DC Microgrid and Control System

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Lecture-35
Stability Analysis of DC Microgrid

Welcome to lectures on the DC microgrid the control today we are going to discuss the very important topic is the stability analysis of AC microgrid. So, in recent years in order to week all discussed we have discussed in detail the necessity of the DC microgrid. And for this reason control of the DC microgrid is an ultimate necessary at the stability problem of it how we will solve real going to analysis by this lectures.

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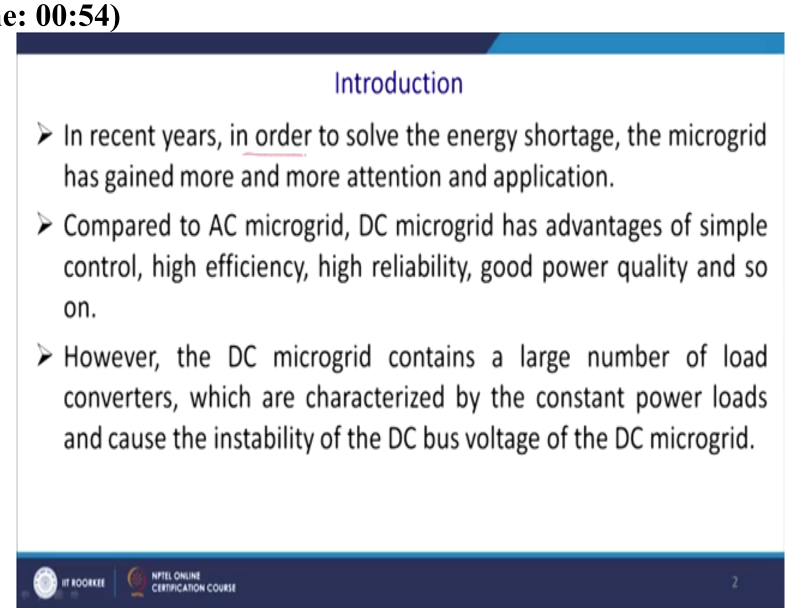

So, in recent years in order to solve the energy storage the microgrid has gained more and more attention and applications. We have seen the difference is advantage of conventional grid and now with the high penetration of the renewable energies we casually moving towards microgrid. Compared to the AC microgrid the DC microgrid has several advantages. DC microgrid are the advantage of simple control because it has only the; does not have a different voltage and frequency like real power imaginary power.

So, you require only to control the voltage and thus control is simple and it is highly efficient because absence of the reacting component of the power you know KVA rating of the coil is same as a resistibility and for this is not it is highly efficient. And also when it is transmit the high frequency power at 50 years and increase feeding adjustable loads and all those entities. Then the supply may have 5th 7th 11th 13th another harmonic.

And due to the skin effect effective cross sectional area get reduced and ultimately you will have a higher resistive loses. And since absence of the frequency makes the system frequency make this frequency high. Highly reliable we ensure the reliability mostly by bipolar connections. And since are there are no power quality issues so there is no problem of the power quality in DC microgrid you do not have a problem of the THD.

You do not have problem the power factor there are missing for in this case good power quality and this highly reliable. However DC microgrid contains large number of load converter. So, you have different load required different level of power supply. And thus you know we can plan accordingly but we are leaving in age of the transition. See most of the systems are AC for this is DC load are not been properly standardized that is one of the greatest challenge.

If you have standardised also the DC load then this issue can be negative a large extent but from the today's perspective we will have a large number of the load convertor for 1 may 5. For example you know laptop charger takes 18 volt. Your mobile charger takes 5 volt. So, why cannot we have only single entity where laptop charger rather than mobile charger can be used and that is what happened which are the characterised for the cost and power load that is one of the features of the modern devices.

These are mostly the cost and power load that is call CPLD in Abbreviation. And since voltage is one of the major problem is having a CPLD in the system that if voltage drops that will track more amount of current and it will take the system towards the instability. And thus what happened cost of; large number of cost and power load cause the instability of the DC bus of the microgrid.

