CHARGING INFRASTRUCTURE

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Week-06

Lecture-26

Lec 26: Closed loop control of three-phase AC-DC converter-I

Hello everyone welcome to the lecture number 26 of the NPTEL lecture series on charging infrastructure and in this lecture we will see closed loop control of three-phase AC to DC converter now in the past two three lectures we have seen that how this particular converter three-phase AC to DC converter works how we can obtain the bi-directional power flow and we have seen that how to size different component of this particular converter We have seen that in this converter we have three symmetrical half bridges and we have three symmetrical inductors which are connected to the three-phase voltage source and we assume that these are balanced three-phase voltage source. and by changing this delta or you can say the power angle between the $V_{sphasor}$ or you can say the source phasor and the v converter phasor which is applied at the output of this half bridge we can change this sign of this delta to get the bi-directional power flow and we can also change this magnitude of this delta that's when we can change the voltage drop across the impedance offered by the inductance corresponding to the fundamental frequency component and from there we can easily able to control the amount of current which will be flowing through the our source.

Now how we can change this delta angle this V_s we cannot change but we can change our this V_{conv} which we are applying from here and that is when we can obtain the required performance. And we have seen how we can calculate the inductance value. So, inductance value is nothing but we can calculate by using this formula. We have discussed what are the significance of individual component of this formula. And after calculating this inductance, one need to ensure that the maximum drop across the inductor in the fundamental sense has to be less than 10 percent of the maximum voltage which is applied through the input.

Otherwise, what will happen is that majority of the voltage will drop across the inductor itself. Then we moved ahead, we have then derived the capacitance, how we can calculate the capacitance. Again in this particular system, there is no second line harmonic component, second line harmonic voltage ripple component on capacitor, on output capacitance. so that is where we can be when we do the power balance we are getting only the DC component at the output of this converter however depending upon the variation in the power or the variation in the load one can size the capacitor such that the output voltage report is within the permissible limit and this is given by this formula where this ΔP_{max} is one of the specification value T_d is also one of the designer's choice where designer can say what will be the response time of the closed loop control which designer will be implementing designer's choice ΔV_o is generally given in the specification and this V_o is actually also given in the specification. So, from that one can predict or one can calculate this minimum value of capacitance which need to be put at the output of a three-phase AC to DC converter, and then, in order to size this particular capacitor bank, because we know the value of the capacitor, but along with this, we must also know what the RMS current will be that flows through the capacitors. There will be a high-frequency RMS current at the output of this converter in the i_{conv}. So, we have to calculate the amount of RMS current flowing through the capacitor bank, and that will help us in designing the capacitor bank—that means designing the series-parallel combination of capacitors. And this one, if you see—look at this one—it is this particular RMS capacitor current that is independent of the switching frequency. It only depends on the modulation index m and $V_{s,pk}$, which is the maximum current you can expect from the source, and that we can easily calculate. by assuming a lossless converter using this particular formula. Similarly, if you take some efficiency into account—I mean, if we assume that the converter is not 100% efficient—we can say this will be eta times three $V_{phase,rms}$, where again, eta is the efficiency of the three-phase AC-DC converter. So, from this, one can calculate the RMS current through the capacitor, and that's how they can design the capacitor bank. Similarly, the voltage rating of the output capacitance is

$$C_{output} > \frac{V_o + \Delta V_o}{2}$$

So, that has to be greater than the maximum voltage you can expect across the capacitor. Similarly, we have also done the RMS current calculations for the switch currents. So, that's how we can choose or select our capacitor. switches accordingly. Further, we have also seen the voltage blocking of these devices—that's how we can calculate and understand the voltage and current ratings of these devices, and that's how we can choose or select the required devices for the realization of our three-phase AC-DC converter. Now, after understanding the operations and how to design the components of this converter, let us see how we can operate this converter and ensure the required operation from it. Now, if you look very carefully again here, what are the control objectives we have? So, the control objectives for the operation of this converter are—obviously, the first is to maintain or regulate the output voltage. to a desired value—obviously, it has to be greater than the maximum voltage you can obtain from this converter operation, and we know that it has to be greater than $\sqrt{2}V_{L-L}$ voltage. It has to be greater than that. So, if we consider the V_{L-L} to be 450, then that has to be greater than 565 V. Generally, they keep values at, you know, 650 or 700 V. Accordingly, we also have to account for the drop, so that will be somewhere around 650 V or 700 V.

