DC Microgrid and Control System
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Lecture-31
Control of DC Microgrid System

Welcome to our lectures on the DC micro grid and the control system. Today we shall visit the different control techniques specifically applied to the DC micro grid system. We intentionally talked about the microgrid engineering our field lectures and its control and then only so that student can derived what are the differences in the DC microgrid. So, as we know that in case of the AC micro grid we have a PQ control and the V by F control and essentially it is leads to the voltage and the frequency control of the two quantities.

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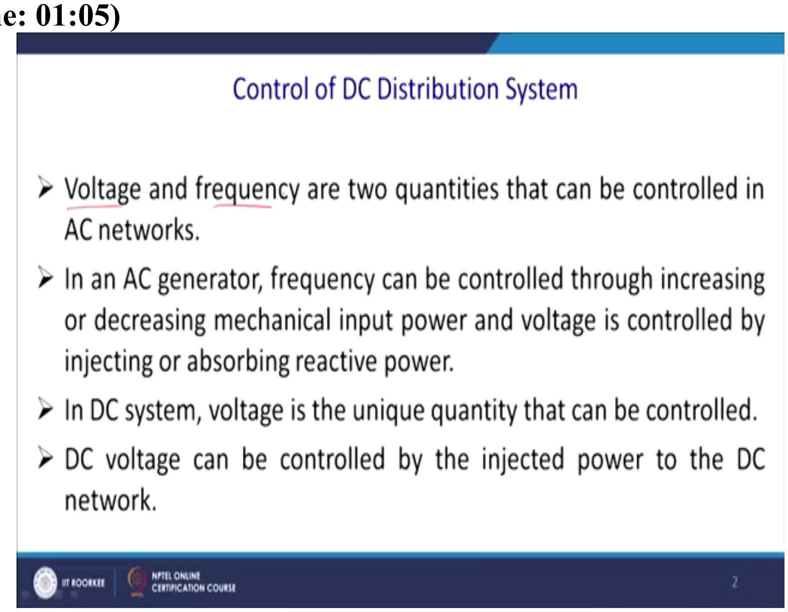

And then really what happened in microgrid when it goes to the islanding mode to manage its demand frequency drooping will be there and with that they general each also changes the voltage and thus they wanted to maintain the V by F control. And in a AC generator frequency can be controlled through increasing or decreasing the mechanical input power. So, that is easily possible because once you want because ultimately you know that once you want to increase the real power then you have to increase the mechanical import.

Once you want to change these excitations and so that you can control the Q you will change the excitation. So, by changing the excitation you control the voltage by changing the mechanical input you control the frequency and thus that will be reflected in the change in the real power. The voltage is controlled by injecting or absorbing the reactive power. Same thing it will be required to do it with the switching solutions.

The STATCOM can be or the since it is a micro gate it can be a shunt active power filter can mimic this characteristics. So, the DC system it has only one voltage so there is no frequency. Voltage is unique quantity and that required to be controlled so you do not have our separate control like you frequency and the voltage you just have a voltage control and there is no concept of the reactive power there as it is.

So, DC voltage can be controlled by injecting power to the DC Network and it can also take out power from the DC Network. So, that control has to be managed and ultimately what you have seen the frequency control that frequency changes while limit while it is increasing the demand. You will find a voltage bus voltage will droop and we require to control the droop. So, that is the basic essence of the DC microgrid.

We can assure that all the generator and the loads are interfaced to the DC network through individual converters.

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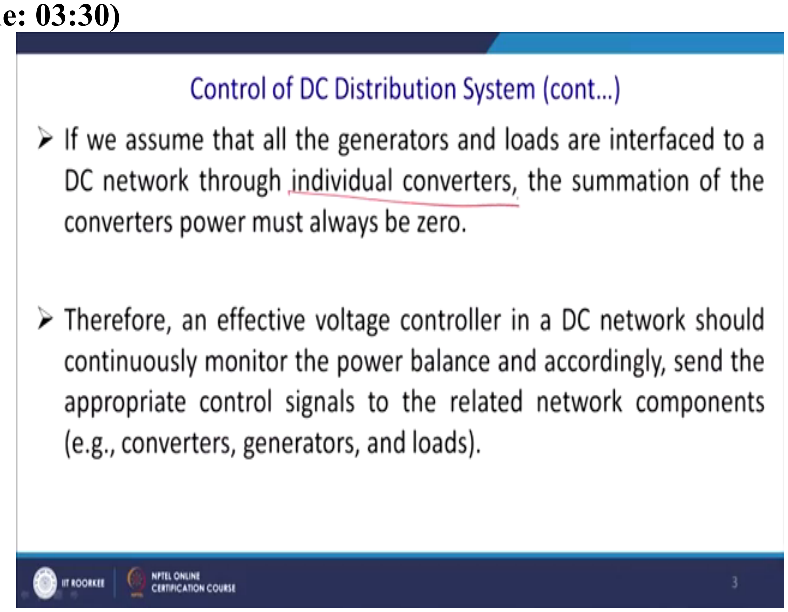

So, of course their bus voltage and there can be a little bit of mismatch between the input of this particular load and for this reason for example if you are charging a laptop so it is 18 volt if you are charging a mobile it is a 5 volt. So, you have to put a laptop charger you have to provide a mobile charger accordingly its output voltage may be different. So, the summation of the converter power must always be 0.

