DC Microgrid and Control System
Prof. Avik Bhattacharya
Department of Electrical Engineering
Indian Institute of Technology-Roorkee

Lecture-32
Control of DC Microgrid System (Continued)

Welcome to our video lectures on NPTEL on DC microgrid and the control system today we shall continue the previous lecture that was a control of the vector control of the voltage source converter. We have talked about the left out aspect of this DC to DC converter at first. So, that is the control of the power.

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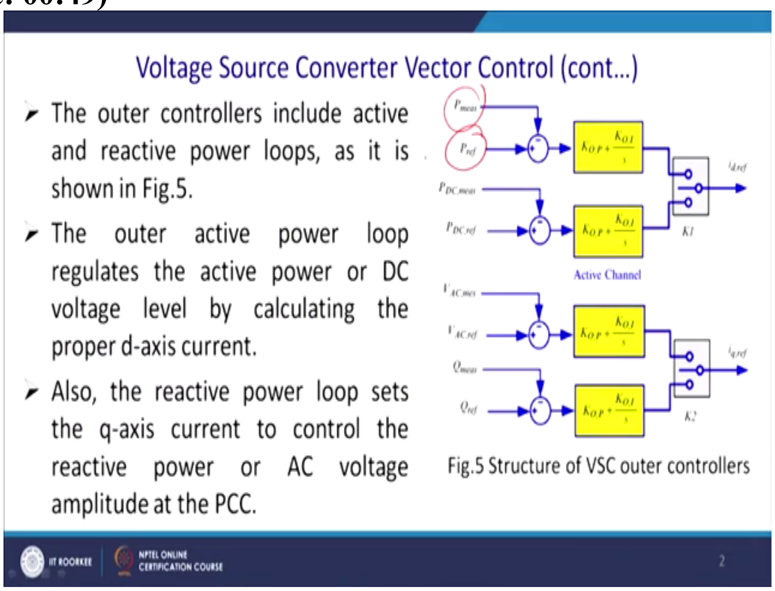

So, that ultimately you got a measured power you got a reference power and then and we required to feed the reference power and for this reason you control the PI controller and thus you got the ID Ref and voltage has to be fed. And here also you measure the DC power what do you require in the DC power in the load side and it may be it is not at all the unidirectional it may be bidirectional you can; if you have a power surplus in the microgrid you can feed back the power to the grid so you have to check it.

So, the DC measurement and fall also will come into the picture and this is called the; these two entities are wholly called the active power handling or the active channel. And ultimately you can switch over to this mode whether you are going into the DC power control or the grid power control. Generally it is islanding mode you go for it and in a grid connected mode you go for this power control. And thereafter you have you may have a sack or soil and that is, but you require to maintain the voltage into the rectify DC output voltage.

Because if you when you have a sack what essentially you will have your descending voltage will come down and you record to pump that the descending voltage and that will be your activity and then this PI controller comes and ultimately that will be boosted by the taking the extra reactive power. And also you cannot allow now in a you; it may be reverse operation also once you converting to Ac to AC we have a surplus of the power.

You have to inject a power as given by the grid court so you required to control the when your voltage is healthy generally then only you were allowed; then only you can afford to do that otherwise if you are; if your voltage is not healthy then of course you cannot control your reactive power flow. Because ultimately your investigations your investment will be to maintain the descending voltage and thus well while in case of the voltage disturbance in the AC side you cannot maintain the reactive power mostly.

But assuming that this is AC and you can control the reactive power flow from the AC side. So, the outer control include active and the reactive power loop as shown in the figure 5 please recall that it is when we I am following the same notations of my previous class for this is in this fingers become 5, previous figure was 4 in my previous class. The outer active power loop regulates the active power or the DC voltage level by calculating the proper d axis or the real axis current by the PI controller.

And also the reactive power loop sets as the q axis currents to control the reactive power of the AC voltage amplitude at the point of PCC.

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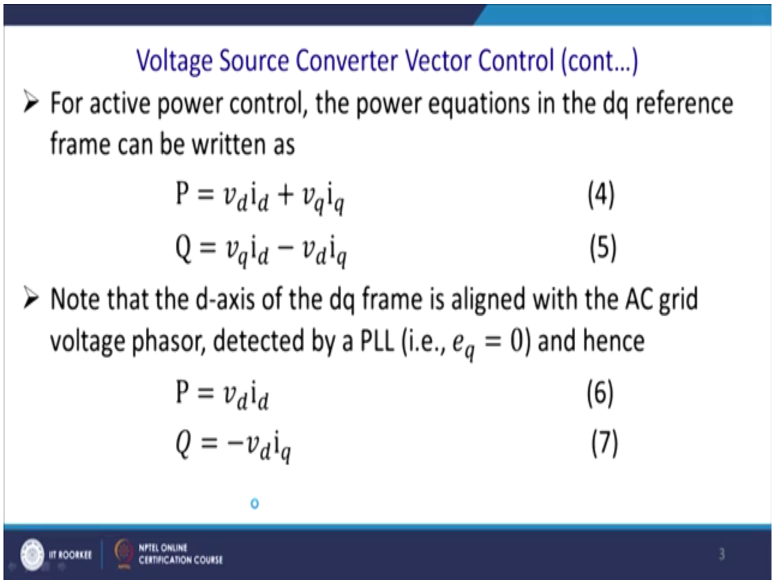

