

And from this, we can calculate the interfacing inductance; I mean which require L ST with this system formula which we derived earlier root 3 by 2 into m a V ST upon 6 f s into del I ST, [FL] that comes 17.92 milli Henry and the dc bus capacitance of a DSTATCOM is computed from the stored energy dynamic as delta equal to half C V square and from this, we get the capacitance value typically of four point 4709.55. Considering that, we will recover this energy in time milli second like or so.

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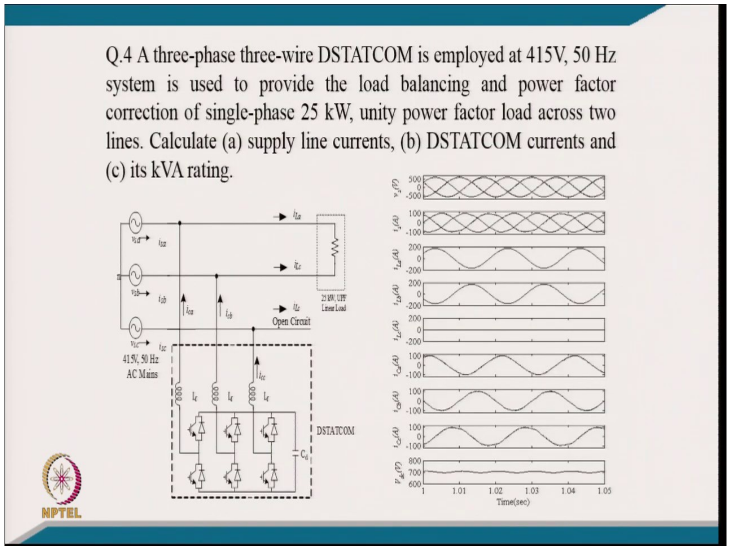

Well, coming to another fourth example of DSTATCOM a three-phase three-wire DSTATCOM is employed at 415 Volt, 50 Hertz system is used to provide the load balancing and power factor correction of single-phase 25 kVA, unity power factor load across the two lines. Calculate the line current, DSTATCOM current and kVA rating. This is the how it is a single-phase load line to line connected and we have a DSTATCOM connected across this.

[FL] DSTATCOM provide the load balancing and unity power factor on the grid side and these are typical waveform of supply voltage, PCC voltage and the grid current which are balanced and transferred at unity power factor and these are typically the load current across the two, I mean like and third phase do not have a load because its open circuit and then, these are the compensator current and dc link voltage like.

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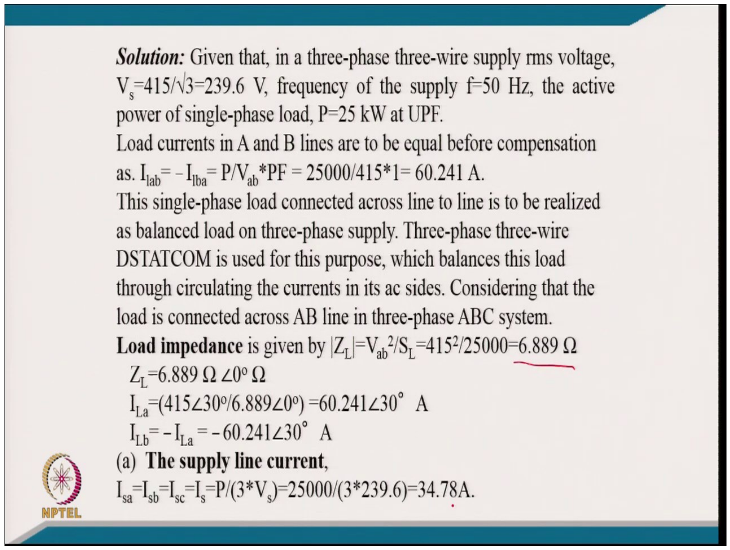

[FL] coming to the solution. Given that, in a three-phase three-wire supply rms voltage 415 by root 3, 239.6 and frequency 50 Hertz and active power of load is 25 kilo Watt at unity power factor. [FL] the load current in AB line to be before the compensation is I lab equal to I lba that is P upon V into PF, [FL] it comes 25000 divided by 415.

[FL] it comes 60.24 Ampere and single-phase load connected across line to line to be realized as a balanced load on the three-phase supply and three-phase three-wire DSTATCOM is used for this purpose, which balances this load through circulating the current in ac side, considering the load connected across AB line in three-phase ABC system, [FL] load impedance we have calculated V square by S L, [FL] that is 415 square by 25000 and comes the load resistance virtually of 6.889 Ohm.

Now, once we know the load impedance, we can find out the typically the current going into the line that is voltage 415 at 30 degree angle divided by 6.889, [FL] it come 60.241 at the angle of 30. Similarly, the current other two will be of 60, same amount of current 60.241 Ampere and the supply line current will be all three equal, it will be P upon 3 V s that is 25000 because that is total power now distributed on three line, [FL] 3 into 2 and this comes the line typically the grid current become 34.78 Ampere like.

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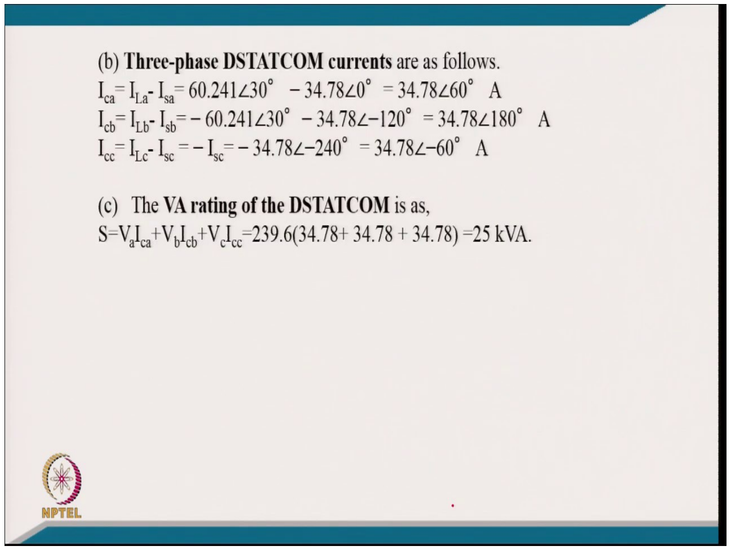

And the three-phase DSTATCOM current, we can find out from those relation. I mean from load current minus the supply current that will be compensator current. We can keep the value it come 34.78 Ampere and other also 34.78 and 34.7 Ampere; of course, at different angle correspondingly and VA rating of this, we can calculate typically from all typically phase voltage imply the respective current, adding together, [FL] it comes around typically it comes 25 kVA or so.

[FL] this example give you the typical example of load balancing as well as it have a unity power factor on supply side; in spite, it was single-phase load connected across unity power factor line to line which is very common load like maybe attraction, maybe furnaces, plenty of load may be of this nature of quite high rating which can be probably can be designed in the same manner, the DSTATCOM for those applications like.

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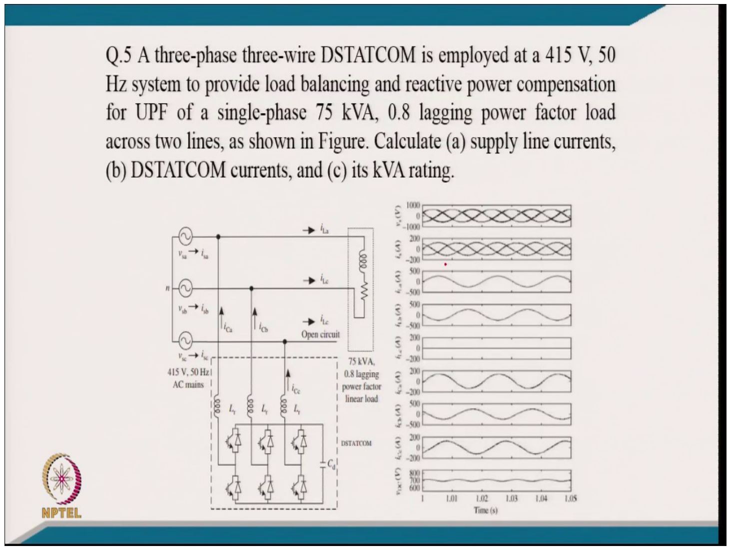

Coming to another example a three-phase three-wire DSTATCOM applied at the 415 Volt, 50 Hertz system to provide load balancing and reactive power compensation for unity power factor of single-phase load of 75 kVA, 0.8 lagging power factor load across two line, as shown in figure. Calculate the supply line current, DSTATCOM current and a kVA current.

[FL] this is just typically a point typically 0.8 lagging power factor load I mean that is across line to line third line is open; but be by DSTATCOM, keeping a DSTATCOM current, we can have a all three line current on the grid side balance and sinusoidal and corresponding waveform after making the control and with these are the three-phase voltage, then three line load current, third phase of line do not have a current. These are compensator current and dc link voltage.

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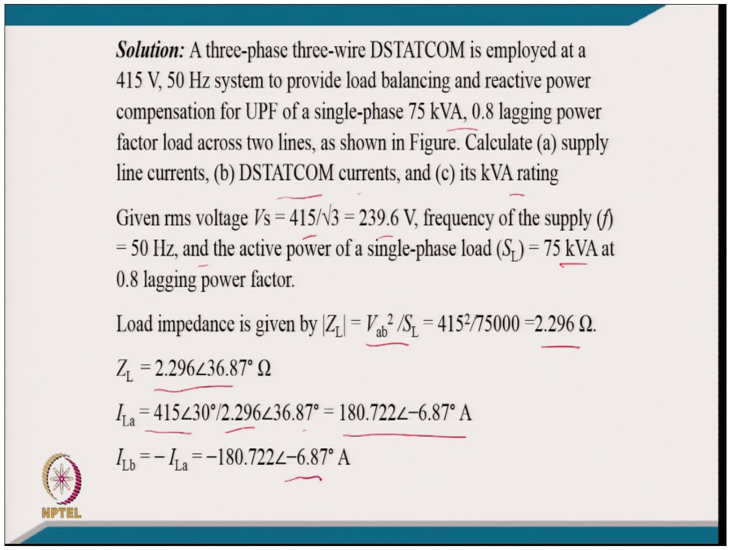

[FL], now coming to the solution part of is a three-phase three-wire DSTATCOM is employed at a 415 Volt, 50 Hertz system to provide load balancing and reactive power compensation for unity power factor of single-phase 75 kVA, 0.8 lagging power factor load across two line as shown in figure. Calculate the supply line current DSTATCOM current and kVA rating. [FL] given that supply voltage of 415 by root 3, 239.6 Volt, frequency of 50 Hertz and active power of single-phase load equal to 75 at 0.8 lagging power factor. Load impedance is Z L equal to V a square as upon S L, [FL] it come 2.296 Ohm and at the angle of 36.87 degree.

[FL] the load current, I mean will be here 415 by root 3; 415 at the angle of 30 degree divide by the impedance of the load 2.296 at the angle of 36.87, [FL] current comes typically 180.722 Ampere at the angle of minus 6.87 degree and of course, the for line b, it will be just minus of the value of this.

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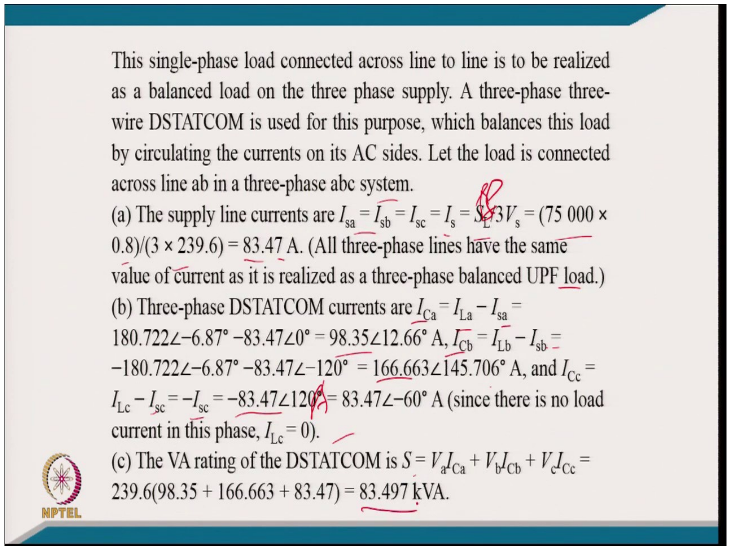

[FL] coming to this single-phase load connector across line to line is to be realized as a balanced load on the three-phase supply. A three-phase three-wire DSTATCOM is used for this purpose, which balances this load by circulating the current on AC side that the load is connected across line ab and three-phase system and supply line current will be I sa equal to I sb equal to I sc equal to I s and that will be your S L upon 3V s [FL] that will be putting the value of your 75 into 0.8, [FL] that comes 83.47 Ampere.

All three lines have a same value of current as it is realized as a three-phase balanced unity power factor load and DSTATCOM current will be your I Ca I La minus I sa and keeping the value, it comes 98.35 Ampere at the angle of 12.66 degree.

Similarly, for line I Cb will be I Lb minus I sb, [FL] it comes typically after keeping the value from 166.663 Ampere at the angle of 145.706 Ampere and I Cc I mean I Lc minus I sc, [FL] that comes typically because there is no load on this, [FL] becomes minus of supply current only, that becomes minus 83.47 Ampere at the angle of 120 degree or so. [FL] and the VA rating of the DSTATCOM will be your S equal to the voltage multiplied the current, [FL] it comes typically 83.497 kVA.