So that is something that we want to make it as a as axioms that the summation of all the converters power must be equal to 0, therefore the effective voltage control in the DC network should continuously monitor the Power Balance accordingly. So, it has to; you want a period of time it may be add in transient time. So, you may we have a extensile power from the one converter and ultimately it will fit it back.

So, then if there is a huge load change of course your battery cannot pump that much of huge amount of current instantaneously so, voltage will go with a subsequent time that by direction DC to DC water from the battery will restore the bus voltage that is the one of the requirement. So, thus if you in terms of the mathematics you put it like that the summation of the all the then converted power must always be 0.

So, therefore an effective power control of the DC Network should continuously monitor the power balance and accordingly send the appropriate control signal to the related network component for example converter generators and the loads.

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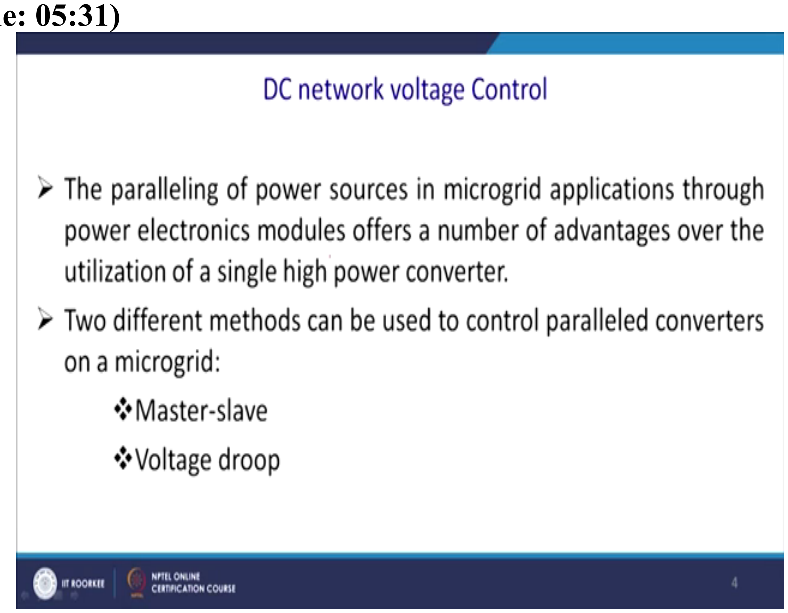

The paralleling of the power sources in micro grid application through the power electronics modules offers number of advantages. We have told in several times in two introductory classes that this power converters era it can have a number of converter over the utilization of a single high power converter. If you are multiple converter then you have your topology will be different generally depending on the topology you choose the DC to DC convertor isolate DC to DC convertors.

And in general what happened if you have a so many small DC to DC converter all the efficiency will be less because you cannot put huge amount of money to investigate or reduce the losses of the particular DC to DC converter. But if you have a centralized DC to DC converter which have a multiple output that is preferred over a multiple DC to DC converter. And thus you have two different method of control what we have seen also in case of the micro grid also in a DC microgrid.

There is a master slave control one will be the master other will be the following the instructions. Another you have a volt frequency control you had in a micro grid AC micro grid and here you have a voltage drop control that is the difference.

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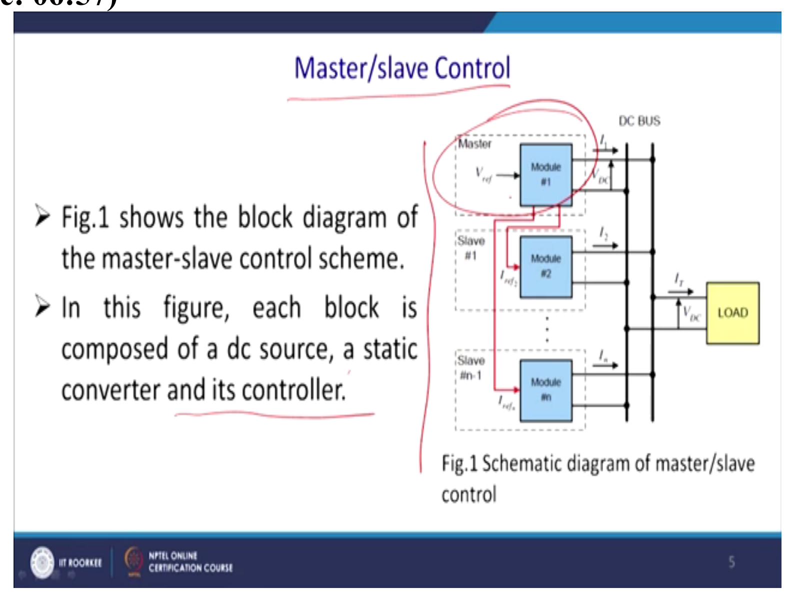

Now master slave control will be almost the same thing what we have discussed in our previous class in case the AC micro-grid. So, master slave control essentially you have a DC bus and this is the master. Task of the master to set the DC bus voltage according to the load condition if it is 48 volt they need to have a little bit of tolerance so load is little bit increasing it can push up it can either take down the voltage little bit low every 46 volt or some amount of tolerance.