Now essentially these are the expressions of the real and the reactive power. The active power control equations and the reactive power equation in the DQ frame has been written. So, you will have a v d i d + v q i q are the real power and similarly you have the reactive power that is the cross term v q i d – v d i q and note that this d axis is aligned with any of the phase for example FS so we can say that if in case of you are feeding essentially if you are feeding a unity power factor sometimes we prefer to do that.

Then e q will be 0 and thus what happened your survival term will be essentially because if e q is 0 then we Q will be 0 your v d into i d and the Q will be – v q into i q, v d into i q sorry.

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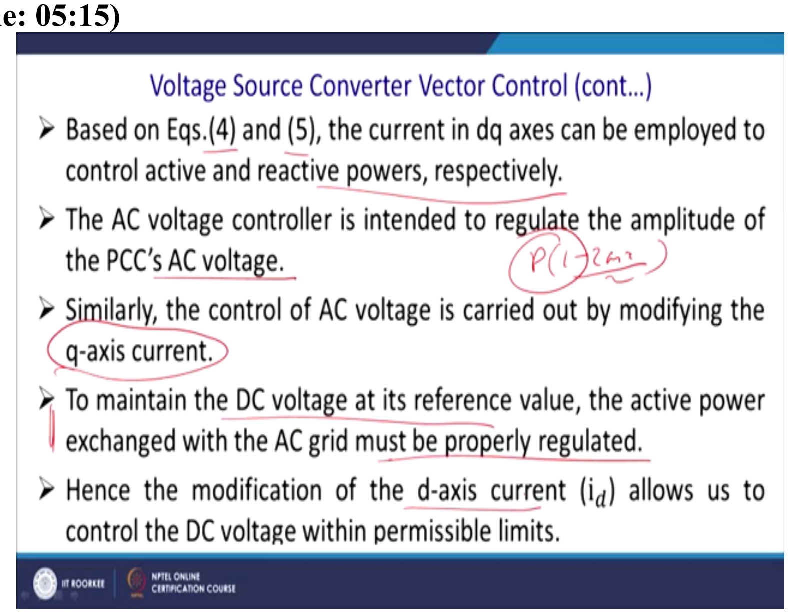

So, based on this assumption that is why unity power factor operation please mind that otherwise e q will be present in terms of the d q and based on this 4 & 5 the current in the d axis can be employed to control the active and the reactive power respectively. So, you can see that only the current is sufficient to control. The voltage controller is intended to regulate the amplitude of the amplitude of the voltage at the PCC so that is something once you have a voltage disturbance axis x and y well that comes into the picture.

Similarly control of the AC voltage carried out by modifying the q axis current. So, if you terminate a load with the capacitor your voltage terminal voltage in slower as simple as that and thus you require to change that q axis current. So, sagging or soiling can be controlled by controlling the q axis current. But in normal healthy condition this is not touched. To maintain the DC bus voltage and the at its reference value the active power exchanged when this a secret might be properly regulated.

And please understand we have discussed classes because there are two issues because power comes with the 2cos Omega T by 2 so there will be a average power and within that there double frequency oscillation. But over a period of time this average value becomes 0. But problem lies instantaneously that power required to be fed because you know if you are feeding a resistive load then a power then when voltage and current both are at its peak positive or negative peak whatever maybe.

Then you are consuming maximum amount of the power what is 0 crossing voltage and current both then also then what do you have any never least power. So, average power will be something but you are firing this power. And for this reason exchange of this power properly required to be regulated. So, that ripple in the DC will be that if something is a very important aspect of the microgrid control.

Hence the modifications of the d axis current ID allow us to control the voltage within the permissible limits.

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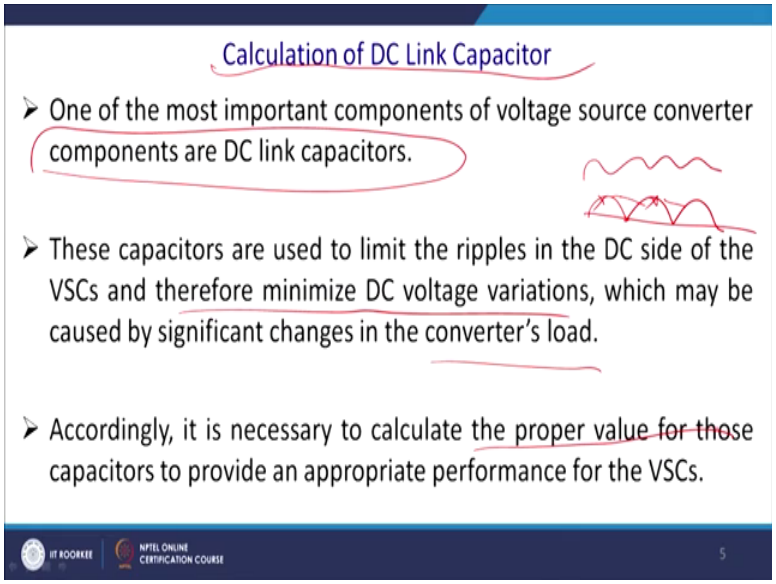