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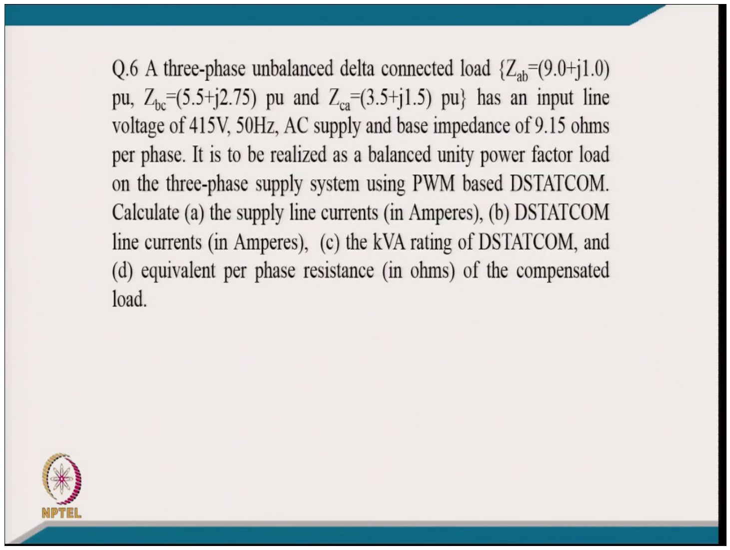

Well, coming to another example. A three-phase unbalanced delta connected load Z ab equal to nine point 9 plus j 1 per unit and Z bc 5.5 plus j 2.75 per unit and Z ca 3.5 plus j 1.5 percent has input line voltage of 415 Volt, 50 Hertz and AC supply base impedance of 9.15 per phase. [FL] it is to be realized as a balanced unity power factor load on three-phase supply system using PWM based DSTATCOM. Calculate the supply line current in Amperes, DSTATCOM current Ampere and kVA rating in DSTATCOM and equivalent resistance per phase of compensated load.

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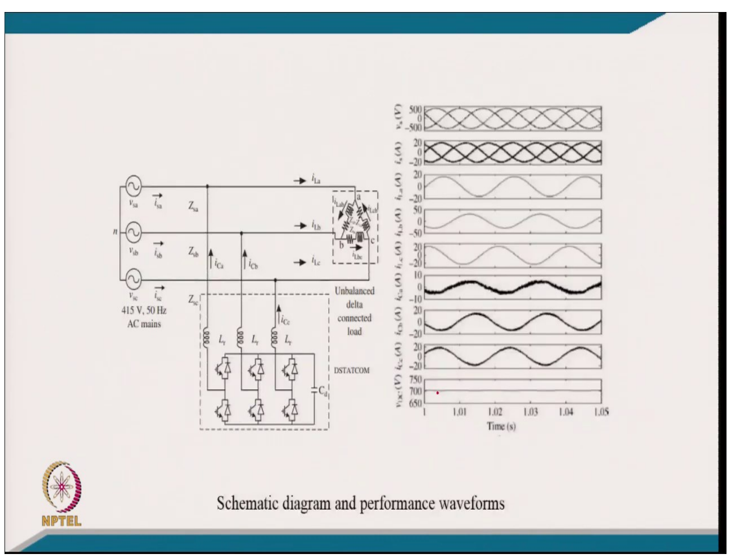

[FL], this is the typically unbalanced data connector load, we have a DSTATCOM and purpose of DSTATCOM is to provide the load balancing as well as for correction of power factors so that supply side, we have a unity power factor balanced supply current here and you can see after the design keeping the value and then, with the power control, these are the waveform of three-phase grid current, then three-phase three phase voltage three-phase grid current then three-phase load current, which are unbalanced and then three-phase compensator current with the dc link voltage.

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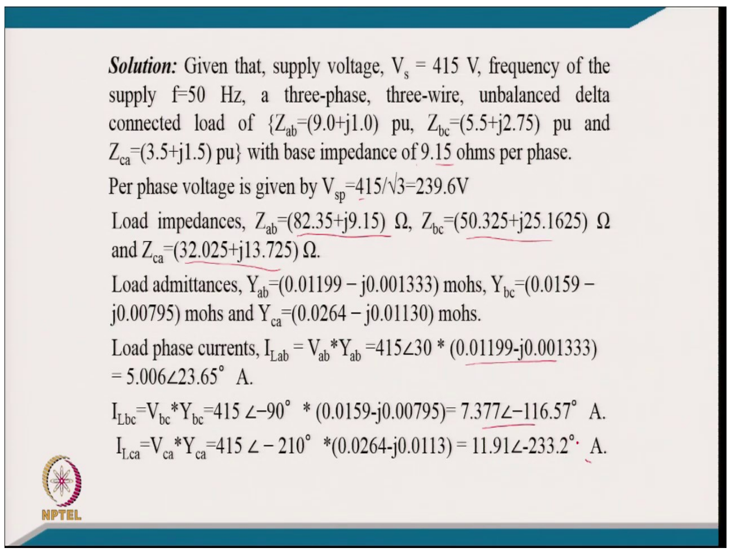

Coming to the solution, I mean from that given that supply voltage 415 and frequency 50 Hertz. Three-phase three-wire unbalanced data connected load with the impedance of Z ab 9.0 plus j1 per unit and Z b 5.5 plus j 2.75 per unit and the Z ca 3.5 1 plus j 1.5 per unit with the base impedance of 9.15 Ohms per phase. We can find out per phase voltage 415 by root 3 in to 239.6.

And we can find out the impedance actual impedance multiplying the base impedance to per unit impedance, [FL] for ab, it comes 82.39 plus j 9.15 and for bc, it comes like 50.325 plus j 25.125 Ohm and Z ca, it come 32.025 plus j 13.725 Ohm.

And load admittance with that is 1 upon Y ab is 1 upon Z b, [FL] we get these typical value and the load phase, we can called it the load phase current that is the voltage line voltage multiplied the admittance of the load, [FL] that is the line voltage 415 at the root 3 because that is the line voltage and that is the admittance of the load, [FL] it comes

5.006 at the angle of 23.65. Similarly, for line load line bc and load ca, we can typically find out admittance this and it comes 7.377 at the angle of minus 116.57 degree and similarly for line ca, it comes 0.1.91 at the angle of 230 minus 230 3.2 degree Ampere like.

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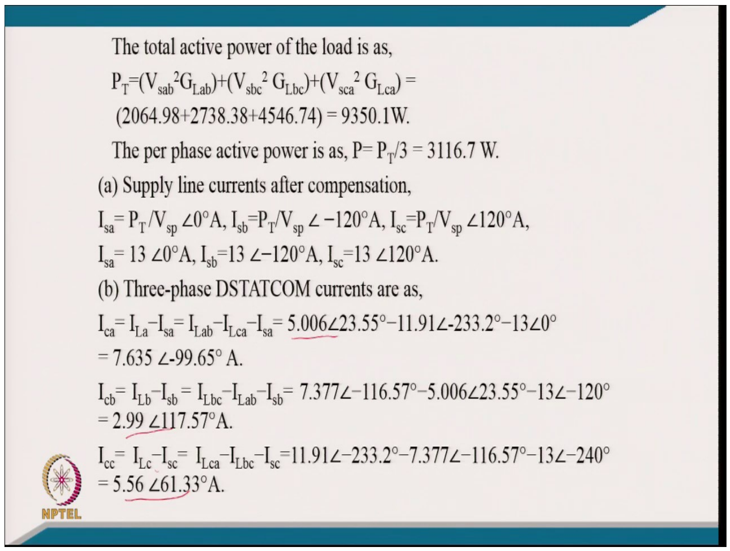

Well, we can calculate once we know the all the conductance, [FL] we can call find out the total active power consumed by the load that is P T V a square G ab because all conductance or substance in parallel, [FL] we can take only active power. Similarly, for b-phase, c-phase and if we calculate all and sum it, it comes typically 9.35 kilo Watt and per phase active power will be by 3.

[FL] it will be just by 3 of it, [FL] it could be 3116.7 Watt and the supply current, we can find out after compensation will be P T by per phase voltage, putting all these, [FL] it comes like typically 13 Ampere at the rate angle 0. Similarly, minus 120 degree, 13 at the minus 120 degree Ampere and for phase c, it will be 13 plus 120 degree Ampere.

[FL] now, we can find out three-phase DSTATCOM current that is a load current minus the supply current or a phase and it comes 5.06. Similarly, we can find out typically for cb and it comes typically after calculation 2.99 at the angle of 117.57; similarly for cc, that I Lc minus I sc, we can keep the value and then, it come 5.56 at the angle of 61.33 degree Ampere like, [FL] that gives the compensator current.

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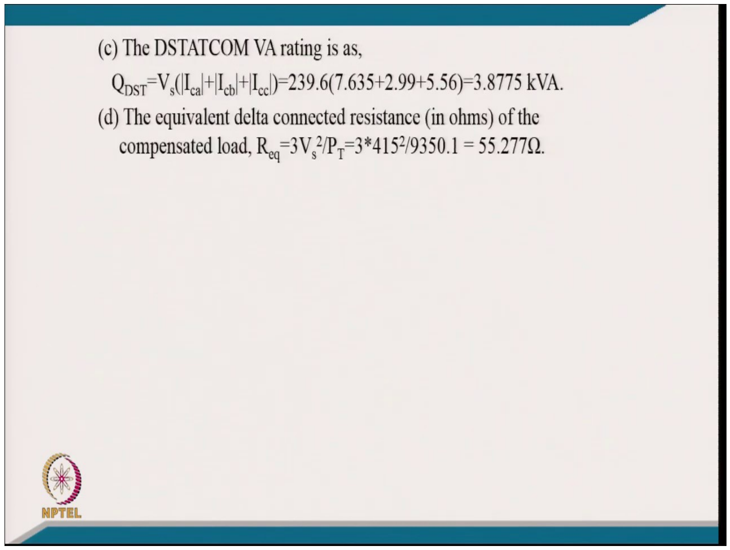

Now, we can find out the kVA, VA rating of the compensator that voltage multiplied the all sum of the three current; per phase voltage 239.6 and the current of all three, it come 3.8775 kVA and equivalent delta connected resistance, I mean you can find out from power 3 V square by P T and we have a here the resistance connected fifty point 5.27 Ohm. [FL] this give you unbalanced; I mean a non-resistive load makes the balancing as well for power factor correction.

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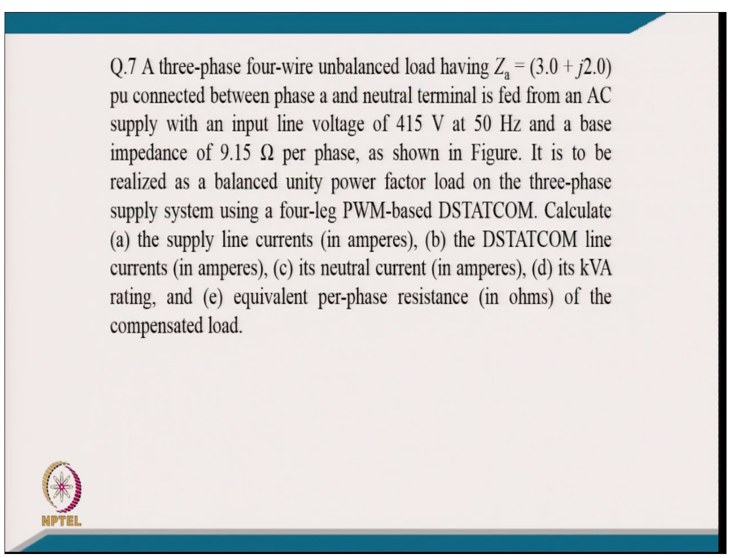

Coming to another example of now three-phase four-wire unbalanced load having a Z a equal to 3.0 plus j 2.0 per unit connected across the phase a and neutral terminal is fed from AC mains with input sub line voltage of 415, 50 Hertz and a base impedance of 9.15 Ohm per phase as shown in the figure.

It is to be realized as a balanced unity power factor load on the three-phase supply system using four-leg PWM-based DSTATCOM. [FL] calculate the supply line current, DSTATCOM line current, its neutral current, kVA rating and equivalent per-phase resistance after the compensation because the compensation provide the neutral current compensation as well as balancing the load and unity power factor on the three line.

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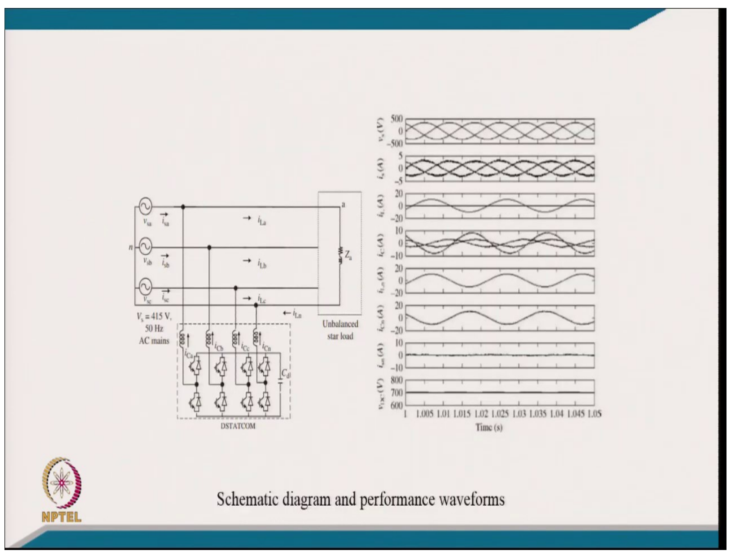

[FL], this is the typically four-leg compensator we are using and the load is to be connected between one phase and line. This is the lagging power factor load. [FL] very purpose of DSTATCOM is to provide the let us say neutral current 0 and all three currents equal balance and unity power factor.

[FL] after designing and with the power factor control I mean you can find the three-phase voltage three-phase balance current at unity power factor, then you have a load current, then you have a compensator current and low neutral current and compensator neutral current and you can see the your source neutral current is made 0 because the load neutral current is compensated by fourth leg of voltage source converter and the dc link voltage is regulated 700 Volt according to the design.

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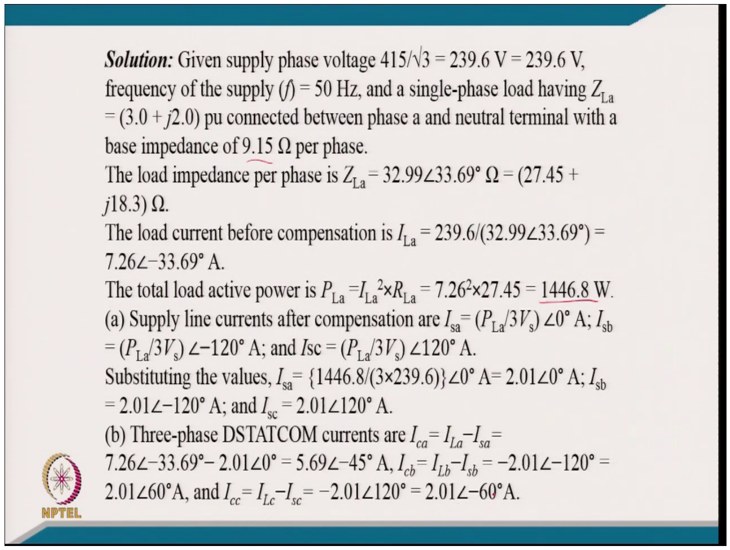

[FL] coming to the solution of it. Given supply voltage of 415 by root 3 that is 239.6 and frequency of 50 Hertz and single-phase loading 3.0 plus j 2 per unit connected between phase a and neutral terminal with the base impedance of this [FL] we if we want to get exact impedance.