And accordingly this converter will adjust themselves. So, and the power is and if you have a constant power load CPLD then accordingly two latches otherwise the power consumption will decrease also because V square by R all you have a parallel connection if the Volt bus voltage decrease then you have a little bit of change of the consumption pattern and in that way you save the power. But problem lies with the constant power load.

If you decrease the bus voltage then it will track more amount of current things will be lousy. So, you have to have a little bit of more control on the constant power loading. So, in this configuration each block is composed of the DC source a static converter and its controller. So, this is the control we require the control because you may have more some entities are constant power.

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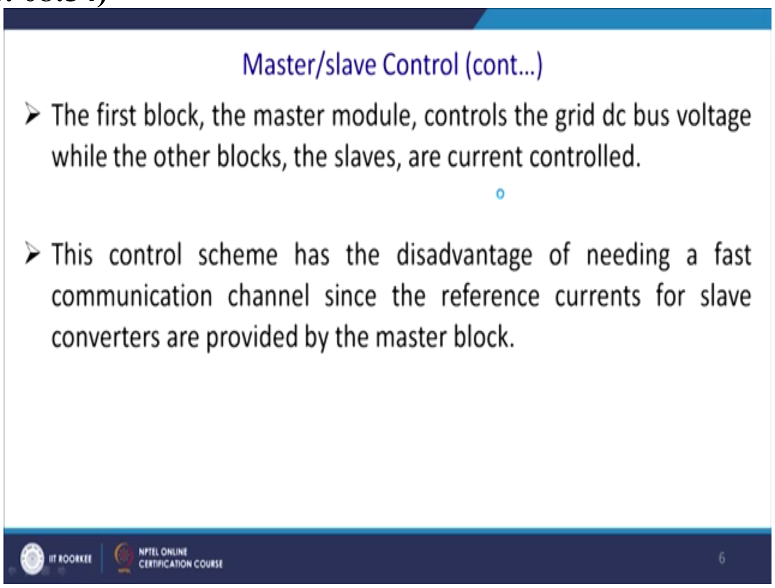

So, let us describe this blocks the first block of the master slave a first block itself is a master slave master block the controls the grid voltage while the other block slips controls the current so that is what it is saying. If it is CPLD then if you have a droop voltage has decreased so you have to increase the current another. And some way or other if you have a different kind of loading pattern then you can control the current so that your consumption pattern will be reduced and accordingly you can change.

This control scheme has an disadvantage getting fast communication channel you know once load change occurs we see transient phenomena while quite severe. So, it does not have a 0 crossing it is a step change so for this reason all the changes are quite severe. And to take care of that high speed of the transient you require to essentially have a very high speed communication channel that is one of the major drawback of the DC micro grid that your communication channel required to have a very high bandwidth.

Since the reference current for the slip and water are provided by the master block. So, it is the switching frequency at 10 kilohertz then you have to have that information to be fed to the next switching second that we need the data to be transferred within a 100 microsecond.

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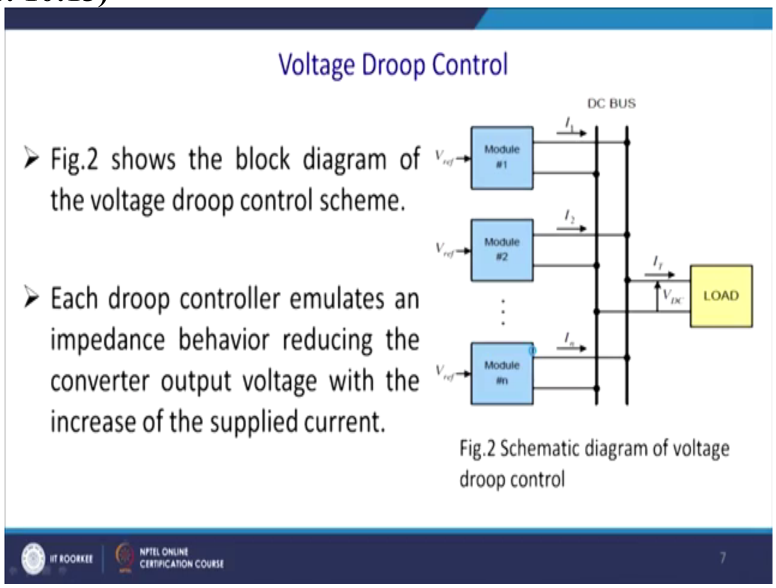

Another control is a droop control so that is quite familiar control here what we have done this has this taken from this the same controlling the AC micro grid or a whatever the grid system while doing your frequency drops and all those things. Here figure 2 this is a figure 2 this is a schematic diagram of the droop control shows the block diagram of the voltage control scheme. The each troop control emulates and independence behaviour reducing the converter output voltage with the increasing the supplied current so this is something we required to understand.