One of the most important components of the voltage source now we shall go by calculations of those entities. How you calculate the value of the capacitor value of the inductor and of course the rating of the switches this also comes into the picture. So, one of the most important component of the voltage source converter is that the DC link capacitor. And how will calculate the value of the capacitor. This capacitor used to limit the ripples as I told you and this is site of the voltage source converter and therefore minimizes the DC voltage variation.

Which can be cause significant changes of the converter load because why there is a receivable? So, since it is a three-phase you have this kind of the receivable 6 pulse and this would have a very big problem in case of a; that means rectifier you know that for a single-phase you have of this kind of FM. Ultimately at this point of time you do not transmit any power when voltage and current both are 0.

And here voltage and current at is peak and it is a negative peak you serve the maximum amount of power and to balance it you have the capacitor. Since in a 3-phase system so you have a less ripple because it does not cross the 0 crossing. Another phase comes into the pictures and thus what happened to balance to smooth out this capacitor you require to put the more smooth out sorry the smooth out this voltage simple would equal to put the capacitor.

Accordingly it is necessary to calculate the proper value so we now we come into the necessity of the requirement of the capacitor. Another issue is that how can you; how you calculate that what actually its value would be; the proper value of this capacitors and so that it can operate beautifully it can operate as you desire.

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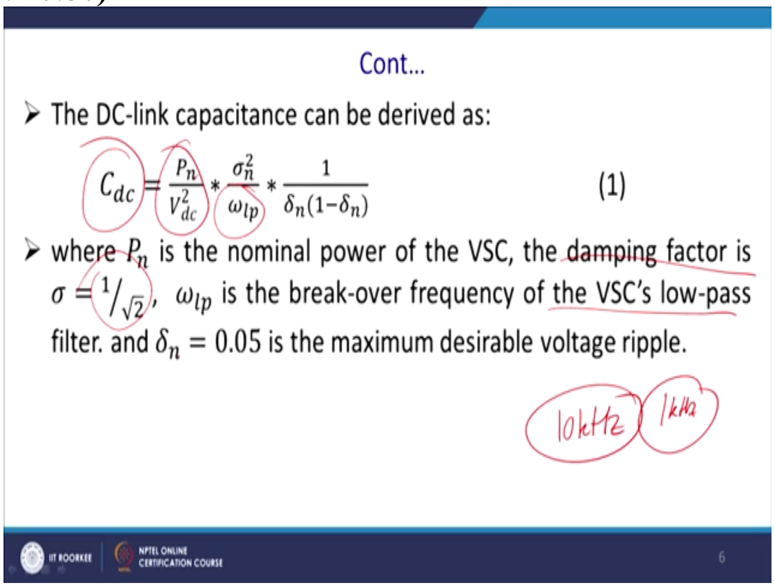

Now the DC link capacitor can be calculated by the following expressions that is C dc there is a value of the capacitor. Essentially it will be given by the power handling capability of the converter. If it is a 10 kilowatt can water rating of this power is 10 kilo watt. Then this what is the voltage level you are intend to maintain. Say if you are three phase through a system we are rectifying it voltage 600 volt, 440 volt line and so you are maintaining little bit of higher maybe you are maintaining at a 750 volt.

So that voltage will come and the Sigma and Omega l p are the term that is the break over frequency of the VSC of the low-pass filters. Once you design it generally we set this value around 10 to 20 times of less than the switching frequency. If you are switching the converter at; please understand this is not the frequency 50 Hertz or 60 Hertz it is a high frequency operation. So, it is the; we have a PI controller and that has its cut-off frequency.

That cut-off frequency we require to consider and generally if you are switching at 10 kilohertz this converter it is better to keep this kind of frequency around 1 kilo Hertz or 500 Hertz. And generally there is a damping factor, so damping factor is 1 by root 2 and this Delta n is the maximum desirable ripple. So, what is the amount of the ripple you can consider if it is 2% then this value will be 0.02 it is a 5% this will be the .05 and so on accordingly size will increase or decrease. So, this is expressions of the capacitor that you require.