[FL] we can multiply this per unit multiplied the base impedance and the impedance comes to be typically of 32.99 at the angle of 33.69 and the load current before compensation I La can be 239 that is a voltage between line to neutral divided by the impedance, [FL] it comes 7.26 at the angle 33 minus 33.69 Ampere.

[FL] total active power, I mean we can find out I square R La and that comes 7.26 square into 27.45, [FL] that comes your 1446.8 Watt and supply line current after compensation, I mean it comes like because this power will be divided by 2, [FL] the P La divided by 3 V s at the angle, [FL] it comes like typically; similarly for all three and putting the value, I mean this we get 2.01 Ampere.

Similarly, for all three, except the angle 0 degree, minus 120 and plus 120 and three-phase DSTATCOM current, we can find load current minus the supply current and keeping the value, it comes 5.69 at the angle of 45 degree Ampere. Similarly, for the cb, I mean keeping the value, [FL] it comes typically order of 2.01; cc it also comes to 2.01 angle of minus 60 degree.

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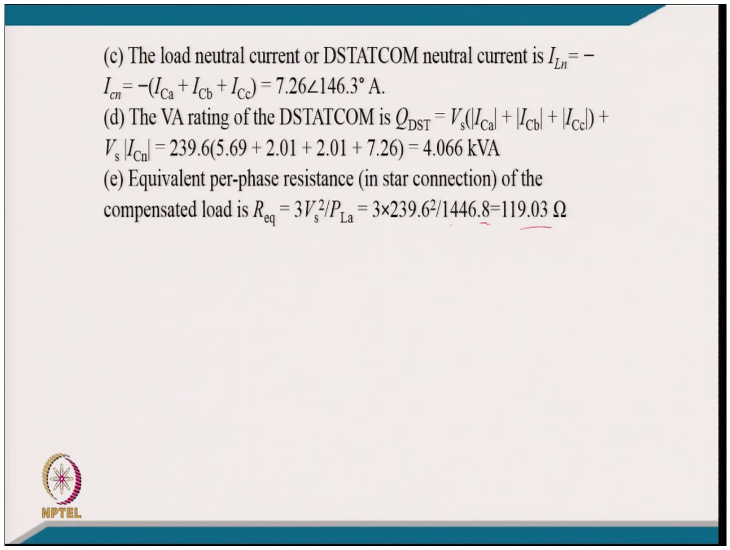

Well, the load neutral current on DSTATCOM neutral current that is I Ln equal to I cn, [FL] sum of the three compensator current that comes 7.26 at the angle of 146, [FL] that is the compensator current which equivalent to load neutral current and the VA rating of the DSTATCOM will be sum of all three-phases plus the neutral current leg of four.

[FL] voltage multiplied the all and then, it come 4.066 kVA and equivalent per phase resistance, equivalent star connected load is R e 3 V square by P La, [FL] three-phase voltage is squared divided by the power, it comes 119.03 Ampere. [FL] a single-phase load I mean which realized as a balance load, at unity power factor on the supply side, [FL] I mean in this example with the proper design and control.

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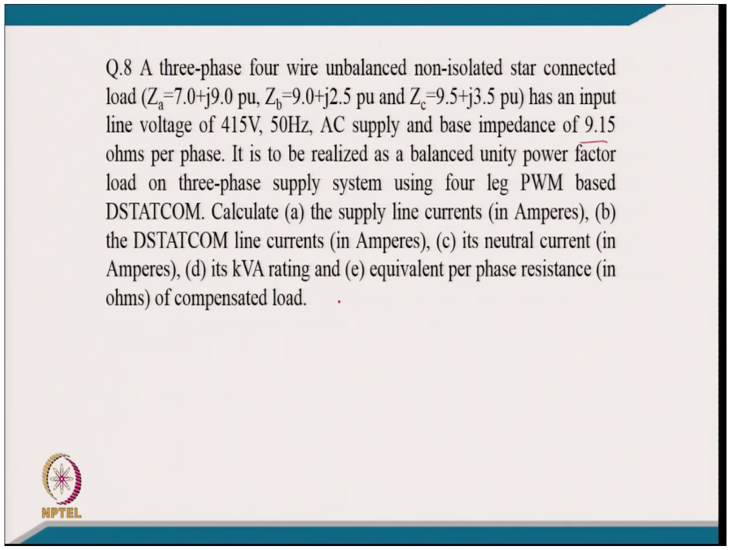

Coming to the eighth example. A three-phase four-wire unbalanced non-isolated star connected load of Z a equal to 7.0 plus j 9.0 per unit, Z b 9.0 plus j 2.5 per unit and Z c 9.5, 3.5 j 3.5 per unit has a input line voltage of 415 Volt, 50 Hertz and AC supply and base impedance of 9.15 Ohms per phase, you should be realized as a balance unity power factor load on the three-phase supply system using four-leg voltage source base DSTATCOM. Calculate the supply line current, then DSTATCOM current, neutral current and kVA rating and equivalent per phase of the compensated load.

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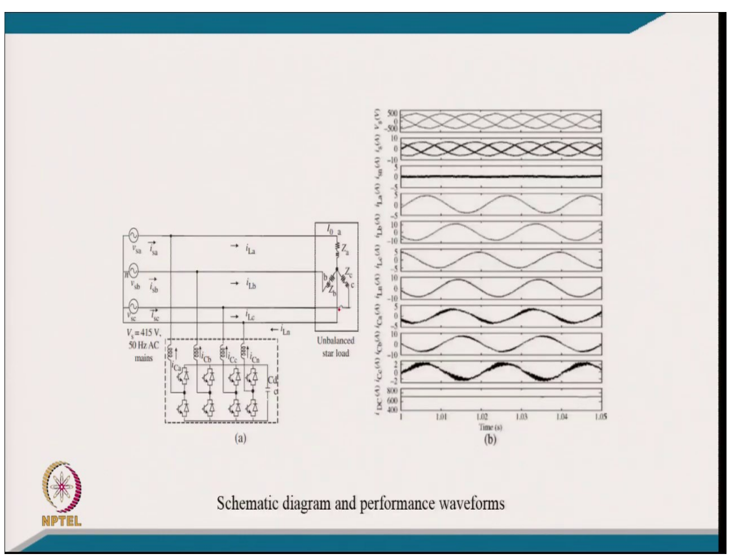

[FL] this is the typically we have a four-wire unbalanced load and we are using four-leg voltage source converter which typically provide neutral current compensation and load balancing and unity power factor on the load and the up to the proper design and the control, we have a three-phase voltage three-phase supply current which are at unity power factor, balance current, sinusoidal current and a phase do not typically have a typically neutral current on the supply side is made 0.

And these are the three neutral current along with the neutral current of the load and these are the three-phase current of the typically of the compensator and this is typically the dc link voltage which maintain 700 Volt like.

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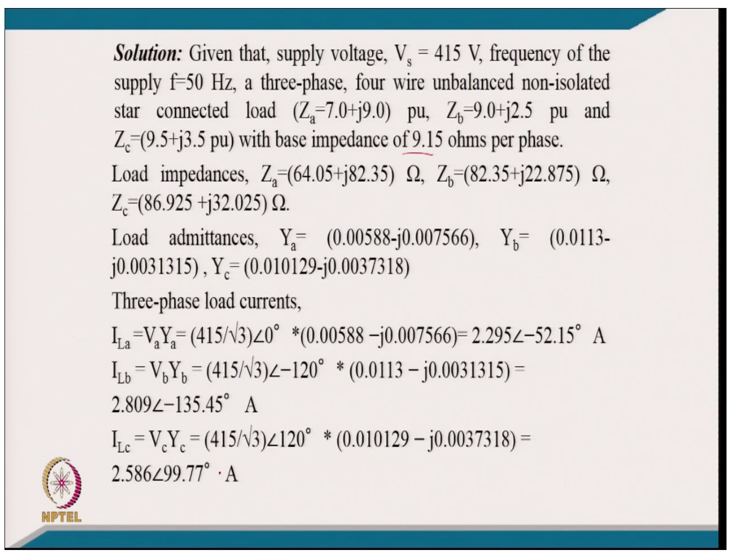

Coming to the solution of this, given that the supply voltage of 415 Volt and frequency of 50 Hertz a three-phase four-wire unbalanced non non-isolated star connected load with the impedance of Z equal to 7.0 plus j 9 per unit and Z b 9.0 plus two j 2.5 per unit and Z c 9.5 plus j 3.5 per unit with a base impedance of 9.15 Ohms per phase.

[FL] we can calculate the actual impedances by multiplying the base impedance to these per unit, [FL] it comes Z a equal to this Z b equal to Z c equal to and from this, we can find out the admittances 1 upon Y a equal to 1 upon Z a, Z b and Z c and now, we can find out the load current V a Y a. This is the typical per phase voltage multiplied the admittance, it comes 2.295 at the angle of 52 minus 52.15 degree Ampere.

Similarly, for b-phase or load current if you put the value, [FL] it comes like 2.809 at the angle of 1 minus 135.45 degree Ampere. Similarly, for load c current, we can find out that also comes after putting the value 2.586 at the angle of ninety 9.77 degree Ampere.

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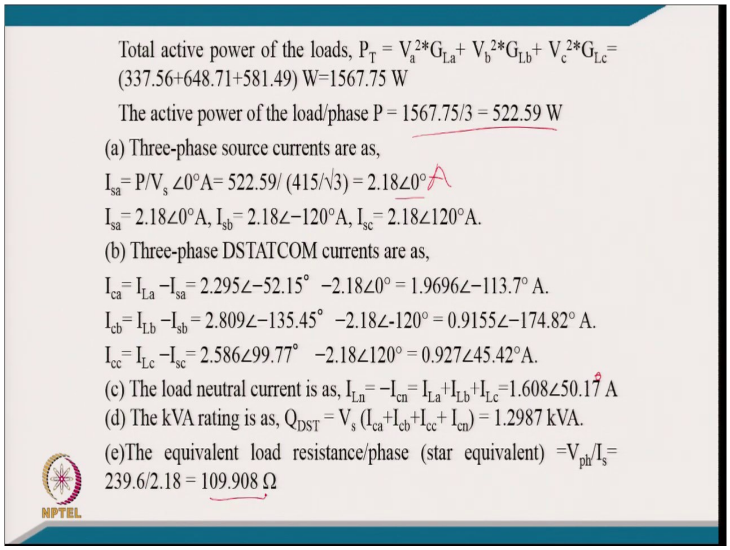

Well, from this load current, we can find out the total active power from the voltage and the conductance of the phase all three-phase voltage from this relation and it comes after putting the value 1567.75 Watt. Now, this power is certainly now after the load balancing, it distributed to all three-phase. [FL] per phase power is now 1567.75 by 3 that comes 522.559 Watt and three-phase source current are now you can find out I sa equal to P upon V s.

I mean at the degree, [FL] this is a per phase power and this is a per phase voltage, [FL] it comes twenty typically 2.19 18 at 0 degree Ampere. Similarly, for b-phase will be at the typically at minus 120 degree and c-phase will be again plus 120 degree Ampere. All three-phase will be balanced current any phase with the supply voltage.

And three-phase DSTATCOM can I mean from the basic relation of current Kirchhoff law, [FL] I ca will be I La minus I sa and keeping the value, it comes 1.9696 at the angle of minus 113.7 degree Ampere.

Similarly, see I cc that is for second phase of the DSTATCOM, putting the value, it come 0.9155 at the angle of minus 174.82 and similarly, for c compositor lag, [FL] that putting the value, it come 0.0927 at the angle of 45.42 degree Ampere and the load neutral current will be equal to the compensator load current and that will be sum of all three-phase current comes 1.606 at the angle of 50.17 degree.

The kVA rating of DSTATCOM will be voltage multiplied the all four current, [FL] it comes 1.2987 kVA and equivalent resistance per phase will be from the power. We have per-phase voltage, we have a per-phase after compensation, the current 239.6 divided by 2.18 that comes 109.908 Ohms per-phase.

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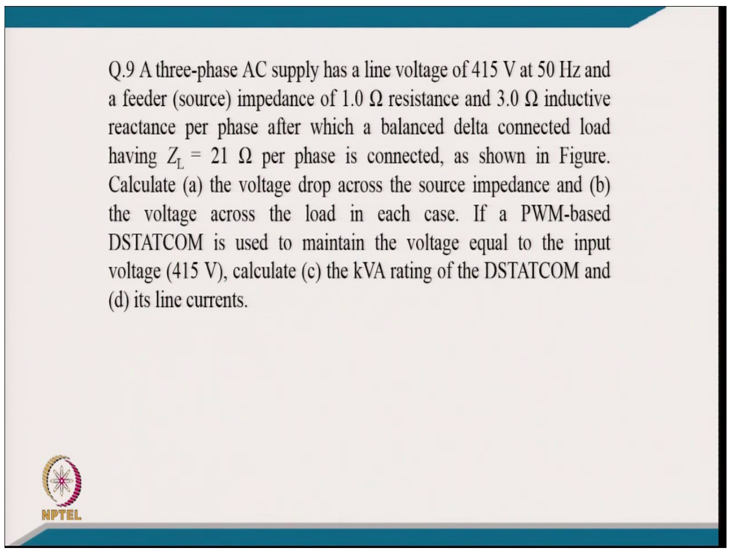

[FL] coming to the another example of typical example number 9, a three-phase AC supply has a line voltage 415 Volt, 50 Hertz and a feeder source impedance of 1 Ohm resistance and 3 m Ohm inductive reactance per-phase after which a balanced delta connected load of 21 Ohm per phase is connected as shown in.

Calculate the voltage drop across the source impedance the voltage across the load in each case and PWM, if PWM based DSTATCOM is used to maintain the voltage equal to the input voltage that is 415 Volt. Calculate the kVA rating of DSTATCOM and the line current. [FL] that is a voltage regulation problem across even resistive load and the drop is because of the source impedance.