So, that occurs once your loads are constant power load otherwise you will be happy if your little illumination is decreased in your light. So, there is a not much problem but you can say power in that way. You can also have a energy saving once your demand is more. So, this is the load and ultimately these are the different kind of source and all will generate the current to maintain that DC bus voltage up to a level of tolerance.

And this strategy promotes the current sharing so this is something like your alt your parallel operation of alternative which you have studied in B.Tech classes in second year or third year.

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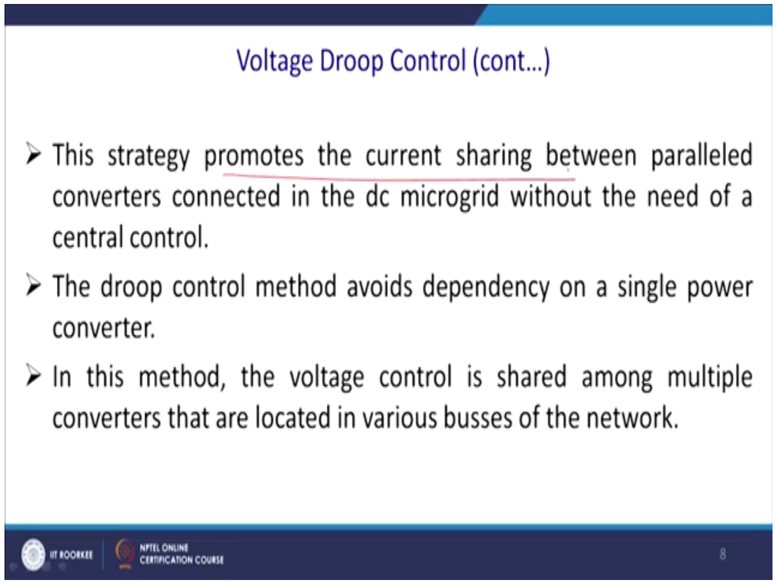

So, the strategy promotes the current sharing between the parallel converters connected in the DC Metro grid without the need of the central control that is quite understandable. The control method avoids dependency on a single power converter. A master controller goes out then it is a total blank you do not have any redundancy but here in this case you have a huge redundancy. So, whosoever can take care of the load it will take care of the load.

If some biggest you know there is no concept of the pilot generator which will fix up the frequency of the system because generally what happens in your transmission line normal transmission line not a micro grid so biggest generator generally asked to set out the frequency and rest will synchronize with it. And in case of the micro grid there is no concept of the biggest generator and that if wind is more than wind will be the sole contributor.

And if solar is more solar in most contributed in absence of the solar and grid may be the energy source energy resources like battery are the sole contributor. And ultimately whosoever has a capability to handle they will handle that is the automatic sharing. Once if solar radiation is more then it will take the lead to control the drooping and ultimately all the boss will be asked to wait that voltage all the convertor.

So that is quite phenomenal advantage so that is what happened that will help you to share the burden of the individual converter. What happened maybe at 12 noon the solar is it at peak and thus it is generating maximum amount of energy then solar can water is fully loaded and that time maybe that bidirectional DC-to-DC converter is evenly idle it is may or may be a small amount of power is transmitting from the bus to the battery.

And think about that the case at a 6 p.m. evening may be that we; is generally in evening wind picks up. So, what happened you know wind will try to flow but meant chunk of the power will come from the battery and ultimately task of this maintenance of that DC bus will be delivered by this back by this actually bi-directional DC to DC converter which is charging and discharging the battery.

So that is what happened the loading of the converter become optimally and one converter is not loaded throughout the period of time so that is a one of the biggest advantage of the voltage droop control. That is what it is set it then this method the voltage control is shared among the multiple converter that are located at the various buses of the network and also it has got excellent relaxation time.

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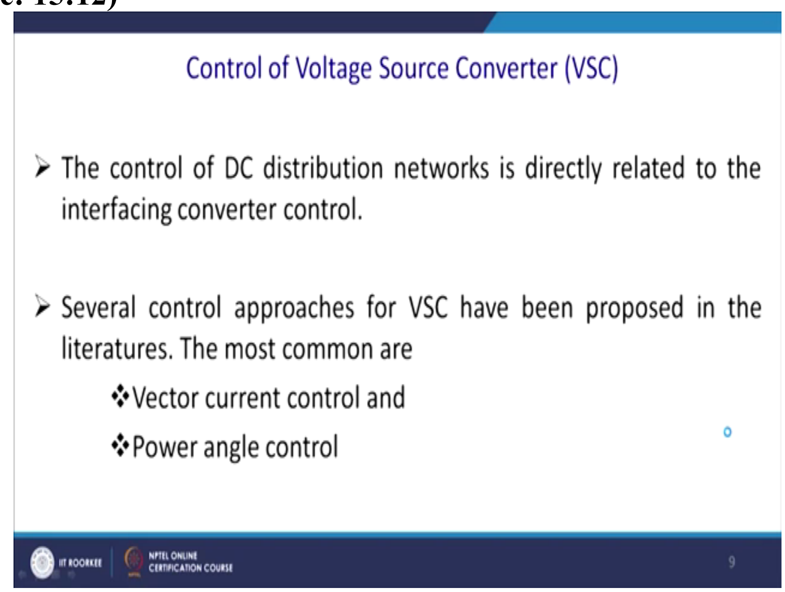

The control of the DC controller DC distribution network is directly related to interfacing control, interfacing convertor control. Several control approach for voltage source converter have been proposed in the literature the most common are the definitely will come little later that is the vector current control and the power angle control. So, we have both those topics we have touched in a AC micro grid. We shall see that what are the little variation here because you do not have any concept of the of the voltage angle control.