So, it has to be greater than this value minimum value it has to be this much and then if we consider the 10% voltage drop overall 10% voltage drop. So, if we do that it has to be greater than greater than 620 or nearly about 625V roughly 625 V. So that has to be greater than that generally they keep the voltage at 650 or 700 V. So this is our first control objective. Now the second control objective is again keeping the constant voltage at the output we must ensure that the current drawn from the source has to have the unity power factor. So, the current drawn along with this, there is another control objective which is current drawn should be or should have UPF operation or you can say unity power factor UPF operations. And that operation has to be there in all the three phases because we assume that we have the balanced three phase operation. So, we must ensure that all the i_{sa}, i_{sb}, i_{sc} must be having the unity power factor operation. That means i_{sa} must be having the same operation.

phase angle as that of the van phase angle and isb should be vbn phase angle and isc phase angle should be vcn phase angle so these these are the two requirements we want to have and we have studied that how we can obtain the closed loop control of single phase ac to dc converter where we do the dual loop structure the outer loop is the voltage loop inner loop is the current loop which ensure that output voltage is regulated at a desired value along with obtaining the unity power factor operation. But in this case, if you look very carefully, there are three phases. Since there are three phases and we have balanced three phase operation, since we have balanced three phase operation, that implies that at any given instance of time, my $i_{sa} + i_{sb} + i_{sc} = 0$.

That means, at any given instance of time, the summation of i_{sa}, i_{sb} and i_{sc} has to be equal to 0. And if this is the scenario, then what happens is that, let us see if I am trying to control the phase current in a phase and b phase. So, because If there is a control of a phase and b phase current automatically the c phase current will be determined by the amount of controlling I am doing at a phase and b phase current. And similarly, if I am doing for b and c phase it is the current in a phase will be determined by the controlled value at b and c phase.

So that means what it indicates that the three phase current quantities or three phase currents are dependent on each other. That means if I am trying to control the phase current a, b and c phase current will change. If I am trying to control the b phase current, c and a phase will be changing. If I am trying to control or I try to do anything in the c phase, b and a phase will be changed.

So there is no independency between the three phases. And now if there is no independency between the three phases, then how we can ensure that all the three phase currents are controlled and they are having the unity power factor because these switches S1 S2 S3 S4 S5 S6 even if we are operating with the balanced three phase operation they may not generate the voltage at the output in the same manner so that means if there could be some difference in the a b c voltages which is been applied and also they are $120°$phase apart from each other so if i'm trying to control the a phase current by applying some voltage at the b at the a phase automatically independent of what will be my b and c phase voltages applied, there will be change in the current in order to ensure the unity power factor operation. And that is what is in order to ensure that balanced three phase operation.

So, either thing is that this condition of balanced three phase operation will be avoided or I must ensure that all the three phase currents are independent of each other. In that way, we can independently control all the three phase currents. So that's when we can say that we can independently apply the accordingly voltage such that these three currents are independent to each other along with maintaining the balanced three phase operation. So if you are making sure it is a balanced three phase operation then all the three phase currents are dependent on each other. So how we can make the control of these three currents to be independent of each other?