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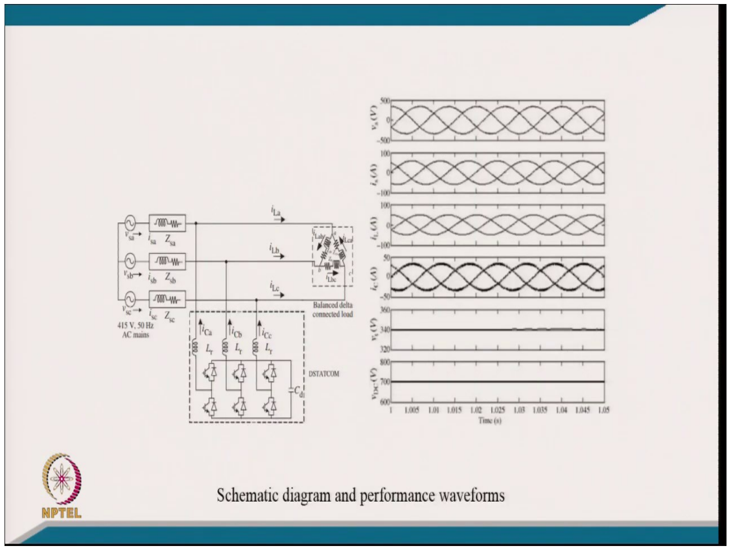

[FL] this is a typical example. This is a typically balanced load, but we have a source impedance and the DSTATCOM is responsible to provide the reactive power so that this voltage, I mean is equal to the source voltage and we have a zero voltage regulation.

[FL] After designing properly, these are the you can call it the typically the source voltage, only we have a typically the source current, then we have a load current and compensator current and the typically, the point of common coupling voltage which we regulated to the same as the source voltage and we have a dc link voltage regulated with the help of both the PI controller as we discussed already earlier.

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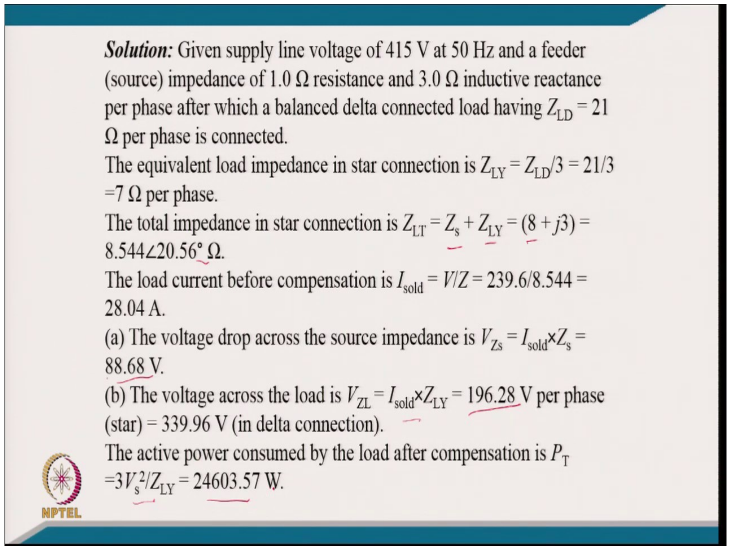

[FL] coming to the solution, given supply voltage of 415 Volt at 50 Hertz after the feeder source impedance of 1 Ohm and 3 Ohm; 1 Ohm resistance and 3 Ohm inductive reactance per-phase after which a balanced delta connected load having Z LD 21 Ohm per-phase is connected and we have to convert per phase equivalent to that, [FL] equivalent load impedance in star connection will be Z LD by 3, [FL] that will be 21 by 3, [FL] it come 7 Ohm per-phase.

And the total impedance in star connection will be source impedance plus this load impedance, [FL] it comes like your if we add it that is 7 Ampere; 7 Ohm plus 1, [FL] 8 plus j 3 and that comes the impedance of total circuit. [FL] load current before compensation V upon Z.

[FL] this will be the current and the voltage drop across this current multiplied the source impedance is typically 88.68 and the voltage across the load will be this current multiplied the impedance of the load, [FL] it comes 199.28 Volt per phase in place of your 239.6 Volt and line current that is multiplied 3 will be 339.96 in place of 415 volt.

[FL] the active power consumed by the load after the compensation, it because voltage across the load is now V square Z LY, [FL] this comes like your typically 239.6 squared or 415 square because root 3 will be divided by the your load impedance, that is 7 Ohm, [FL] this will be your power 24.603 kilo Watt.

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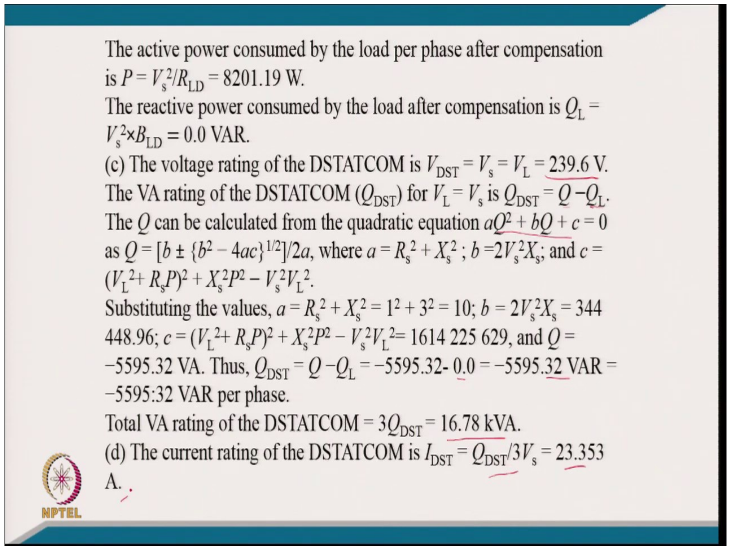

Now, coming the active power consumed load per phase, we can take it V s square typically, [FL] it will be one-third of that, [FL] it will be 8201.19 Watt and the reactive power of consumed by the load after compensation, it is 0; I mean like because we do not have B LD, the voltage rating of the DSTATCOM will be V s equal to V L that is the voltage rating of DSTATCOM 239.6.

And the VA rating of DSTATCOM will be typically Qs Q minus Q L, [FL] Q can be calculated from quadratic equation for voltage regulation; aQ square plus bQ plus c equal to 0, where I mean this derivation is already given earlier. [FL] Q equal to b plus minus on to b square minus 4 ac 1 divided by 2a, where a defines in terms of R s square source impedance and b coefficient, 2 V square X s and c coefficient V L square plus R s P the power plus X s square P square minus V s square V L square.

[FL] putting the value of all, we get typically I mean Q equal to here minus 5595.32 VA and Q DSTATCOM will be Q minus Q L and Q L is 0. [FL] DSTATCOM rating will be the same as typically your 5595.32 VAR, I mean like and divided by 3 will be the per phase ok. [FL] total kVA rating will be 3 times this, [FL] this will be 16.78 kVA and the current rating of DSTATCOM will be 3 divided by, [FL] it come to 23.35 Ampere. [FL] this I mean provide the zero voltage regulation across the load.

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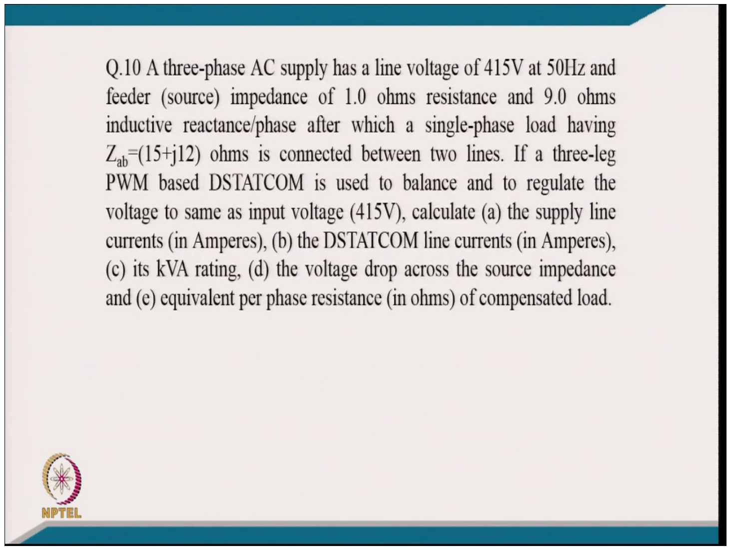

Coming to another example 10, a three-phase AC supply has a line voltage of 415 at 50 Hertz and feeder impedance is a 1 Ohm resistance and 9 Ohm inductive reactance per phase after which a single-phase load having a 15 Ohm plus j 12 Ohm is connected between two line. If the three-phase PWM DSTATCOM is used to balance and to regulate the voltage to the same as the input voltage of 415, calculate the supply line current, DSTATCOM line current, kVA rating of DSTATCOM, the voltage drop across the source impedance and equivalent resistance per phase of the compensated load.

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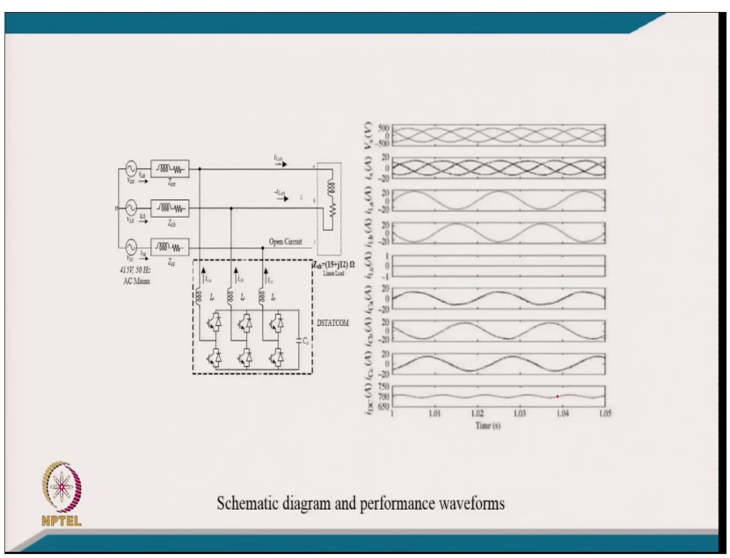

Schematic diagram and performance waveforms

[FL] this is the typical circuit that we have a only the line to line connected, you can call it lagging power factor load and we have a three a DSTATCOM, [FL] very purpose of DSTATCOM is typically to have a balancing of the load across the all the three line and moreover, to provide the same voltage across the load. What is the source voltage? The voltage regulation and typically, the load balancing in the task.in this case.

[FL] after proper designing, you will find three-phase voltage and three-phase source current, these are the two load current third load current is 0 because this connected line to line and we have in then three-phase compensator current and followed by the dc link voltage. Since, it is a load balancing, you will find the second harmonic on the dc link voltage; I mean that would get reflected into the on the dc link because of load balancing.

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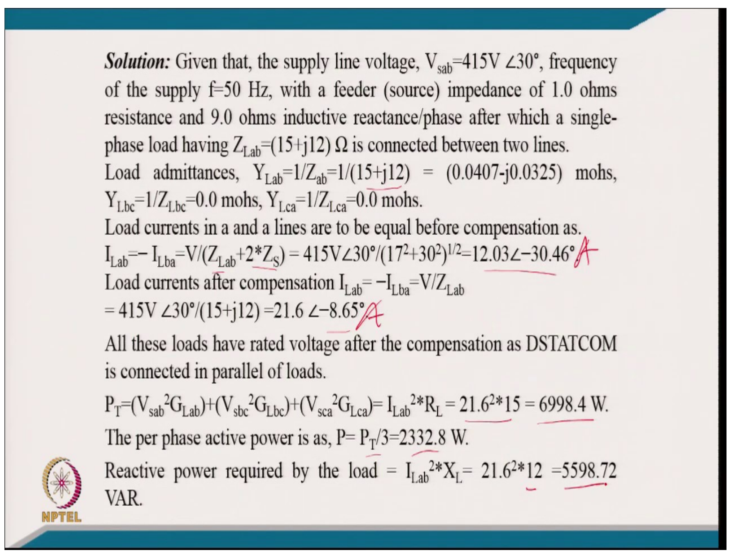

[FL] coming to the solution, given that the supply line voltage is V ab equal to 415 at the angle of 30 degree that is a line and frequency of 50 Hertz with the feeder impedance of 1 Ohm per resistance, 9 Ohm inductive reactance after which a single-phase load of typically 15 point j 12 is connected between the two line and we can find out the load impedance Y Lb 1 upon Z ab. With this, [FL] this is a load admittance and for another I mean typically Y Lb, it is not connected is 0 and for Y Lca is also 0.

[FL] we can find out like now the load current typically before the compensation that will be your I Lab equal to minus I Lba because current is coming from, its only line to line connected load. [FL] load impedance plus the both line source impedance and putting the value that we get the typically here current 12.03 at the angle of minus 30.46 Ampere.

The load current after the compensation will be typically I mean equal to the V L upon Z b. [FL] this current will be 21.6 at the angle of 8.65 Ampere. [FL] all these loads have a rated voltage after the compensation as DSTATCOM is connected in parallel to the load and we can find out the power of the typically the load V square into the your conductance of the ab line, bc line and ca line and that is because load is only connected across this, [FL] it will be current through this R L.

[FL] we have a current in this and multiplied the resistance, [FL] this is the power 6998.4 Watt and per phase active power will be divided by these 3, [FL] it will 2332.8 Watt and the reactive power required by the load will be typically of I square this, [FL] that is 21.6 square multiplied the 12, [FL] that is the reactance of the load, [FL] it comes 5598.72 VAR.

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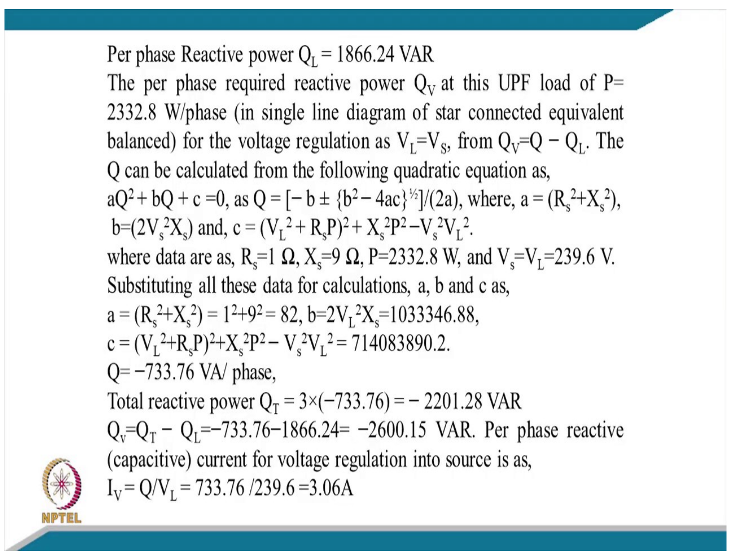

Now, coming to the per-phase reactive power, I mean from that, it comes like 18.642 for VAR. The per-phase required reactance I mean for regulating the voltage Q b at this you know power factor load of P equal to this in single-phase line diagram for voltage regulation V L equal to V s and Q b equal to Q minus Q L.