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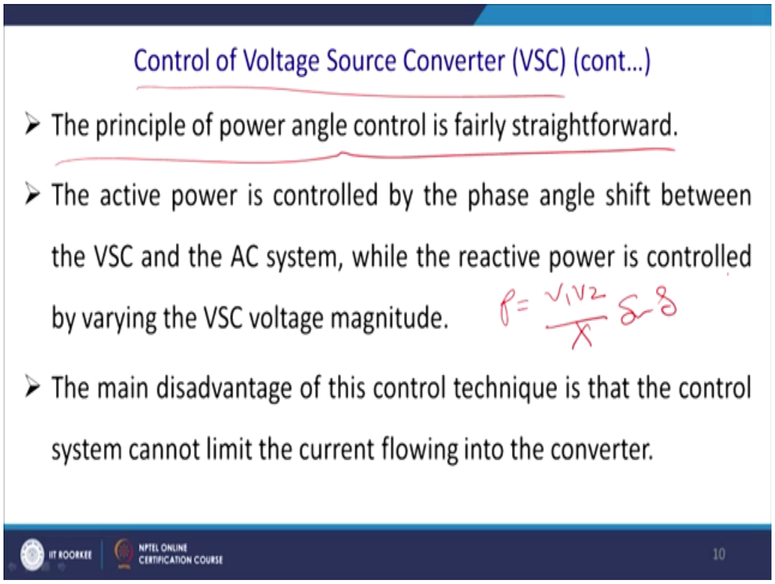

In case of the; but you may have a some sources AC to DC like you are if you are a grid connected your entry point to the active rectifier and also wind? So, let us discuss it the principle of the power angle control is fairly straightforward why it is so? The active power is controlled you know that P equal to V1 V2 by X sine Delta this is the relation and thus where V1 is a sending end voltage V2 is the receiving end voltage and X is the impedance and sine Delta is a angle between this V1 and V2.

Thus what happen the active power is controlled by the phase angle between the VSC and AC system. So, if you want to send power you change the till change this angle within 0 to 90 degree this challenge is that if it is a short transmission line generally phase angle is very less and while the reactive power is controlled by firing the VSC voltage magnitude. So, generally the same thing we have we have done in case of the rotating solutions.

The main disadvantage of the control technique is that the control system cannot limit the current flow within the converter because you know ultimately what happen once you are increasing the power then essentially you are not changing the voltage and thus we are changing the current. So, you have limitations of the flow of current ultimately it will be restricted by the protective devices. So, you have a limitation of the power change. On the other hand if you have a direct vector current control that is a direct control method.

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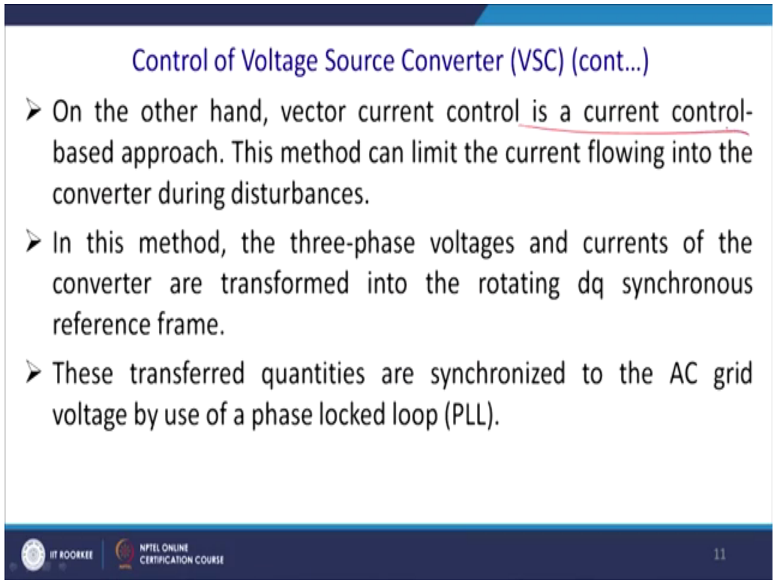

And the current control technique is approached we have an average or the peak current control and in this method and it can be limited the flowing current between the two converter during the disturbance. So, you fix out that this because was voltage is fixed that is something you require to do that and while doing it you can fit maximum 15 mm ampere of the current that is your rating. So, that is an advantage because you are inherently protecting from the short-circuit condition.