So, to obtain that particular independency among the three-phase quantity, we generally go from three phase system to the two-phase system and let us see how that thing makes sure that we have independency. So, now if you look very carefully this particular system and let us assume we have you know let us say this is my V_{an}, this is my V_{bn}, this is my V_{cn} and you can say that these are the source voltages which are applied and since they are having the balanced reference operation they are $120°$ apart from each other. Now, let us see a very simple thing where let us say we define the reference frame which is nothing but there is let us say if you consider yourself as the reference frame and you are moving in this direction like this and you are moving in this direction with the let us say this is a time t and these three voltages are varying in sinusoidally with respect to time. So, they are time varying quantities and you are there as a you know you are making sure that you are one of the reference frame and you are also running with the same speed as that of this waveform that means this waveform are actually changing its value with the time mean over the time nothing but $\frac{1}{f_s}$ and this time we can represent the angular speed corresponding to this is nothing but w, which is nothing but $2\pi fs$ or you can $2\pi fs$.

Now, if the reference frame, which is u, if you are actually moving with the same speed, speed ω, then what you will see? So, this w and this w are same. That means w corresponds to the 50 Hz or corresponds to the line cycle. Now if you are moving along with this with the same speed as that of the you know time variation of this voltage signal then you are running here in this direction with speed w which is same as the variation speed of or the speed with which this voltage is varying and let us say you have reached to a point let us say at this place where you have we have reached a point where you have peak of a phase where this is you can say w t equal to if we assume from here to here it is $360°$.

So, we have reached the angle $90°$and since this all the three since all the three voltages since all the three voltages are 120^o apart from each other we because we can write

$V_{an} = V_{s,pk} \sin sin\, \omega t$, $V_{bn} = V_{s,pk}\, sin(\omega t - 120°)$ and $V_{cn} = V_{s,pk}\, sin(\omega t - 240°)$

So, we can say that if you are also moving with the same speed as that of that. So, let's say this is your A axis. Now this is not with respect to time. Here I am taking the space which is in a spatial domain and let's say we have synchronized this axis in such a way that at this axis the ‘a’ phase peak with respect to time has arrived.

So obviously after $120°$in time domain the B phase peak with respect to time will arrive. So now we can define B axis which is $120°$ apart from A axis and similarly after another $120°$ your C axis will come where ‘c’ phase peak with respect to time will arrive. Let us define it as a small ‘a’, ‘b’, ‘c’ because your thing $120°$. And let us say you as a reference, you are also running with the same speed as that of speed with which the voltage is varying or the voltage is varying with time. So, after $\omega t = 90°$, you have reached to a point where a phase is at the peak.

So, that means after the $\omega t = 90°$, you have reached to a point where you’re ‘a’ phase is at peak value, which is nothing but $V_{s,pk}$. Let us say this is $\omega t = 0°$. So, at $\omega t = 90°$ you have reached from here to here. You have displaced by an angle $90°$. with the same speed as that of the speed with which the voltage is varying with time. So, you have reached at this this is the peak you will get along this direction you have the but $V_{s,pk}$ which is been applied and at that point you will see if this is your but $V_{s,pk}$then obviously the point at which they are crossing is nothing but $\frac{V_{s,pk}}{2}$.

Now at that point if we assume this at this point you are applying the minus $V_s/2$ from the b phase and you are applying $-\frac{V_{s,pk}}{2}$ from the C phase because this is in the negative direction you know in the time domain. So, from a phase you have applied maximum value of $V_{s,pk}$ and from the b phase you have applied You have applied nearly. So, you are now applying minus

$\frac{V_{s,pk}}{2}$ from the b phase. Which is $-\frac{V_{s,pk}}{2}$ from the b phase. And at the same point from the C phase you are applying the voltage which is minus $\frac{V_{s,pk}}{2}$.

Now, since all the three voltages you have applied, so the resultant of this will be, if you take the resultant of this, so let me draw the resultant with the red indication. The resultant will be, this will be, you know, this is nothing but your 60°. This is nothing but you 60°.. So, the resultant will be, you know, if I try to find the $V_{s,resultant}$, it is nothing but $V_{s,pk}$. In this direction, it is minus $\frac{V_{s,pk}}{2}$.