[FL] Q can be calculated from this quadratic equation aQ square plus bQ plus c for voltage regulation zero voltage regulation and keeping this all I mean parameters of the system and the load power with R s and P and V L this, [FL] we can find out abc constant and then, Q comes like minus 733.76 and then, total Q, we can find out 3 times of this that is minus 2201 VAR and we can find out Q v equal to Q T minus Q L.

[FL] keeping this value, it comes like not only voltage regulation; but we try to feed the reactive power of the load. [FL] it comes minus 2600.15 VAR per phase reactive power for the voltage regulation into the source and we can find out the typically the current Q upon V L, [FL] that comes 73 point 733.76 divided 239.6 and that comes current like 3.06 Ampere of typically of DSTATCOM.

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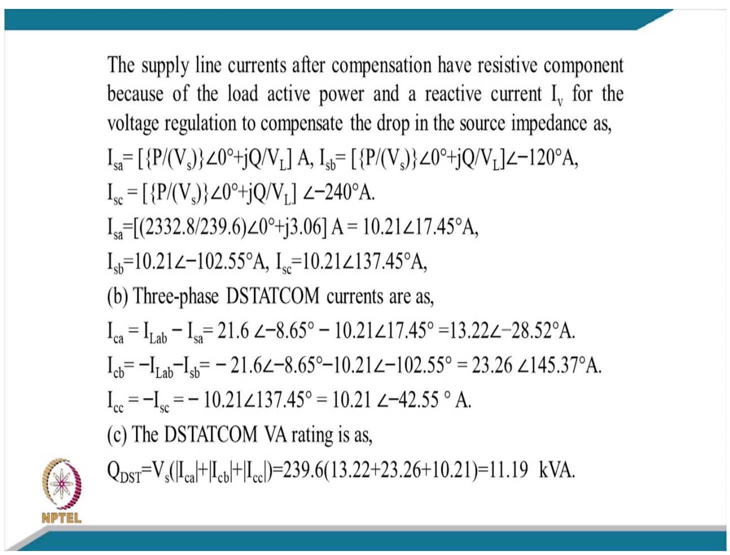

[FL] the supply line current after compensation has a resistive component because of the load active power and reactive current I v for the voltage regulation to compensate the voltage drop of the source impedance, [FL] we can have a current. Now, you can find out this is the current for active power, this is the current for reactive power and keeping the value, we can typically put the value here and we can get this current typically 10.21at the angle of 17.45 Ampere.

Similarly, for b line and c line, [FL] all balance typically will be the balanced current, but a different angle and three-phase DSTATCOM current will be the load current minus this source current, that comes for a phase 13.22 Ampere; similarly for b, it will be like

23.26 at the angle of 145.27 Ampere and similarly for c-phase of the compensator after putting value, [FL] it come 10.21 at the angle of minus 42.55 Ampere DSTATCOM. VA rating will be the sum of all three current substitute multiplied the phase voltage, it comes 11.19 kVA.

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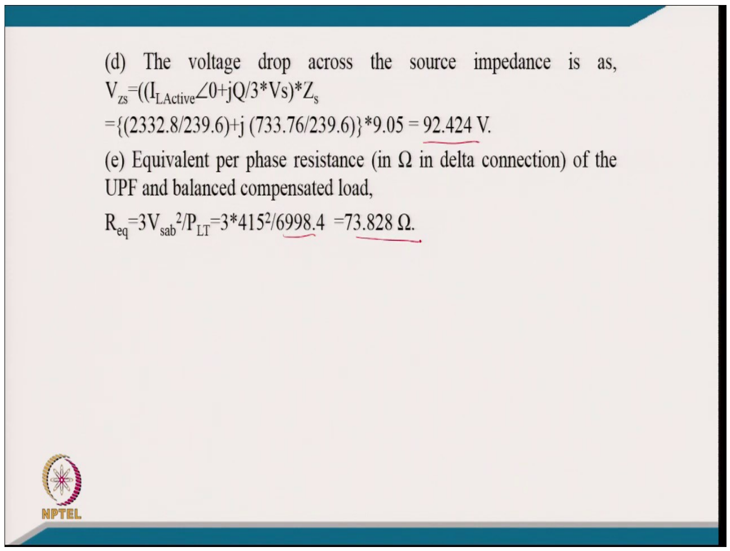

And the voltage drop across the source impedance will be equal to that current multiplied the typically the source impedance. [FL] we can find out current and this, [FL] it comes 92.424 Volt and equivalent per phase resistance in delta connected equivalent will be R equal to 3 V square by power and that is the voltage and this is the power, [FL] it comes 73.828 Ohm.

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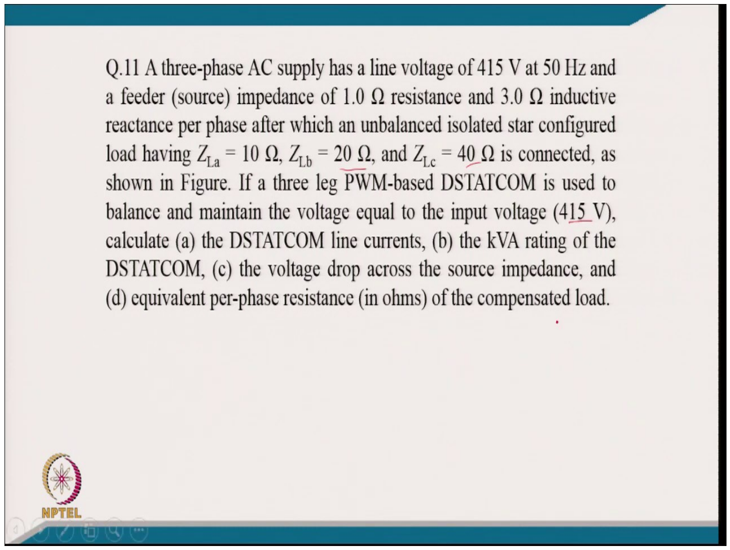

Coming to now example, example will 11, a three-phase ac supply has a line voltage 415 at 50 Hertz and a feeder impedance of 1 Ohm resistance and 3 Ohm inductive reactance per phase, after which an unbalanced isolated star configured load is connected Z La equal to 10 Ohm, Z Lb 20 Ohm and Z Lc 40 Ohm is connected as shown in figure if three-leg PWM voltage source based DSTATCOM is used to balance and to maintain the voltage equal to the input voltage. Then, calculate DSTATCOM line current, kVA rating of DSTATCOM, voltage drop across the source impedance and equivalent resistance of the compensated load.

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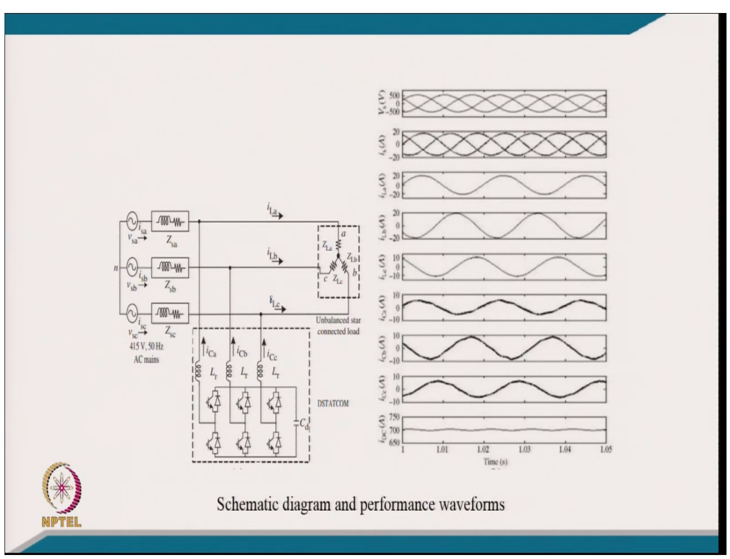

Schematic diagram and performance waveforms

[FL] this is the typical circuit that we have a source impedance and we have a load here and we have a this compensator which supposed to balance the load and regulate the voltage across the load equal to the supply voltage. [FL] voltage regulation and load balancing is the typically the very purpose of putting DSTATCOM. [FL] after proper design and putting proper control, these are the voltage. Typically, at the point of common coupling and these are the current flowing into the line and these are the typically load current, these are the compensator current and this is the typically the dc link voltage like.

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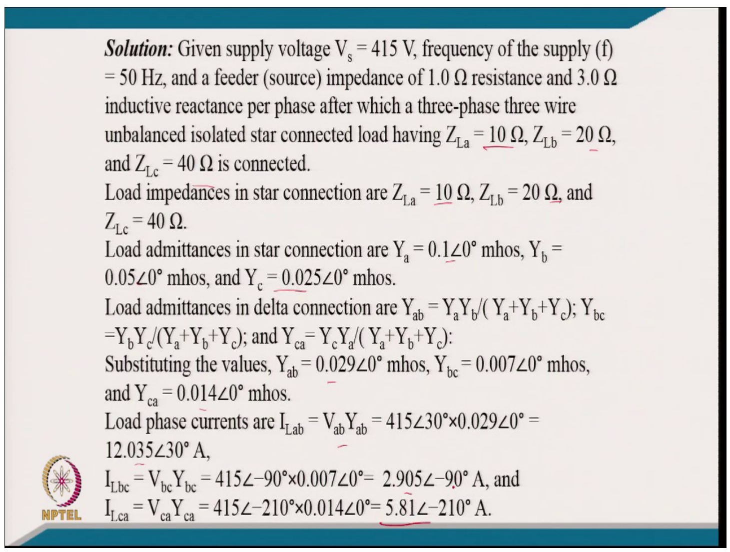

[FL] coming to the typically solution part, numerical part of this. [FL] given a supply voltage of 415 Volt frequency of 50 Hertz and feeder impedance on 1 Ohm and resistance of 3 Ohm inductive reactance per phase after with three-phase three-wire unbalanced isolated star connected load I mean with the Z a 10 Ohm, Z b 20 Ohm and Z c 40 Ohm which connected and load impedance in star connection on this is there and load admittance, we can calculate 1 upon Z La.

[FL] these are the virtually the conductance of the load and you can find out the load equivalent to delta connected. We can apply the for this equivalent star to delta connection and these are the typically equivalent delta connected substance and load phase current, we can find out from now voltage multiplied the connection. So, this comes for line ab and for the load this comes for line bc and line ca; these are the three-phase load current.

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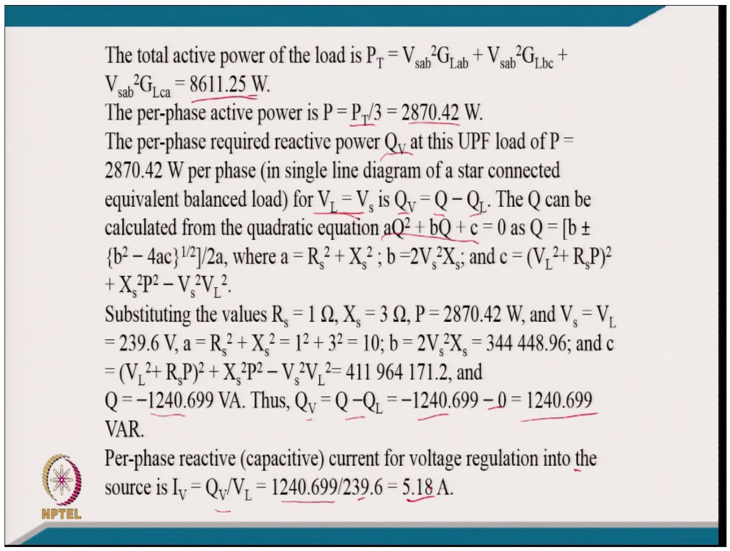

And total active power now we can find out taking V square into the conductance of line ab, bc and ca, [FL] it comes 8611.25 Watt and per phase active power will be by 3, [FL] it will be divided by 3, it will be 2870.42 Watt and per phase required reactive power at this for voltage regulation at this UPF load P equal to 2870.42 per phase in single-phase line diagram of a star equivalent load, that will be V L equal to V s for voltage regulation and where, Q v is equal to Q of minus the Q L.

And the Q can be calculated from this quadratic equation relation which we derive a square Q square plus b Q plus c, where the abc constant are defined here and putting calculated abc constant, [FL] we can get the Q and minus the Q L, we will get the for voltage regulation since Q is 0 for load, [FL] it comes like a 1240.699 that comes 1240.699 VAR and per phase reactive current for the voltage regulation, it come from this Q v upon V L, [FL] it comes 1240.69 divided by 229, [FL] it comes like 5.18 Ampere.

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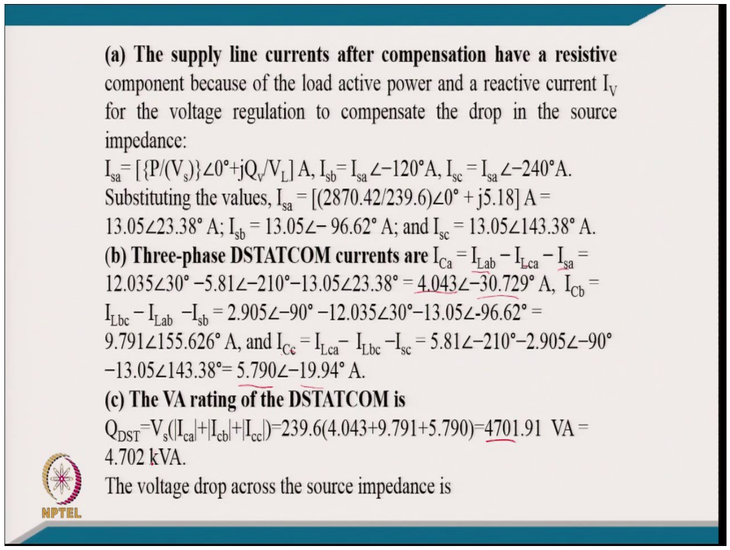

And supply line current after the compensation have a resistive component because of the load active power and reactive power for the voltage regulation to compensate the voltage drop, [FL] we have a typically line current I mean from load active power and this is the compensator reactive power. [FL] keeping the value of all, [FL] it comes like a typically I mean if we get it comes 13.05 Ampere at the 23.38 degree.