Protection is a very big issue in the micro grid in DC micro grid because you do not have a problem you have a huge problem related to your short circuit because you do not have natural zero crossing and apart from that absence of the inductance that makes the system very fast and transients has a very detrimental effect on this DC microgrid. And in this method the three phase voltage and current of the converter is transforming to the rotating DQ frame once you are converting the AC to DC to fit into the DC microgrid.

This transform quantity is synchronized to the AC grid voltage by using a phase lock loop. So, you will generate the; you will convert into the AC to DC and DC will maintain the phase lock loop we shall discuss it here.

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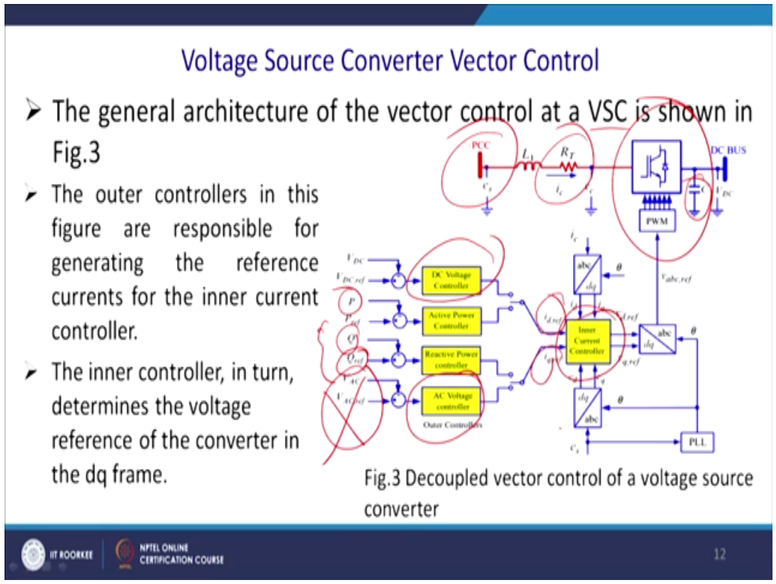

So, this is the point of common coupling and there is a little change here we rotate the; and we assume that there is a sufficient amount of the RT terminal resistance generate terminal resistance is neglected while writing the power flow equations there was no mention of the resistance. But in a micro gate I have told you please visit our I think lecture number 3 or 4 so we have discussed in detail what are the changes of the normal grid and the micro grid.

So, resistance plays a huge role in case of the microgrid and thus you have a PWM converter and the; you got a DC bus and it may be from the grid or it may be from the other AC sources for example the wind. So, the general architectures of the voltage control vector control of the voltage source converter. Now what happened if you have a problem of the DC bus then you will have our DC bus control.

You required to maintain the DC bus voltage generally and on 20% higher than the rectified voltage because you have a this is a bi-directional switch even if you we draw the pulses of the PW when you get some voltage here that will be the three-phase rectifier voltage 6 pulse voltage you will get three root 3M by PI. So, this kind of expression you will get. So, you have to take it above 20% by switching because essentially it sees a boost converter in it if you see through that side.

So, you require to maintain the voltage that is the V Ref is generally 20% higher and now you will once you maintain it is just like the synonymous will be there controlling the excitation of your synchronous generator. So, visualize is a static solution of your synchronous generator but it converts also AC to DC. So, you have a P; now next thing is that you are required to control the power because you will take this is the infinite source or sync your grid assume that.

So, you should not take a; you take that number one upon which is has been required by the load how it control it also. So, generally what happens so you have a this power reference you will be cal and we will compare it and accordingly you will actually generate and this will be fit to the PI controller and these two controller current will add up since this will be a DC quantity in a rotating frame and thus you get the ID reference.

Same way you will have a Q reference and the; because you may not allow to take the current and you really power factor you may be allowed to take the current in some power factor prescribed by you. So, you may be penalized for doing that and for the resistance you will have that issue also. So, moreover you may require a group control and that comes into the pictures once you have; see that it can switch over.

Generally you can have a; you cannot have IQ Ref to compensate both your sack ultimately this will come into the picture generally it does not come into the picture in a normal healthy condition. If you have a sacks and soil then only this comes into the picture that is a AC reference and PA controller ultimately this will effects your reactive component on the power. So, accordingly it will affect then you can also differently why we have a transient sacks and soil definitely this operation required to be off.

Similarly once you have maintaining a DC voltage fast that is your first task and then only you will go for the controlling the current and it may be time shared also time division multiplexing. So, this switch sometime will maintain the receivers voltage and then will sometime will help you to restore the reactive power and same way this also possible. And then you have got a inner current loop and that has to be very fast and that is operating near close to the switching frequency.

And thus what will happen you know so you got a peer, so you got a then you convert into the DQ to the ABC frame ultimately from the PLL you generate theta and that logic you fit to the PWM and again what theta you are getting you can de-convert it to the ABC to DQ and also you can compare what current you are getting and thus it will be a closed loop operation in that way this voltage source converter vector control is used just like in a induction machines microgrid control.