So, since I have already taken the direction, I can just write down $\frac{V_{s,pk}}{2}$. So, it is $V_{s,pk}$ + this. You take the component of this, you know, in this direction. So, and see $V_{s,pk}$ is already this phasor is already in this direction. So, we can write $V_{s,pk}$.

The component on this axis will be $V_{s,pk}$ + this one. If we take $V_{s,pk}$ + , cos 60 $V_{s,pk}$ + by 2 cos 60

$$V_{s,pk} += \frac{cos\ 60\ V_{s,pk}}{2cos60}$$

and this one if you take $\frac{V_{s,pk}}{2}$.

Again this is 60 it is cos 60 and that will nothing but $\frac{3\ V_{s,pk}}{2}$, so the resultant will be along the A- axis nothing but $\frac{3\ V_{s,pk}}{2}$ because cos 60 is 1/2. So, this is Vs 4 plus Vs peak by 4, the resultant will be 3 by 2 Vs peak.

$$\frac{V_s}{4} + \frac{V_{s,pk}}{4} = \frac{3\ V_{s,pk}}{2}$$

So, $\omega t\ =\ 90°$,, we are having the resultant or you can say the resultant voltage which is applied will be nothing but $\frac{3\ V_{s,pk}}{2}$ Why? Because in this space already your B and C phases are displaced by 120 degree. Now,

now let us try to see what will happen if we further move ahead if that that reference frame which is there is further moved ahead so let us draw the reference frame which is u and you are again running here with the same speed with which the voltage is also varying this is your van this is your vbn this is your vcn And at that place, let's say you have reached to place where you have reached at this point. At this point, this is nothing but your w t equal to 90 plus 120. So, which is nothing but your 210 degrees. Now, at that 210 degrees, you have reached here from the B phase, you are applying VS peak.

from the a and s phases you are applying minus VS peak by 2 so now let us try to draw the resultant you know you have A axis you have B axis you have C axis now so let us try to write down or let us try to see what will be mine resultant values which is been applied so from the if you look very carefully at w t so from here w t equal to zero zero degrees so from here you have moved to this place which is w t equal to 210 degrees and at that point you are actually you have reached along the you know the axis which is aligned along the B phase because they are 120 degree apart from each other so at that point you are actually applying your VS peak from B phase from A phase and C phase you are applying minus VS peak by 2 so let us define minus VS peak means here I am applying VS peak by 2 A phase and C phase is again you know minus vs peak by 2 and if we see the resultant of this again this is 60 degrees this is again 60 degrees so if we try to find the resultant of vs resultant if we try to define is nothing but vs peak plus vs peak by 2 cos 60 from B phase, VS peak by 2 from the C phase component we are getting.

And this will be nothing but again equal to 3 by 2 VS peak. So what we have realized the resultant will be nothing but equal to 3 by 2 VS peak. So if we see the previous resultant, The previous resultant was 3 by 2 VSP and it was aligning along the A axis and then you have another resultant which is aligning along the B axis So what we understood what we have understood that we have ABC axis and we assume that let us say in this space they are displaced by 120° again how you can get displacement by 120°.

So we can derive the inspiration from the machine having three phase windings which are 120° displaced from each other. and that's when you apply the voltage to it. So, the MMF which will generate will be the combined of the three phases, and that three phases will be spatially displaced by 120° . At the same time, from the excitation perspective, they are 120° displaced from each other in terms of time. So, here what we have seen, when we moved by 20°, and we have assumed that there are three axes, A, B, C axes.

which are $120°$ apart from each other. And then when we reach to the 'wt' equal to 200, we saw the resultant will be nothing but same value $\frac{3V_{s,pk}}{2}$. Now, let us take when we reach to a place where my Vcn is nothing but equal to the peak value. So, let us see what will happen. Again, let me define the reference frame, which is U who is running at a speed

ω corresponding the same speed as that of the speed with which van and vbn and vcn are varying with respect to time this van bbn are varying with respect to time however u who is the reference is actually varying or is actually changing its stage with respect to the space not with respect to time so what is happening is that at this point let's say you have reached to this point at this point that means you have moved from here to here in.