Similarly, for b-phase and c-phase and three-phase DSTATCOM current, we can find out load current minus the typically the compensator current and source current and from this, we can find out typically the current come 4.4 Ca 4.03 at the angle of t30.729 degree and similarly for your b-phase, it comes to typically 9.71 at the angle of 155.69. Similarly, for c-phase, it comes equivalent to 5.790 at the angle of minus 19.4 degree at Ampere and VA rating of DSTATCOM will be voltage per phase multiplied the current of all three absolute value, [FL] it comes typically 4701.91 that is 4.702 kVA.

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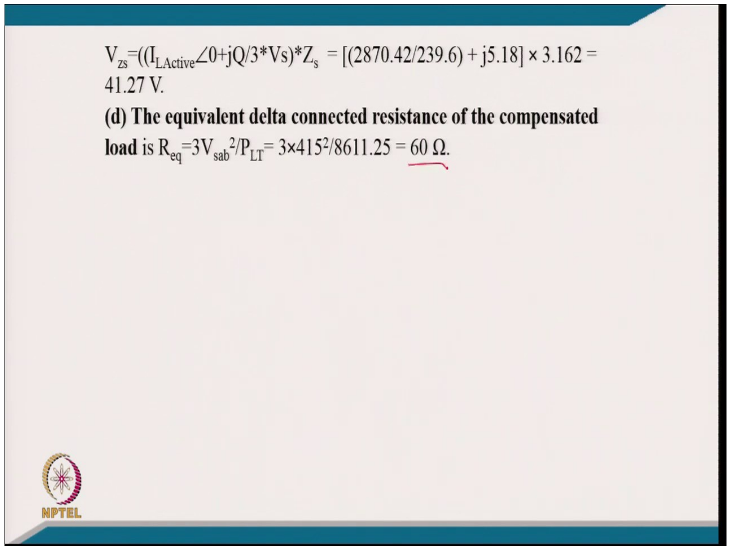

And voltage of across the source impedance will be because we know the typically the current and we know the impedance, [FL] we can this is the voltage 41.27 Volt and equivalent delta connected resistance load will become the active power 3 V square by P LT and it will be 3 15 square into 8611.25, [FL] that comes 60 Ohm.

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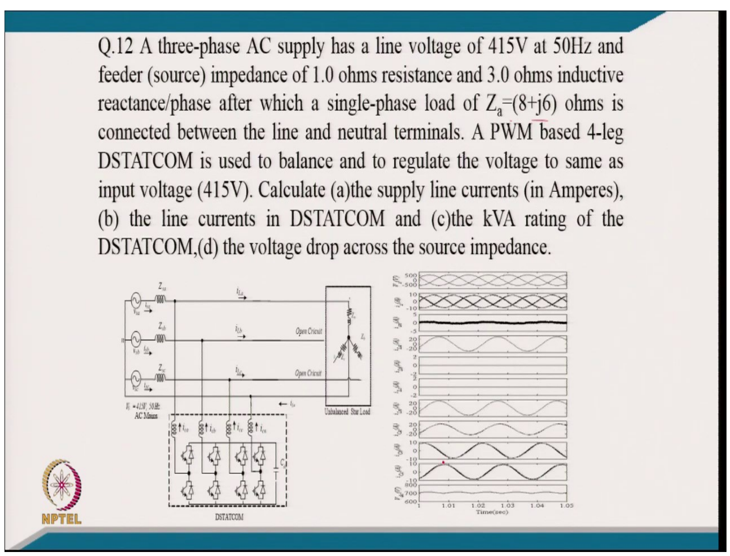

Well, coming to another example of three-phase four-wire, a three-phase AC supply has a line voltage of 415 Volt at 50 Hertz and the feeder impedance of 1 Ohm resistance and 3 Ohm inductive reactance after which a single-phase load of 8 Ohm plus j 6 Ohm is connected between line to neutral terminal a PWM four PWM based four-leg DSTATCOM is used to balance and to regulate the voltage same as the input voltage. [FL] calculate the supply line current, line current in DSTATCOM and the kVA rating of the DSTATCOM and voltage of across the.

[FL] we have a source impedance, we have a load here line to neutral, [FL] we are connecting four-leg voltage this voltage source converter by DSTATCOM. The very purpose to compensate the load neutral current and to balance the current and regulate the voltage across the load, the same as the supply voltage and after proper design and proper control and making model of this, these are the three-phase supply voltage.

This is equal to load voltage and this is the supply current and neutral current is made 0 on the supply side. This is the typically the load current only one phase, other two phase have 0 and these are the compensator four-leg currents and this is the dc link voltage. Since it is a unbalancing, [FL] second harmonics will be there on the dc link of the DSTATCOM.

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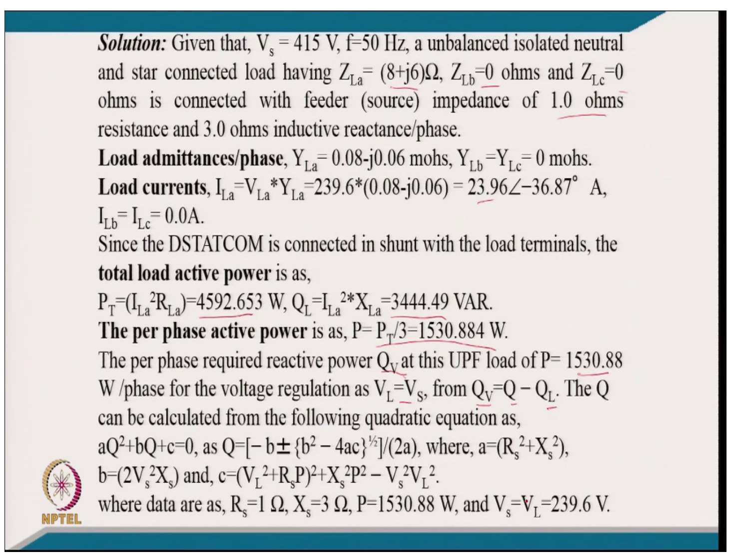

[FL] coming with the numerical part of the solution, given that V s equal to 415 50 Hertz and unbalanced isolated neutral and a star connected load having Z La equal to 8 point j 6 Ohm and Z Lb 0 and Z Lc also 0 with the feeder source impedance 1 Ohm and 3 Ohm inductive reactance. You can find out the load admittance for other two phase zero, we can find out the load current which come 23.96 at the angle of minus 36.87 flowing between the line fa to neutral and other two are 0 and DSTATCOM is connected in shunt with the load.

[FL] we can find out the power active power of the load I La square R La, [FL] this is the active power of the load reactive and we can find out reactive power of the load from inductive part and per phase power if we really have a load balancing, [FL] per phase power will be by 3.

Of it, [FL] it comes 1530.884 Watt and per phase required reactive power I mean for voltage regulation unity factor, [FL] will be your P equal to 1530.8 Watt per phase for the voltage regulation L equal to V s [FL] Q will be Q into Q L and Q can be calculated from this quadratic equation, putting the value of all and the power respective in this.

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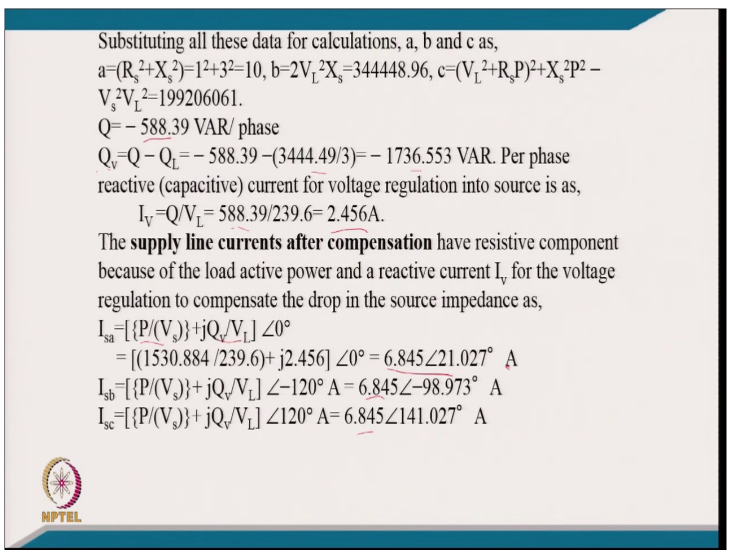

[FL] we get the Q equal to 588.39 and the total Q will be for voltage regulation and load balance load compensation, [FL] that will be equal to typically this by 3, [FL] it will be 17 point 36.55 VAR per phase and the reactive current, I mean for voltage regulation will be total Q divided by V L and we have a 588.39 per phase divided by 239.6 [FL] compensated current 2.456 Ampere.

And supply line current after compensation have a resistive component because of load active power and reactive component for the voltage regulation, [FL] we can find out the active part of source current and reactive power for voltage regulation and from this, we get the value of 6.845 at the angle of 21.027 and for other two phases will be a same magnitude; but at the 120 degree phase shift from one to another and then, another or so. [FL] that is typically the nautical compensation load balancing and voltage regulation across the load.

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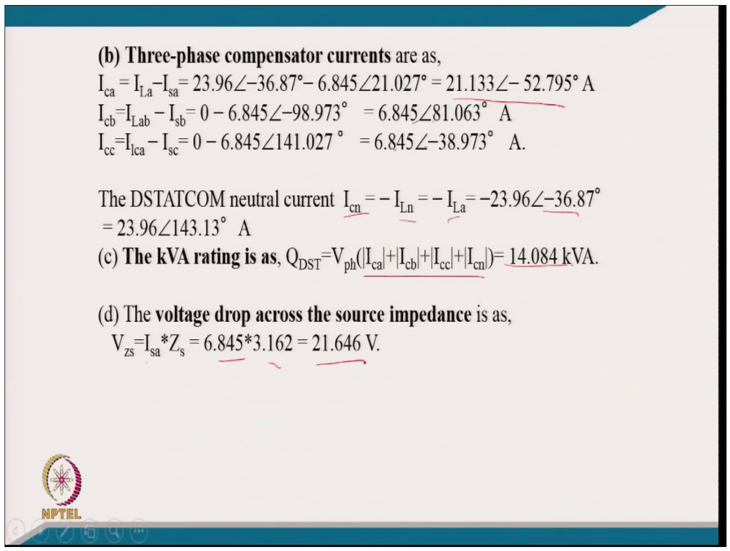

And the three-phase compensator current will be load current minus the source current and keeping the value, we can get the compensator A, a-phase current, b-phase current and c-phase current and neutral current will be just equal to load neutral current that is a phase a current exactly and this will be 23.96 Ampere.

The kVA rating will be all for three line and neutral and it will comes 14.084 kVA and the voltage drop across the source impedance will be the current of the source multiplied the source impedance, [FL] we got already the source impedance earlier. I multiply the source impedance comes 21.646 Volt like.

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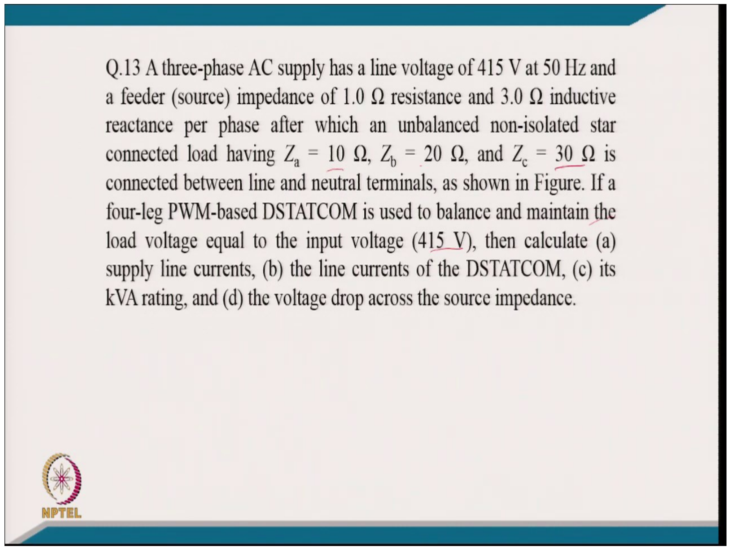

Coming to an another example of 13 number, a three three-phase supply has a line voltage of 415, 50 Hertz a feeder source impedance of 1 Ohm resistance and 3 Ohm inductive reactance per phase after which unbalanced non isolated star connected load is connected with the Z a equal to 10 Ohm, Z b equal to 20 Ohm and Z c equal to 30 Ohm is connected between line and neutral terminal and as shown in figure.

And if the four-leg PWM based DSTATCOM is used to balance and maintain the load voltage equal to the input 415, then calculate the line supply line current, line current of DSTATCOM, it is kVA rating and voltage drop across the source impedance.

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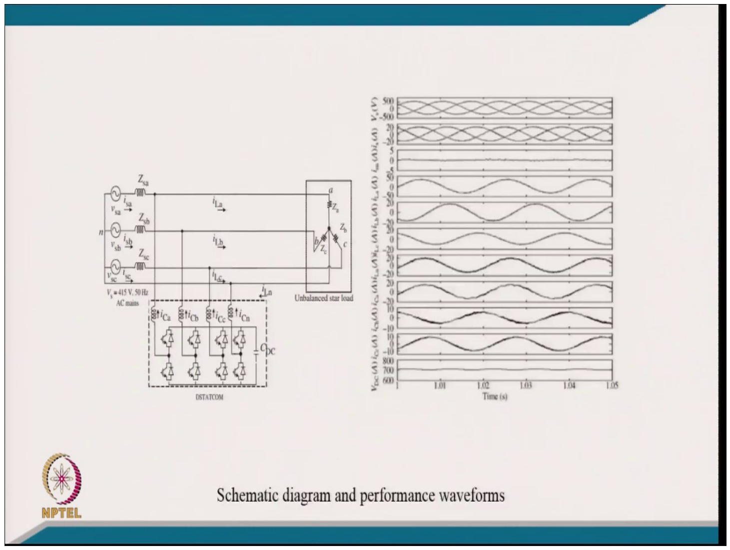

[FL] this is typically you can see the load here, which is connected unbalanced load here with the different impedance and we have a four-wire DSTATCOM which provide the load balancing, the voltage regulation and neutral current compensation; all three. [FL], after designing properly and making a model of these, these are the waveform of three-phase voltage of source which is equal to load voltage.