Ultimately there you from the encoder you sense the speed and from these positions from this and here you sense the theta. The inner controller in turn determines the voltage difference of the converter in the DQ frame so hope you have understood it.

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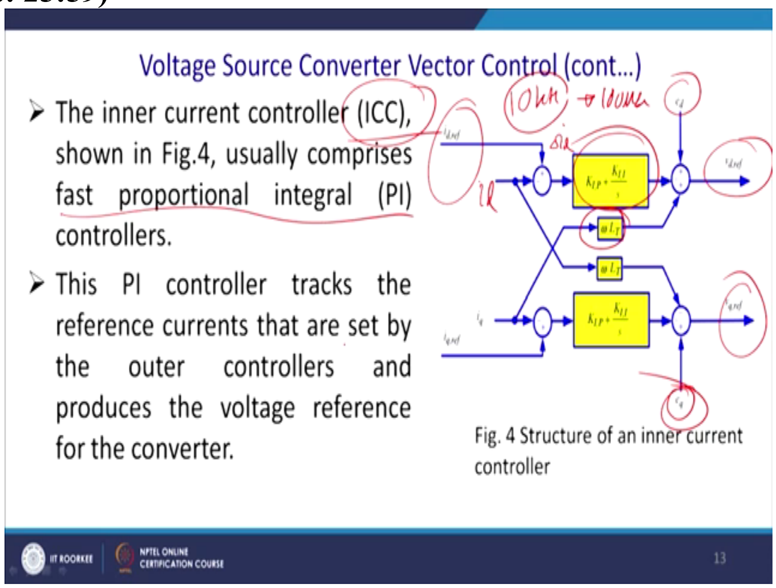

Now the inner current controller that is ICC shown in the figure here see that how does it work and it has a cross relations. So, you have ID reference and this is essentially is a voltages in DQ frame and ultimately you have to you have to compare with other voltages. So, what happened here you know this point is your ID and this is your ID ref and thus you get the Delta ID and that you feed it to the PI controller.

And same way the IQ has to be multiplied with this term is a cos term and the ultimately you will add up and he had to be subtracted and that will be your VD reference. Same way here IQ and it is I Ref you got IQ Ref you feed it to the PI controller and same way ID will be multiplied as a costume then subtract it with it and it over or it will be subtracted from the IQ and thus you get the we did it then you convert into the DQ to the ABC frame.

So, what we can say that this inner current control that is ICC in abbreviations is shown in the figure 4 here and usually comprises the first proportional PA controller its bandwidth has to be very high. So, it depends on the switching frequency say if you have a 10 kilo Hertz switching frequency that we need you will get a known 100 micro second. So, 100 micro second and we expect that within a 10 cycle so you will actually compensate an error.

Then your band will record to me one millisecond so that will be quite first controller. So, the PI controller tracks the reference current that is set by the outer controllers and produces the voltage difference for the converter.

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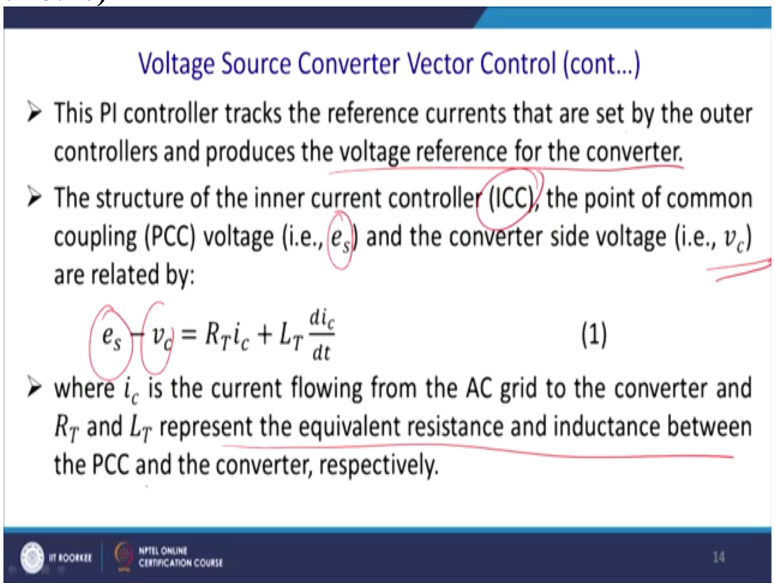

Now the PI controller tracks the reference current that is said by the outer controller and produce the voltage reference of the converter. So, the structures of the inner current controller of ICC at the point of common coupling that voltage we will represent in the ABC frame at S and in DQ frame please see that in DQ frame will be ED and EQ. And the converter voltage as VC, so we can replace this that is e s – V c equal to R l into i c + L t d i c for i c a current from the a AC grid to the converter and RT and the LT represents the equivalent resistance and the resistance and the inductance from the point of common coupling to the pole of the inverter.