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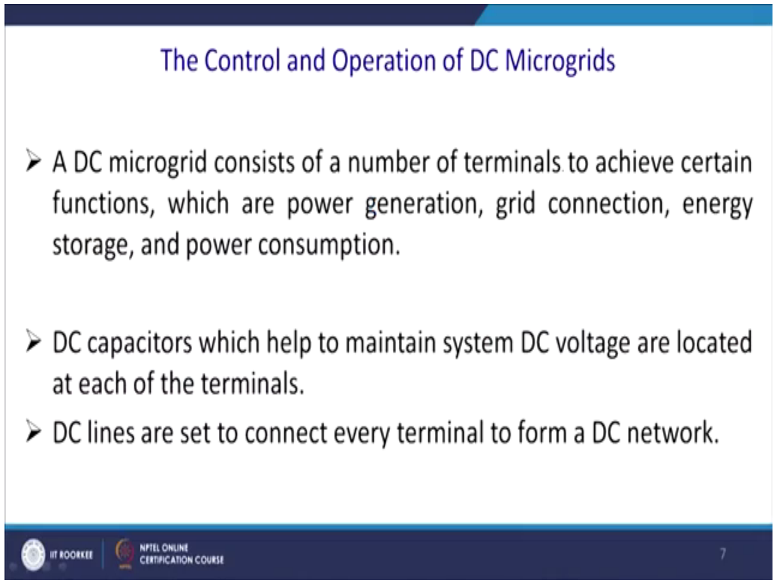

DC microgrid consists of number of terminal to achieve the certain functions which are power generations, grid connections, energy storage and the power consumption. See these are the few entities that we required to consider. The DC capacitors which help to maintain the system voltage are located at each of the terminals. So, that is something we require to keep in mind that the DC capacitor which maintains the DC bus voltage are located at each of the terminal. The DC lines are said to connect every terminal to form the DC network

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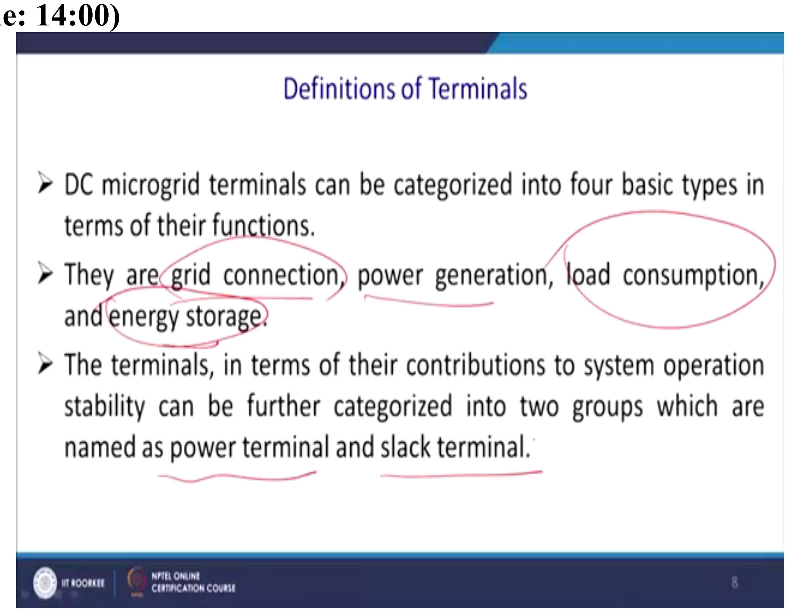

DC microgrid terminal can we categorize into the 4 basic types in terms of their functions, their grid connections, power generation, load consumptions and the energy storage. So, once you are converting; this is a bi-directional DC converter a DC-AC converter or AC-DC converter that is a grid connection. Power generation it can be solar, load consumption you may have a loads point that is not bidirectional or by direction and also the energy storage mostly battery.

So, these are the 4 terminal you will be having and thereafter the terminals in terms of the contributions the system operation stability can be further categorize into the 2 groups which are named as a power terminal like this radiation is taken from the power flow model in the you know a power system that is not a slack bus and you got a voltage bus and all those things. And the similar term will be there that is the power terminal and the slack terminal where the voltage is fixed.

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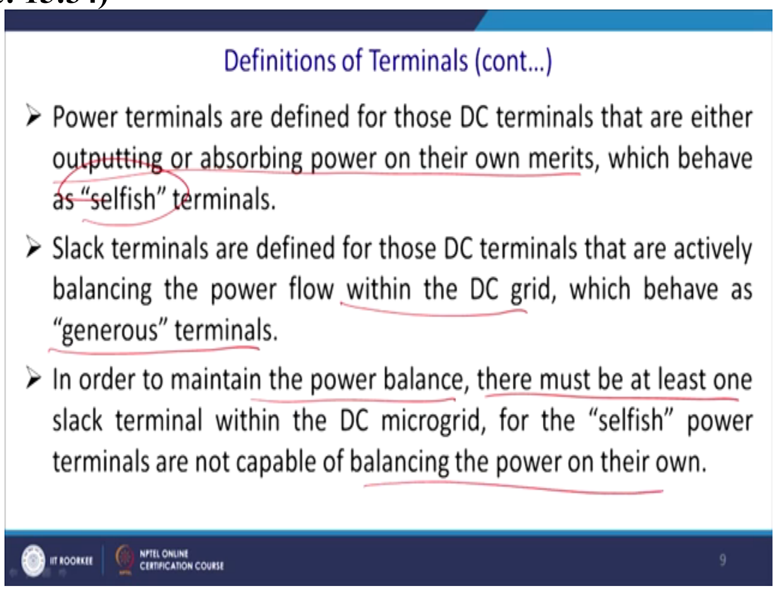

The terminals are defined for the those micro wave terminal that are either outputting or absorbing the power into their own merits which behave as a selfish terminals the slag terminals are defined as a those DC terminals are actively balancing the power flow in the microgrid these are the reference points which behaves as a generalist terminal. So, this is the difference between the power terminals and the slack terminal. Slack terminal will mainly control the DC microgrid voltages.