Let's say $\omega t = 210° + 120° = 330°$, now at $330°$what is happening you are applying from the c phase, $V_{s,pk}$voltage and from the a and b phase, you are applying minus $V_{s,pk}/2$. So, let us try to define. So, here we have three axes A, B and C which are $120°$apart from each other and you are now applying from a phase, you are applying minus $V_{s,pk}/2$.

From the b phase, you are applying minus $V_{s,pk}/2$. And from the c phase, you are actually applying $V_{s,pk} + V_{s,pk}$.

So, let us try to draw the resultant. This is you are applying $V_{s,pk}$from the along the phase c. You are applying $V_s - V_{s,pk}/2$,which is $V_{s,pk}/2$ in the opposite direction to that of the phase a. And you are applying from the b phase nothing but $V_{s,pk}/2$. And if you see very carefully, this will have, you know, if this is $\omega t = 0°$, it has, you yourself have displaced by $\omega t = 330°$, and you are making this particular angle. Then, let us try to see what is the resultant. So, if we see this is nothing but $60°$and if you see this is nothing but the $60°$. So that's when we can say the resultant which will be applied will be nothing but VS peak plus VS peak by 2 cos 60 plus VS peak by 2 cos 60 same as the previous thing.

$$V_{s,pk} + \frac{V_{s,pk}}{2} cos60° + \frac{V_{s,pk}}{2} cos60° = \frac{3V_{s,pk}}{2}$$

$$V_{s,pk} + V_{s,pk} cos60° = \frac{3V_{spk}}{2}$$

This is the contribution from a phase, this is contribution from b phase and this is contribution from c and that's when the total is 3 /2, we speak so what we have seen is that whenever a reference who is also changing in space or you can say when the reference which is also moving with the speed same with which the voltages are varying with respect to time, so the resultant which are been applied is nothing but having the same magnitude and if you see the resultant in this direction it is $\frac{3V_{s,pk}}{2}$.

so what we saw that the resultant the resultant is a vector quantity the vector quantity whose magnitude is nothing but $\frac{3V_{s,pk}}{2}$ in our case and it is rotating with the and it is rotating with the speed equal to ω i mean angular speed equal to ω which is nothing but w is nothing but 2πfs line frequency corresponding to line frequency. Now this vector is also sometimes called as the space vector which has magnitude and angle which varies with theta is equals to ωt in the space.

And this space vector has the combined information of all the three phase quantities which are actually varying with time. And the vector is rotating in a the resultant vector is rotating in a two dimensional space. So if we see this is nothing but a two dimensional space we have defined this is x axis this is x axis and this is y axis. So that's when since the vector is rotating in a two dimensional space in order to in order to obtain the independent quantity because see our Aim is to obtain the independent control over the three phase currents which we have.

So, we have to define the independence. I mean, how we can define the, how we can represent the three-phase currents in a quantity which are independent of each other. So, in order to obtain the independent vectors or independent components of vectors, Vectors, the axis of representation or the representative axis, you can say, the representative axis has to be 90 degrees apart from each other. What I mean by that is, if we define the two axes which are 90 degrees apart from each other, then the component of quantity on one axis is completely independent of the quantity which is represented on the other axis.

Let us see what I mean by that. Let us take, we have already seen, we have A axis, we have B axis, C axis, and they are displaced. In a space by $120°$, and we know that when we define the three-phase quantities using these three-axis components, these three-axis components will not be independent of each other because when there is a change in any one of the three-axis components, this change will get reflected on the other two-axis components as they have non-zero projections onto each other. So, in this case, we will define The two axes, and we define axes in such a manner that their projections onto each other are zero. That means the component of a vector on any one of the axes is completely independent of the component of the vector on the other axis.