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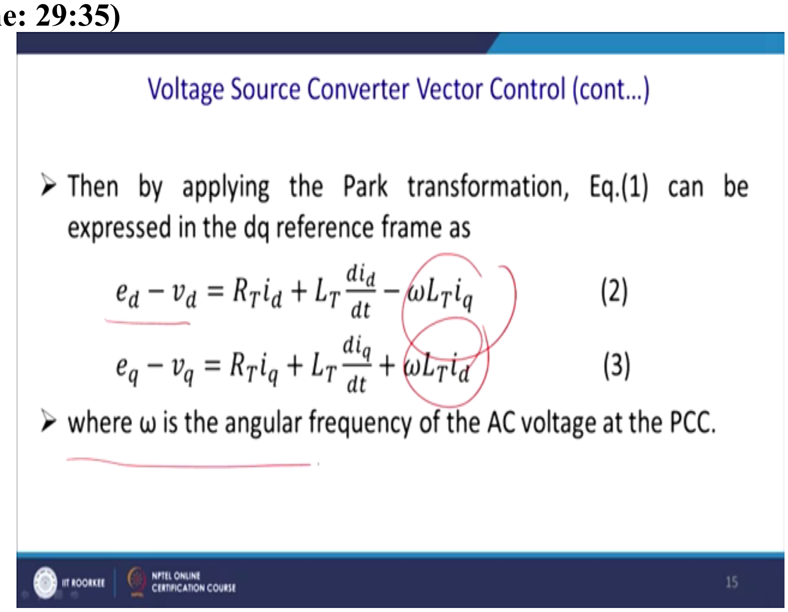

And thus we can rewrite this equation this is the cross term this is the cross term, please go back to this and this is has been multiplied with the Omega LT and this has multiplied the Omega LT. So, this is the value of the v d R td and from there we have these two equations.

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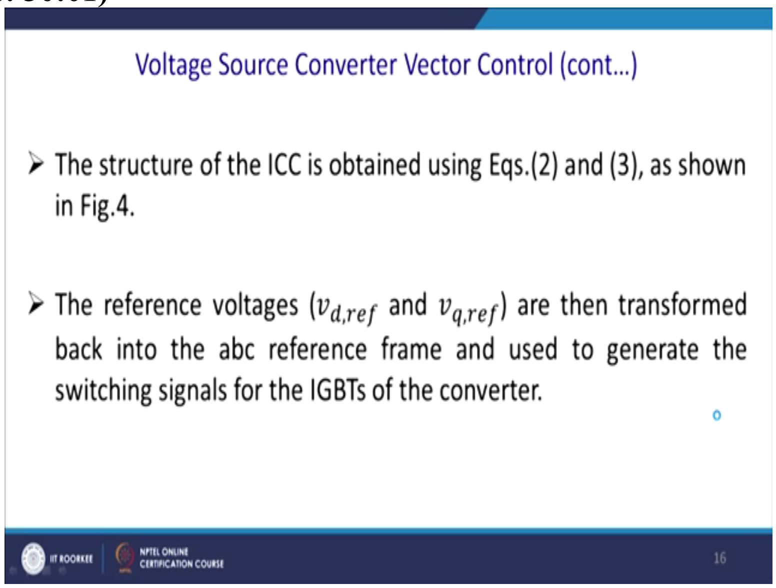

Now the voltage of the ICC is obtained as we have shown in the figure also in equation 2 and 3 and the reference voltage of v d and R l had been transformed and back into the ABC frame by the reverse transformation.

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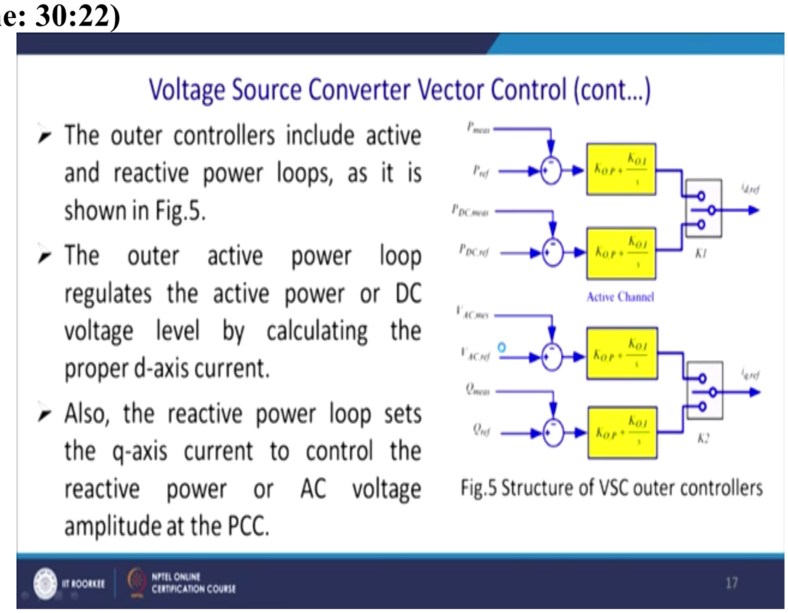

So, thereafter we require to talk about the voltage source converter control in detail and so that will take you in a next class thank you for your attention. I shall take that next class from this point that is the voltage source converter control and how it will control these voltages at this power and the AC mains problem that is drooping and also the reactive power control, thank you thank you for it.