These are the typically source current, balance current and typically, it balance and saturated current. These are neutral current of the source which is made 0 after compensation; these are the four-leg currents of the compensator and then, this is the dc link voltage. Since it is typically I mean you can see the even the you will have a typically here unbalanced load, [FL] second harmonic gets reflected on the dc link of DSTATCOM.

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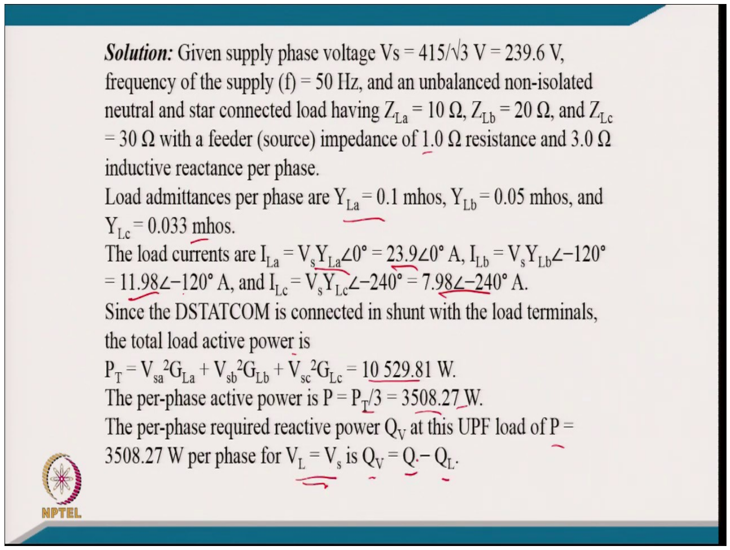

[FL] coming to numerical part of the solution, [FL] given supply phase voltage 415 by root 3, 239.6 Volt and frequency of supply 50 Hertz and an unbalanced load star non-isolated neutral and star connected load having Z a 10 Ohm, Z b Z Lb 20 Ohm, Z Lc 30 Ohm with the feeder source impedance of 1 Ohm resistance and 3 Ohm reactance per phase.

[FL] we can find out load conductance 1 upon z by these three-phases and we can find out the load current from these respective value. [FL] these comes the three load current or a phase and then b-phase and c-phase, these are the load current and the DSTATCOM is connected in shunt with the load terminals.

[FL] load active power can be calculated from voltage square conductance of all three-phase load that comes typically are 10529.81 Watt and the per phase power will be by 3 of it, [FL] this is 3508.27 Watt and per phase required reactive power for this load, I mean for given power and same as load voltage equal to source voltage for voltage regulation Q minus QL. [FL] this is the voltage regulation, this is the load power.

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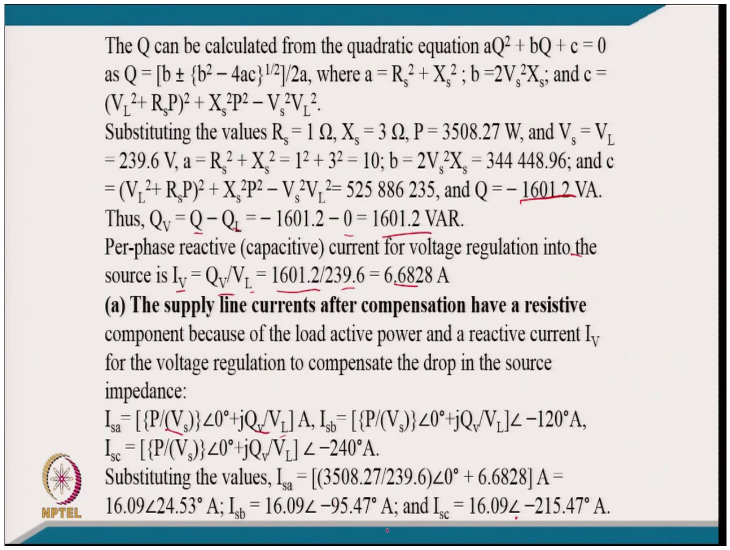

[FL], you can find out typically from this quadratic equation the typically Q required for voltage regulation, we are putting the value of all these elements and solving this, we get typically Q equal to 1601.2 VA and putting the Q minus Q L, [FL] Q L is 0 here, [FL] it comes the same as 1601.2 VAR and per phase reactive power from this for voltage regulation can I equal to Q v by V L.

And we know Q and divide by voltage, [FL] we can find out the typically 6.6828 Ampere and supply line current after compensation have a resistive component because of the load and reactive component before the voltage regulation to compensate the drop in source impedance.

[FL] this is the active power, this is reactive power which is for voltage regulation and keeping the value of this, I mean like substituting this of I sa, I sb and I sc typically comes about 16.09 at the angle of 24.53; all three will be balanced, [FL] it is a at the 120 degree minus and then, 240 minus from a-phase.

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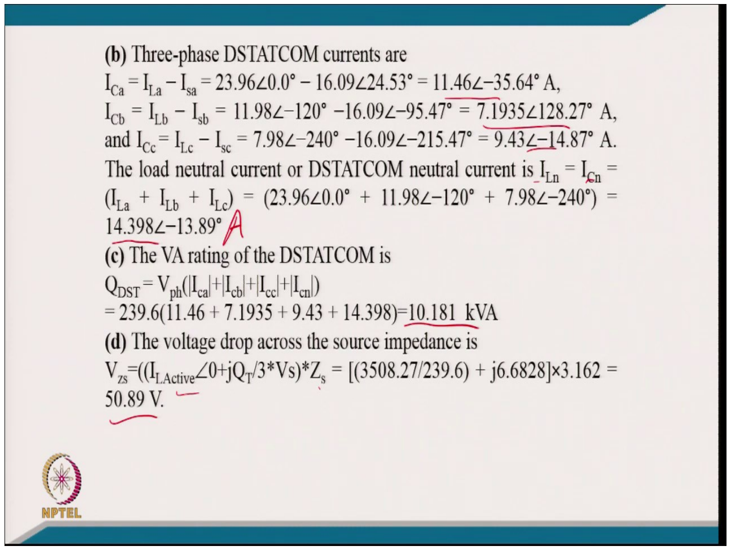

And the three-phase DSTATCOM current can be from load current and supply current, putting the value then you get a-phase DSTATCOM current, 14 11.46 at the angle of 30 minus 35.36 Ampere and for b-phase and for c-phase and then, neutral current DSTATCOM will be I Ln equal to I minus Cn and I Ln will be some of the three load current and keeping the value, you get the neutral current 14.398 at the angle of typically minus 13.89 Ampere.

And VA rating of DSTATCOM will be I mean voltage multiplied. So, absolute some of the current, [FL] it comes 10.181 Ampere and voltage drop across the source impedance will be your typically the current multiplied the source impedance. Putting the value, it comes 50.89 Volt. [FL] these are typically the Volt regulation problem which really in kind of sub registration.

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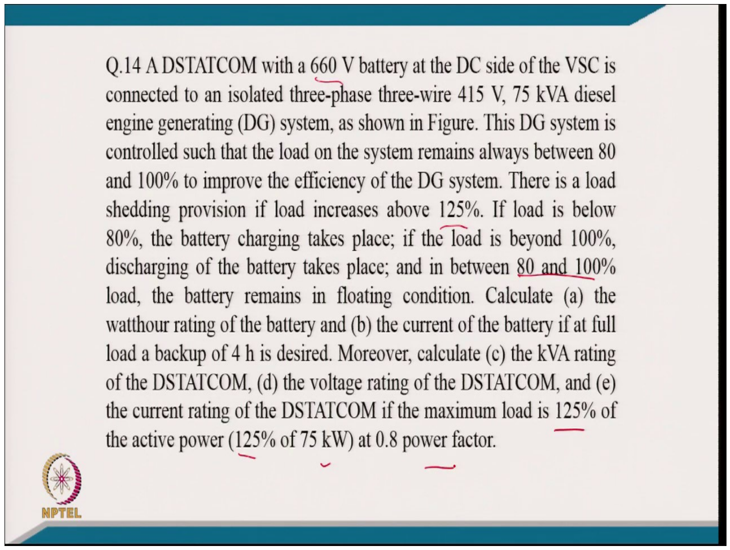

[FL] coming to a very interesting example. This example number 14 a DSTATCOM with the 660 Volt battery at the DC side of the VSC is connected to an isolated three-phase three-wire 415, 75 kVA dg set diesel engine generating system as shown in figure. And DG set is controlled in such a such that the load on the DG system always remain between 80 to 100 percent to improve the efficiency of DG diesel generator system and there is a load shedding provision if the load increases above 125 percent.

If the load is below 80 percent, the battery charging take place and if the load is beyond 100 percent, discharging of the battery take place and in between 80 to 100 percent of the load, the battery remains in floating condition.

Calculate the watt hour rating of the battery and the current rating of the battery and the load on backup of 4 hour is desired. [FL] moreover, calculate the kVA rating of the DSTATCOM, voltage rating of DSTATCOM and current rating of the DSTATCOM if the maximum load is 125 percent of active power; 125 percent of 75 kilo Watt of DG set at 0.8 lagging power factor.

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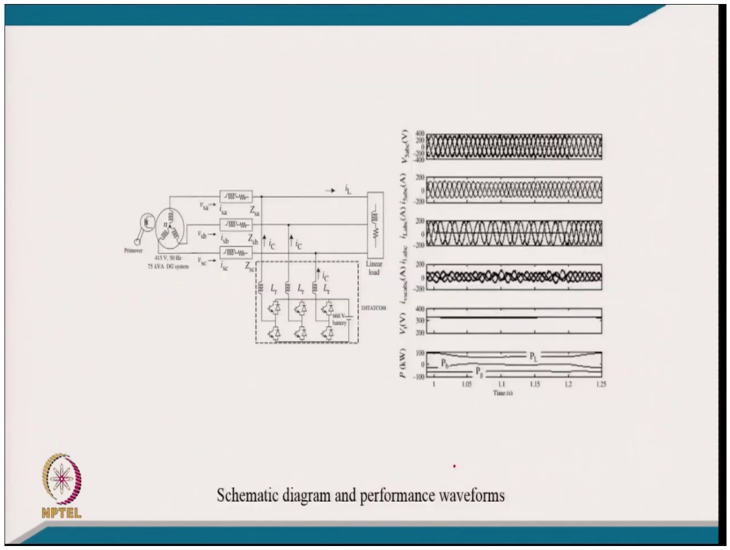

[FL] we have a DG set isolated which have a certainly the source impedance and we are putting DSTATCOM along with the battery on the dc link energy storage and we have a load here varying load. [FL] the very purpose of DSTATCOM with battery to provide the load labelling on the DG set so that the DG set is never loaded less than 80 percent and its never loaded up to more than 100 percent, even the load is 120 percent here.

[FL] that battery takes the energy and give the back like and these are of course, the typically making a develop of complete model. These are typically you can call it the voltage at the across the load than the typically genetic current and these are typically load current which is unbalanced current load is also unbalanced load and these are the of course the three compensator current and typically, terminal voltage which is regulated and these are the power different power, when load is varying because two phase load is there, then power battery, power of generator on which are varying.

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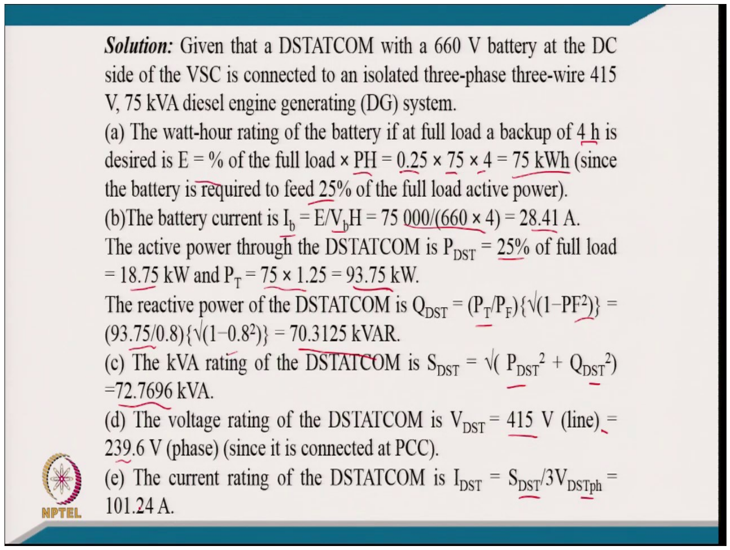

[FL] coming to the solution for this question, given that DSTATCOM with a 660 Volt battery at the DC side of the VSC is connected to isolate the three-phase three-wire 415 Volt, 75 kVA diesel generating set and the watt-hour rating of the battery at full load with the backup of 4 hours I mean equal to percentage of full load into PH, [FL] it is a 0.25 into 45 into 4, it comes 75 kVh; since the battery is required to feed 25 percent of the full load of active power and the battery current will be E upon V into H.

[FL] from this, we can find out the battery current 28.41 Ampere and active power through DSTATCOM will be 25 percent of the full load that is 18.75 kilo Watt and P T of 75 into 1.25, [FL] that is 93.75 kilo Watt like and the reactive power of DSTATCOM required for I mean corresponding to reactive power of the total power generated, [FL] that is for that kilo Watt and the power factor of typically 0.8 how much will be the rate?

[FL] that comes the 70 point 70.1225 kVAR and kVA rating of DSTATCOM form P and Q we can find out, that comes around 72.6696 kVA and voltage rating of DSTATCOM is 415 is connected across line and the current rating of DSTATCOM will be your S divided by 3 V D, [FL] it comes 101.24 Volt like.