In order to maintain the power balance there must be at least one slack terminal like you have a slack bus and analysis which within the microgrid for the selfish or terminals are not capable for capable of balancing the power of their own.

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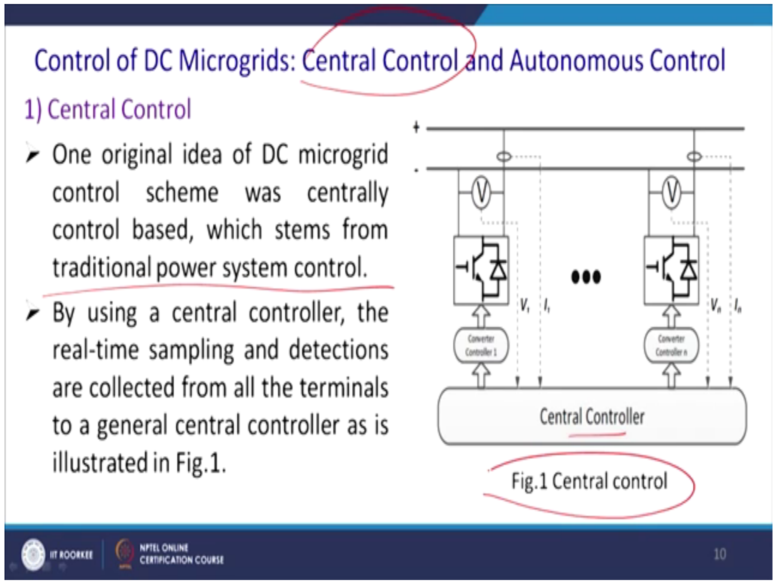

Now let us see that this is the control of the microgrid and we may have as we have seen in case of the IC microgrid also you have a central control and the autonomous control this is a central control everything will be put into the; under central control all the converters. And thus we require a very fast communication challenge and the central controller is a pretty much overloading also. So, original idea of the DC microgrid scheme was central control which stems from the traditional power system control.

You have a master controller room from there you try to control the SKADA all your power system equipments. So, that is something was thought process while initiation of the DC microgrid why as there are many limitations. Using a central control the real-time sampling and detection are collected from the all the time in and all the data to be fetched and to be processed an instruction required to send back to the individual converter.

And thus you require a very fast communication channel very fast processes. But those are not a challenge nowadays but still it will have a network block bottlenecking and as well as faster action we will be revert back because you please understand that unlike DC Microgrid, unlike AC microgrid, DC microgrid has to be very fast in operation. Because transients are very severe in nature so detection, so if the fault has occurred.

Let us say and voltage is increasing in case of the AC microgrid or in case of the; then there is a problem if voltage itself is decreasing and fault has occurred. So, you automatically your current comes down. So, you have a good time to react till it goes to the peak and thus by that time you should be able to react but that kind of that kind of aspects unnaturally does not exist in case of the AC microgrid DC microgrid.

And for this reason we require to have a very fast channel of communications the sampling and the detection or control found all, the terminal to the general central controller as illustrated in this figure. So, this is the one converter they can have in one over two converter you can fetch voltage and current from the each of the converter and you process it check it and send the instruction everything has to be done by the central control.

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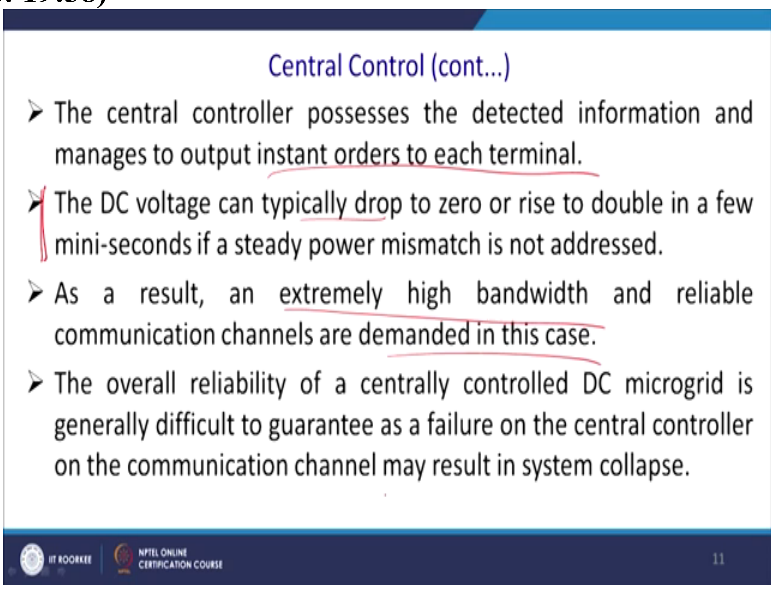

Now central control processes the; processes and detect the information's and manage the output instead in order to the each terminal so there we are time delay system. Because what you get it you process it you send it back that will be a time delay system. So, that is one of the aspect that researchers can think of this is a particular example of the microgrid DC microgrid to the central control is a time delay system.