Let us define that axis. Now, let us define that axis to be the two axes to be alpha and beta axes. This is alpha axis and beta axis, and the simplistic thing we can do is we can align this alpha along the A axis, which is inherently synchronized with the peak value of a-phase quantity with respect to time. And the beta axis is displaced by 90°. So, when we ensure that these two axes are 90°from each other, then any resultant vector, let us say, if any resultant vector, let us since we have understood that the Vs vector is rotating in a space with the speed same as that of the ω, so we can say we have, let us say, define this as a $\vec{V}_{s,}$ and this, and again since they are rotating in a space, we can define that $\vec{V}_{s,}$ to be a space vector because they are rotating in a space. So, that space vector Vs is actually, let us say, at one given instant of time, this theta is nothing but ωt at that point, we have this $\vec{V}_{s,}$. Now, if we take this $\vec{V}_{s,}$ component along the alpha axis and beta axis, so V component of Vs space vector along alpha axis $V_s\alpha$ which is somewhere here.

$V_s\alpha$ and we will define this as $V_s\beta$. So we have $V_s\alpha$ and we have $V_s\beta$. Now if we take any projection of $V_s\beta$ onto the $V_s\alpha$ or if we take any projection of $V_s\beta$ onto the beta axis the projection is 0 because cos 90 is nothing but equal to 0. So, if we take projection of $\vec{V}_{s,}$ along the alpha axis into the beta axis, so it is nothing but Vs alpha cos 90 which is 0. And if we take the projection, you know, beta axis along the alpha axis, that means $V_s\beta cos\ 90^0$ is again 0. So that means what? If I can represent this space vector using the two axes which are 90^0apart from each other, then the component of that vector on those axes are independent of each other. That means whenever you are changing any value in $V_s\alpha$, there is no impact on the beta component. Let us say if you reduce the size of this alpha, let us say reduce the size of this alpha component of Vs, then your vs beta is independent of this because the reduction of that if you take the projection of that reduction along the beta axis it is 0 as cos 90 is equals to zero so you can independently control the alpha component and beta component and the change of alpha component will not be changing anything on the component of beta axis and if you are changing anything on the beta axis component you are not going to change anything on the alpha axis component So, what we are going to do is we will define this alpha and beta and we represent this $\vec{V}_{s,}$ which is rotating in a space with the speed similar to that of the speed of the voltage variation with respect to time. Then we can take the component of that vector along the alpha and beta axis who are 90^0 that means who are 90^0 apart from each other who are actually independent of each other. So, in this case what we do is from a phase, b phase, c phase we will obtain the alpha, $V_s\alpha$ and $V_s\beta$ and then we can independently control, $V_s\alpha$ and $V_s\beta$.

That is when we can get the independent control of the alpha component and beta component, and accordingly, that will reflect the component on the ABC axis. Now, if we look very carefully, this alpha and beta are sometimes also called the stationary reference frame, stationary reference. Reference frame, and in this reference frame, why is it called the stationary reference frame? Because we have kept this alpha and beta stationary while the vector space vector, which is Vs determined by Vs, is actually rotating in space, and this space vector actually combines the information of the ABC phases. And then, when we take the component of this Vs vector onto the alpha axis and beta axis, and if we control the alpha axis and beta axis, we will get independent control of the alpha axis component and the beta axis component. That means whenever we change anything on the alpha axis component, there is no impact on the beta axis component, and whenever we change the beta axis component, there is no change on the alpha axis component.