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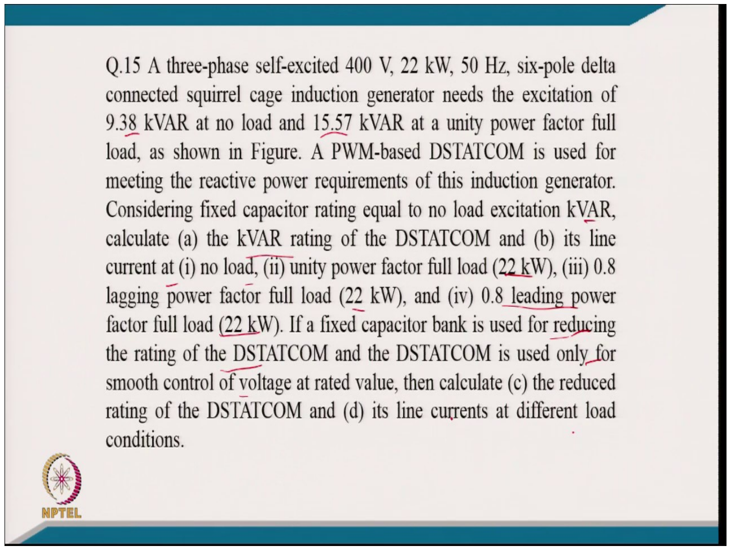

[FL] coming to an another example a three-phase self-excited 400 Volt, 22 kilo Watt, 50 Hertz, six-pole delta connected squirrel cage induction generator needs an excitation of 9.38 kVAR at no load and 15.257 kVAR at unity power factor full load as shown in the figure.

A PWM based DSTATCOM is used to meet the reactive power requirement of this induction generator considering fixed capacitor rating equal to the no load excitation kVAR, calculate the kVAR rating of the DSTATCOM, line current, no load at no load and unity power factor load of 22 kilo Watt and 0.8 lagging power factor of load of full load of 22 kilo Watt and 0.8 leading power factor 22 kilo Watt.

If a fixed capacitor bank is used reduce the voltage rating of DSTATCOM and the DSTATCOM is used only for smooth control of voltage at rated value, then the calculate the reduced rating of the DSTATCOM and its line current at different condition.

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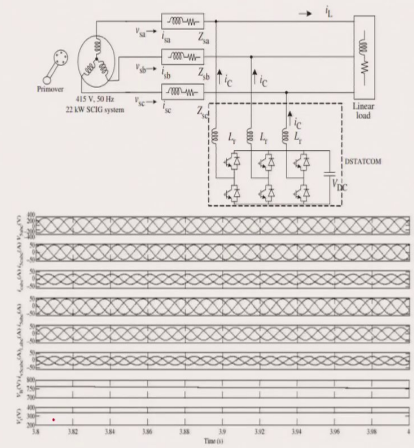

Schematic diagram and performance waveforms

This is the typical system that we have a generator and we have a DSTATCOM here. The very purpose of DSTATCOM is typically providing here the reactive power and along with the capacitor connected here like I mean. [FL] these are the typical waveform after the making the model and simulation and where, the thermal voltage as well as dc link and all the currents are given.

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Solution: Given that a three-phase self-excited 400 V, 22 kW, 50 Hz, six-pole delta connected squirrel cage induction generator needs the excitation of 9.38 kVAR at no load and 15.57 kVAR at a unity power factor full load. For the first case considering fixed capacitor kVAR rating equal to no load excitation, Q_0
(no load excitation requirement) = Q_C = 9.38 kVAR.

(i) At no load:

(a) The kVAR rating of the DSTATCOM is $Q_{DST} = Q_0 - Q_C = 0$ kVAR.

(b) The line current of the DSTATCOM is $I_C = Q_{DST}/\sqrt{3}V_s = 0/(\sqrt{3}\times 400) = 0$ A.

(ii) For a unity power factor full load (22 kW):

(a) The kVAR rating of the DSTATCOM is $Q_{DST} = Q_{fl} - Q_C = (15.57 - 9.38)$ kVAR = 6.19 kVAR.

(b) The line current of the DSTATCOM is $I_C = Q_{DST}/\sqrt{3}V_s = 6.19/(\sqrt{3}\times 400) = 8.93$ A.

Coming to the solution, [FL] given that three-phase self-excited 400 Volt, 22 kilo Watt, 50 Hertz six-pole delta connected squirrel cage induction generator needs the excitation of 9.38 at no load and 15.57 kVAR at unity power factor full load. For the first for the first case considering a fixed capacitor kVAR equal to no load, [FL] the no load excitation Q is a 9.78 which given from capacitor and at no load, the kVAR rating of the DSTATCOM will be Q equal to Q c that is 0 kVAR, it does not support to give any and current rating will be equal to 0.

For unity power factor full load on kVAR rating is Q fl minus Q c, [FL] we have here the load reactive power minus the here generated I mean that is capacitor one and this we get the 6.19 kVAR and line current for DSTATCOM will be Q L through, [FL] it will be 8.93.

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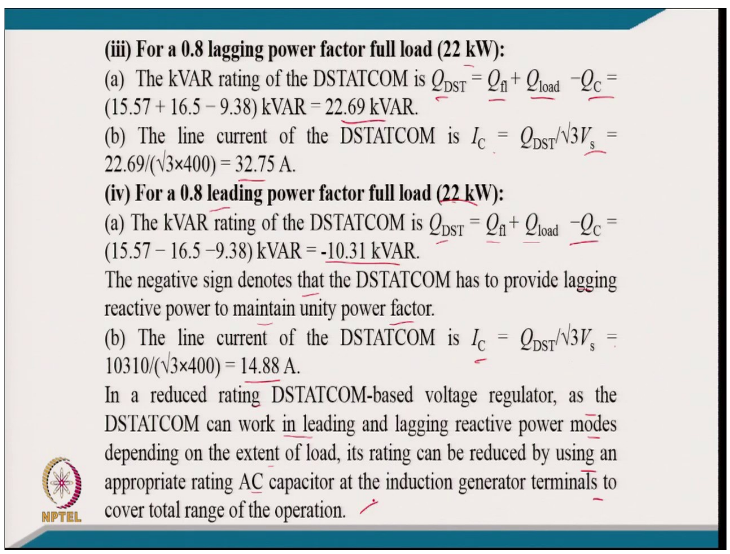

[FL] 4.8 lagging power factor load of 22 kilo Watt the kVAR rating of Q DST equal to Q fl plus Q load minus Q c [FL] in the value, it come 22.69 kVAR and the line current corresponding to that calculating it come 32.75 Ampere and for a load for a 0.8 leading four-leg leading power factor full load of 22 kilo Watt comes. The kVAR rating Q DST equal to Q fl plus Q l minus Q c, [FL] putting the value, it come minus 10.31 kVAR and the negative sign denotes the DSTATCOM had to provide the lagging reactive power to maintain unity power factor.

[FL] line current of DSTATCOM will be your I c equal to Q DST upon by root 3 V s, [FL] it comes like a 14.88 Ampere. [FL] in a reduced rating DSTATCOM-based voltage regulator, as the DSTATCOM work can work in leading or lagging reactive power modes depending upon the extent of load, and its rating can be reduced by using the appropriate AC, appropriate rating of AC capacitor at the induction generator terminal to cover the total range of the operation.

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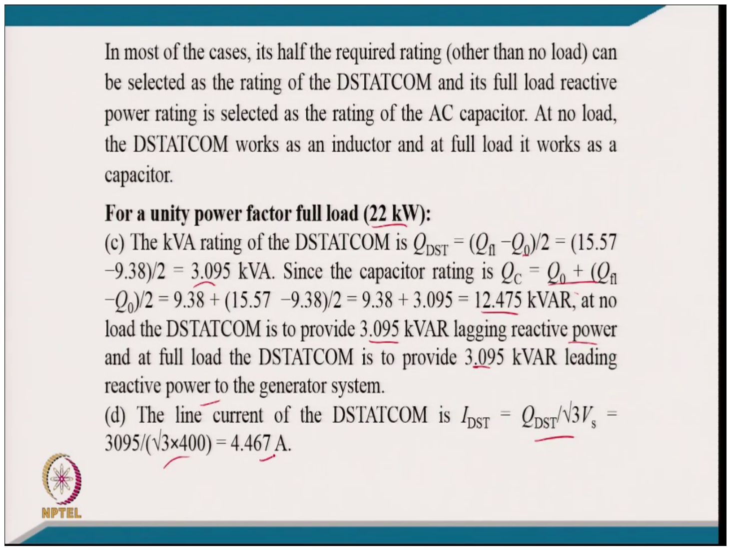

And in most of the cases, it is half required. It is half the required rating, other than no load can be selected at the rating of DSTATCOM and at full load reactive power rating is selected as the rating of AC capacitor. At no load, the DSTATCOM will work as an inductor and at full load it will work as a capacitor.

So, for unity power factor load of 22 kilo Watt, kVA rating of DSTATCOM will be Q fl minus Q 0 by total by 2, [FL] 15 this, [FL] this is the kVA rating of DSTATCOM. Because at no load, it will work in inductive and at full load, it will become capacitor, [FL] it will compensate on both the side.

[FL] we can find out that typically the capacitor rating, I mean from this [FL] this comes the typically capacitor rating at no load and the DSTATCOM is to provide this much kVAR lagging reactive power at full at no load at no load and at full load, it provide the three point this leading the reactive power. [FL] line current of the DSTATCOM will be Q upon root 3 V L, [FL] this will be 4.467 Ampere.

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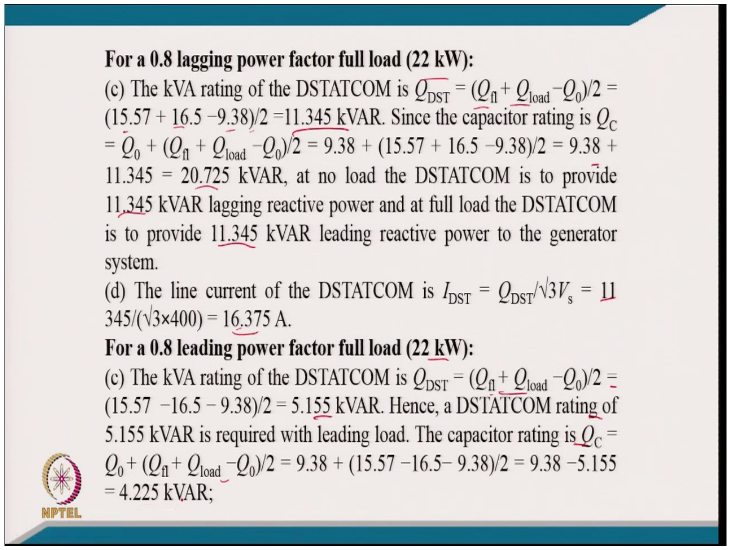

And for a 0.8 lagging power factor load of 22 kilo Watt, [FL] this capacitor rating will be of corresponding to generator at full load, load kVA rating at full load minus the capacitor rating which is abstracted. [FL] this is the kVAR rating of corresponding to the DSTATCOM and the capacitor rating will be corresponding to accordingly calculate, [FL] this will be the capacitor rating and at no load and DSTATCOM is to provide 11.345 kVAR lagging reactive power at no load and at full load, DSTATCOM is to overload the leading reactive power.

A line for DSTATCOM will be correspond to putting the value, [FL] 16.375 Ampere and for leading power factor at full load like kVA rating of DSTATCOM will be keeping the Q minus this correspond to half, we put the this will be 5.15 and the DSTATCOM rating of this kVAR is required leading load and the kVA rating will be corresponding to putting the value, it will be 4.225 kVAR.

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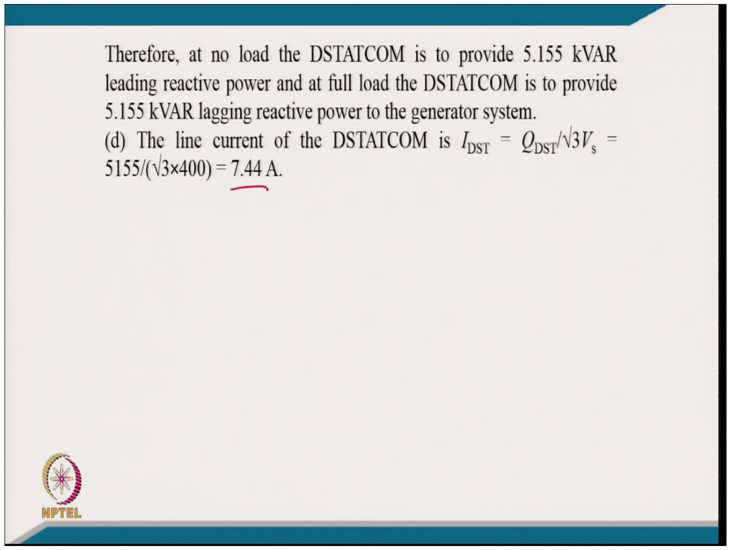

[FL], therefore, at no load the DSTATCOM is to provide 5.155 kVAR leading reactive power and at full load DSTATCOM can provide the this lagging power factor, [FL] lagging current of DSTATCOM I ST equal to Q root 3, this will be 5; typically, of 7.44 Ampere.

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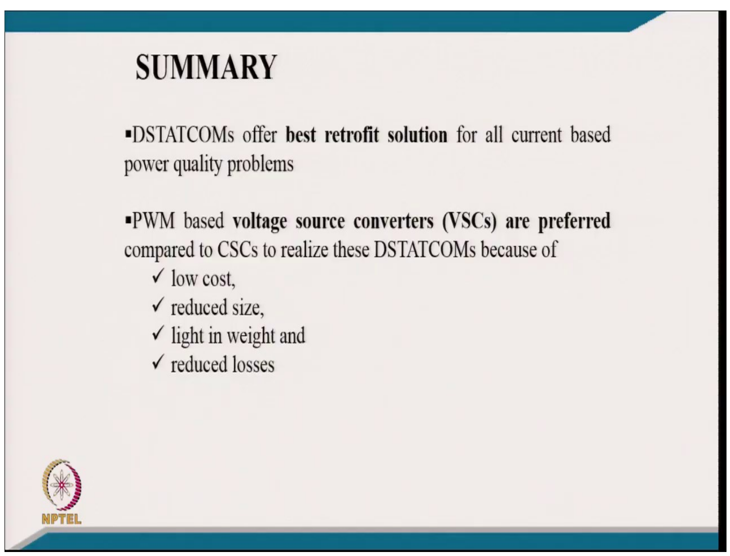

[FL] to summarize this DSTATCOM, I mean we have covered the DSTATCOM offer best retrofit solution for all current based power quality problem including the like single-phase system, three-phase supply system or three-phase four-wire supply system or DG set which we have given example late one and PWM voltage source converter are preferred because of the compared to the current source converter to realize DSTATCOM because of low cost, reduced size, light in weight, reduced losses because of that. And these are the some of the references and we like to conclude the DSTATCOM.

Thank you all.