The voltage can typically drop to 0 or rise to the double in few millisecond in steady state mismatched if it is not addressed this is a severity. So, we have to keep in mind that it has to act very fast because in absence of the inductance, inductance does not work because it does not have a frequency. And transient so will be very fast in case of the DC. As a result extremely high bandwidth and reliable communication channels are demanded in this case that is what I was narrating.

And overall reliability of the central control DC microgrid is generally difficult to guarantee as a failure on the central controller on the communication channel by results in the total collapse. So, if some portion of the microgrid is not fitting a write data then you may collapsed the whole data if some so you require to isolate the grid very fast unlike the AC microgrid otherwise hold both system voltage may collapse.

So, that is a few challenges of the centralized control and what this is looking for the autonomous control.

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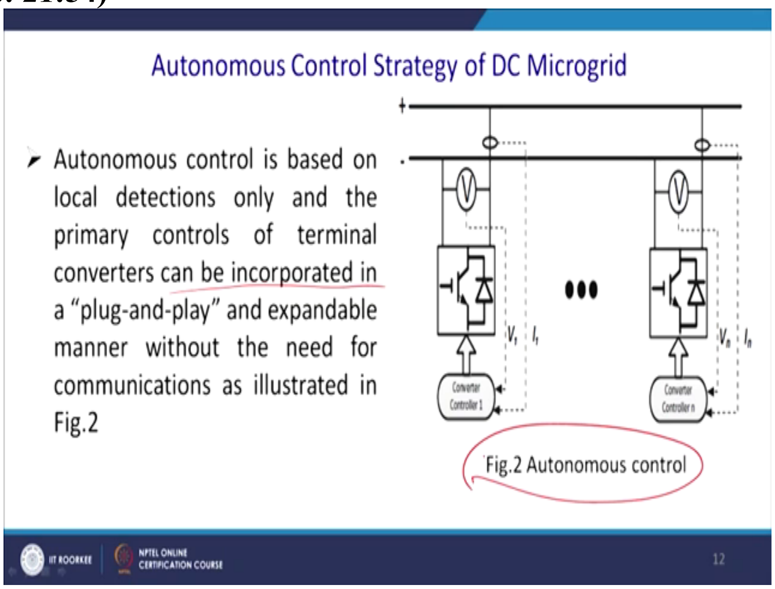

So, what happened here each bus is connect each microgrids connected to each bus and each individually try to maintain the DC bus voltage depending on the slack terminal or the power terminal. So, slack time when I will try to maintain the voltage and the port terminal and you understand that this slack terminal important nutrient are interchangeable whose; like solar maybe at the 12 noon is another maximum capability so that can be a slacked terminal.

And similarly in a waning when actually solar goes out ultimately you have to dependent on the grid and grid is also at this peak value and a peak price. So, there may be the battery storage will be the slack terminal. And at night maybe a when your create, is cheap then your active rectifier will be the slack terminal other will be there follower power terminal. So, accordingly it will change so thus autonomous control is based on the local detection and the primary control of the terminal converter can be incorporated in the plug and play that is one of the user-friendly features.

You can add or disconnect any controller as we wish an expandable manner without the need of the communications as illustrated in the figure.

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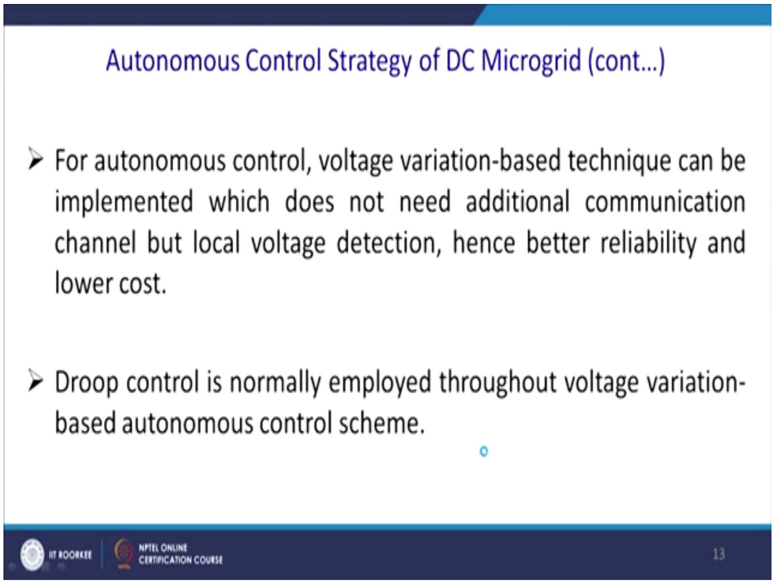