So, with this, that is nothing but the stationary reference frame, and in this stationary reference frame, you can easily convert the ABC quantities into the alpha-beta quantities by just doing the trigonometric calculations, and we will see what is there in the next slide. Similarly, we can also define another axis frame, and that axis frame is also 90 degrees from each other. I mean, if we want to have independent control, let us define one axis frame, which is to be aligned across the rotating space vector. So, let us say theta equals w t. I will define my another axis frame. Let us define it as a direct axis, and the perpendicular is nothing but,

The quadrature axis, you can say $90°$., which is nothing but the Q axis or quadrature axis. So, this DQ axis is nothing but R, since they are—this D is always aligned across the Vs space vector, and this Vs is rotating in space with the speed w. So, we will always make sure this axis, which is $90°$. —this DQ axis, which is $90°$. —is also rotating along with this space vector, and that is why it is called the Rotating reference frame, sometimes also called the synchronous rotating reference frame, because they are rotating synchronously with the speed corresponding to the line frequency. Now, if we take, let us say, after some time, this $\vec{V}_{s,}$ will not be here after—let us say this is—let me take another example where at ωt equal to, let us say, a

b , c phase and let us define my alpha axis my beta axis and let me define this as you know v s vector and that vector is nothing but at the theta one which is w t one a different time instance then at that time instant my rotating reference frame will be will be along the same direction as that of the $\vec{V}$s this is d frame and this is q frame and if we take this vector vs along in in this direction $\vec{V}$then d-axis will be here and q-axis will be here so accordingly my this dq axis are also rotating with along with these space vector and since this dq are here are $90°$, from each other so they are also independent of each other that means whenever you are doing any changes on the d component there is no effect onto the q component and whenever you are doing changes in the q component there is no effect onto the d component so that's when we can ensure that we will get the independent control if we can somehow represent the three quantities who are $120°$. apart from each other if we can represent the same quantity in the spatial domain and using the two axis which are $90°$apart from each other in the space we will get the independent control over those two axis components that means whenever we change one component on one of the axis there is no chain on the other axis component and vice versa.

So, with this, we will get independent control over the operation of this particular system. Now, if we have Va, BC phase component, how we can define the Vα, Vβc omponent and how we can define Vd and Vd component. So, if we look very carefully, if we define this VS phasor, this one. So, if we have, let us say, you know quantity VA, VB, BC at one of the samples, at one of the instance, Let us say T. My sample quantity is ABC.

The quantity could be either voltage or current. This is sample quantity. So, these are the sample quantities. So, we can define this quantity with respect to alpha beta is nothing but A to be alpha component of that quantity to be A because it is along this axis. And B from B since the B it is 60^0 and that we would take the component of B along the A axis it will be minus 60.

V/2 whatever the quantity you are applying minus V/2 and then from the C phase similar $60°$. apart in the negative direction so we will get C / 2. Similarly, you can define beta to be nothing but equal to you can define beta to be A cos 90 the quantity along A axis in this direction cos 90 plus this b is here in this this is a 30 degree.

So, b cos 30 and this is c, c will be along this direction -c cos 30 and that will define alpha to be nothing but 3 / 2 and this we can that point the beta quantity corresponds to a b c quantity will be nothing but root 3/2 b minus root 3 /2 c similarly you know you can define the d component you will get That alpha component you got, it is component of alpha onto the d component which is nothing but d to the alpha cos alpha.

theta plus from beta which is $90° - \theta = sin\theta$,which is nothing but beta sine theta and Q quantity of that alpha beta quantity to be this is theta so this is beta cos theta this beta cos theta and alpha quantity you can take the negative and then it is 90 - theta so that will be alpha minus alpha cos $90° -$ minus theta so that will be minus alpha sine theta. So, using these three quantities, you can actually represent your voltages, supply voltages, your voltages applied from the converter side and your current which has been drawn from the source.

So, you can define $I_s\alpha$, $I_s\beta$, $I_s d$, $I_s q$. Similarly, you can apply from the supply side VSD, I_{sQ}, I_{VsQ}, $V_s\beta$ and you can from the converter side, you can define $v_{conv}\alpha$, V $v_{conv}\beta$, V converter D, V converter Q axis component. And once you define those components, you can independently control those components because they are independent of each other as these axes are 90° apart from each other and then we can control those components.

Thank you. We will discuss the remaining discussion in the next lecture. Thank you.