So, let us discuss the autonomous strategy for autonomous control voltage variation best technique can be implemented which does not needs additional communication channel but local voltage detection hence better reliability and the costs. Droop control is normally employed through the employed throughout the voltage variation based autonomous control scheme. So, that is something we required to also keep in mind that group control is normally employed throughout the voltage variation based on the autonomous control scheme and that is also find it is lot of advantage and attendances.

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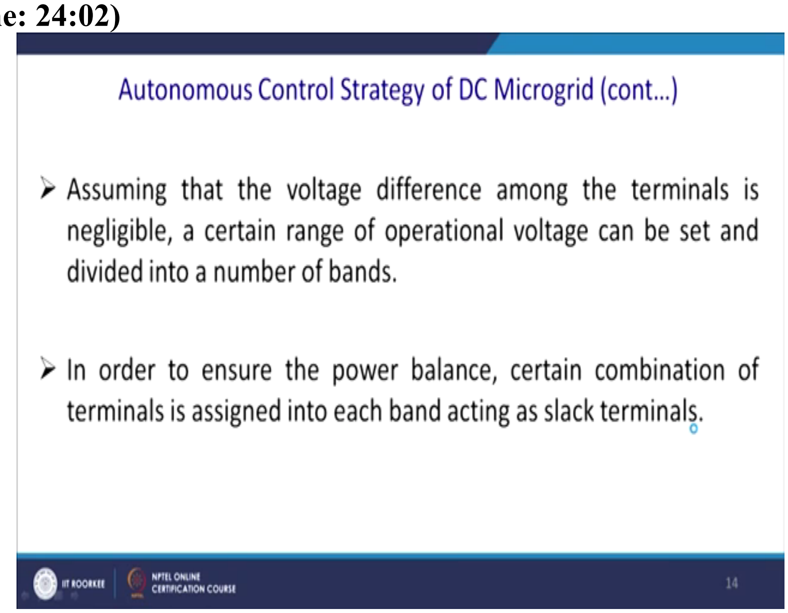

Assuming that the voltage difference among these terminals is negligible because it is a DC bus and it is a very minor very small resistance and certain range of operation of the voltage can be set and divided into the number of bands. In order to ensure the power balance certain combinations of the terminal is assigned to the each band acting as a slack terminal. So, that is something we required to also operation in such a way that in order to ensure the power balance certain combination of a terminal is resentment.

So that is what happened let us a solar is healthy and grid is less price. When you make solar and the grid as your slack point and other required to follow. So, battery may charge or discharge depending on the requirement. But after some time when great price increases in evening so maybe you want to plenty of wind then wind and the battery will take out and that will be the slack bus and others required to synchronize.

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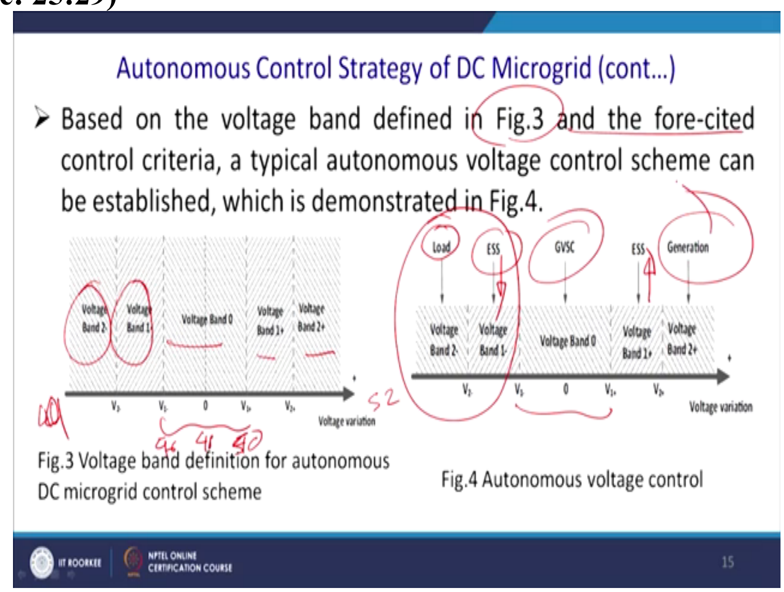

So, for this reason we see that based on the voltage band definition in figure 3 and the therefore the fore-cited control criteria in the typical autonomous voltage control schemes can be established and which is demonstrated in this figure. So, there is a voltage band -1 voltage when -1 voltage when 0 voltage when +1 voltage when +2. So, there will be a different kind of voltage band. It may be actually; let us say 42 – 52 volt and you may have or you may have a very narrow voltage band.

And this is maybe your; this voltage is 48 volt this may be 50 and this may be your 46 and this make it 44. So, this is the range and so generally what happened these things happen generally when solar is not there. So, the ESS and a load that has to be fed into that combinations. So, you are you know what is voltage band then you require to control the voltage. Then second is that you are in a negative voltage band one.

Then ultimately task of the power balance it will be delivered to the mainly the storage element. Thereafter in this zone generally there is a little bit of small voltage difference generally grid set converter will come into the picture depending on the price of the grid. Same thing generally here it will feed power ESS and in positive band it will take out power. And if you go to this voltage band +2 then you have to cartel the generation.

Cartel generations mean you have to ultimately you just referred back here. If you have feeding power to the grid then you try to increase the power from the grid and this is the mode of operation or with other that means to follow. So, that is the autonomous voltage control.

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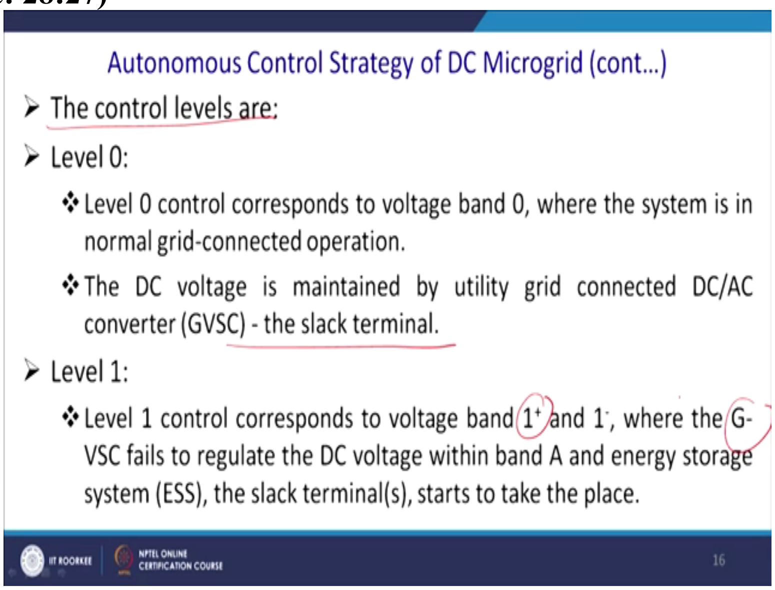

And thus let us explain it very fast. The control levels are level 0 the level 0 correspond to the 0 voltage band where the system is in the normal grid connections and it is a very close to this required voltage level. The DC volt was for is maintained by the utility grid by the Ac to DC converter or DC to AC converter and this becomes the slack terminal and level one when you have energy surplus generally it controls the corresponding voltage in +1 band or -1 where the grid fails to regulate the DC bus within the band A and the energy-storage ESS the slack bus starts takes taking the responsibility of maintaining the DC bus.

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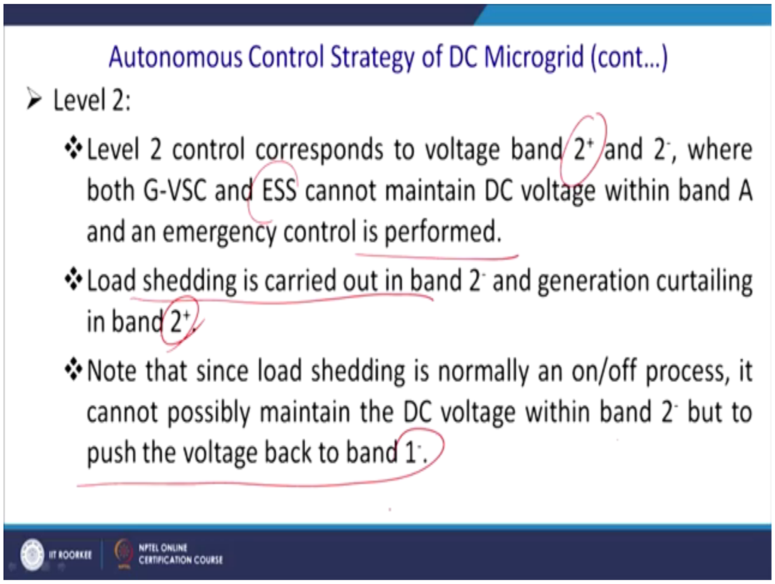

Similarly the level two corresponds to the voltage band +2 and the -2 where the grid site convertor and the ESS cannot maintain the DC bus voltage within a band A and an emergency control is performed that when you measure down the load in -2 the non-critical load required to be shut it down. So, the leading load shedding is carried out in band 2 and generation curtailment in band 2 class.

So, wind has twin pitch has to be control something like that note that same load shedding is normally is on and off process that is also something will occur to keep in mind. It cannot possibly maintain the DC voltage within a band but it pushes the band back to the -1 and then your previous control technique comes. Thank you for your attention we shall discuss with our DC microgrid control system in our next class.