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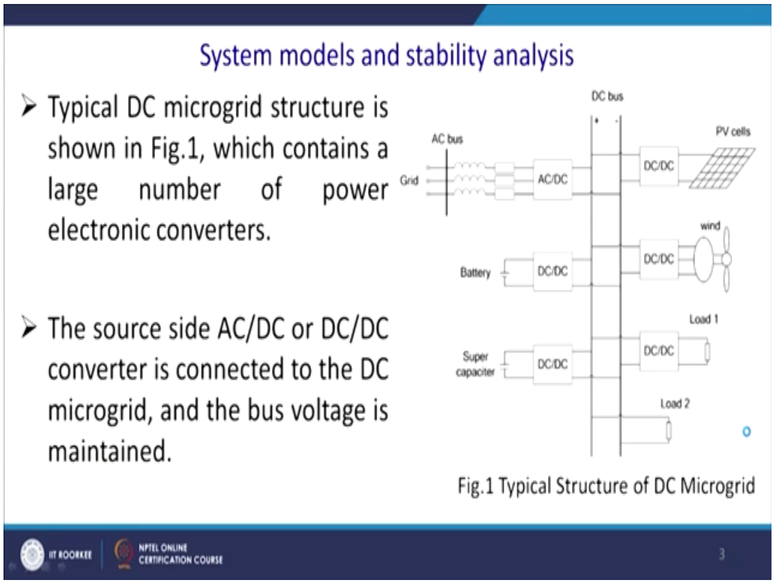

So, let us take a typical microgrid which has been shown in the figure. A typical DC microgrid structures is shown in the figure 1 which contains large number of power electronics converter. You have a grid you have an active rectifier mostly we see at the higher voltage site. You have a bidirectional DC to DC converter it depends but battery mostly is around 48 volt and your bus voltage may be close to that or little different or may be some other voltage.

You have a very first charging and discharging ultra-capacitor the super-capacitor. And there might be a load that can be correct; can be directly connected to the DC bus voltage 48 volt. And there might be DC - DC converter that because this supply is bus voltage and the load require different kind of supply is a wind. Again we have a rectifier followed by a bus topology DC to DC converter that will fit.

And since it is boosting for MPPT so then you required to have another DC to DC converter to balance the voltage level of the DC bus. Same way for the solar, you have a solar DC to DC converter ultimately you will track the maximum power point. And you know please understand that maximum power point tracking is challenging. Many of you have studied the maximum power theorem in your early days of your B.Tech.

So, you know when source impedance is equal to the load impedance then only you will able to transmit the maximum power so that is the criteria. For this reason you required to manage the impedance so that the source impedance equal to the besides impedance and that maximum power will be transmitted from this PV cells or the wind to the bus voltages.

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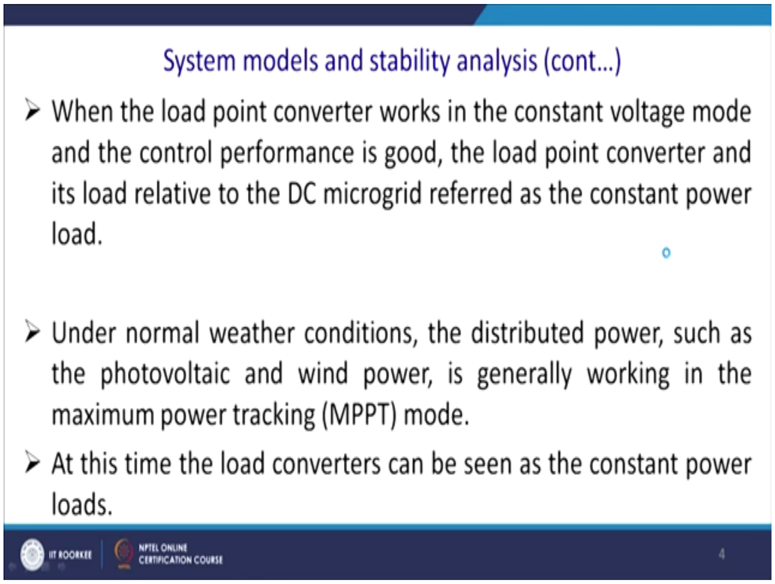

So, when the load point converter works in a cost and voltage mode and the control performance is good the load point converter and the load is relative to the DC microgrid referred as a costant power load or in appreciation been sometimes say CPL and if it is a device then it is CPLD constant power load device. Under normal weather condition when solar is healthy and you have a plenty of wind may be the distributed power such as the photovoltaic and the wind power is energy works at the point of maximum power point.

So, it has to track the maximum power so it can harvest maximum power from the sources. At which time load converter can be seen as a constant power load that is something also be required to understand. So since it is transfer impedance matching and all those things so that can be seen as a constant power source.

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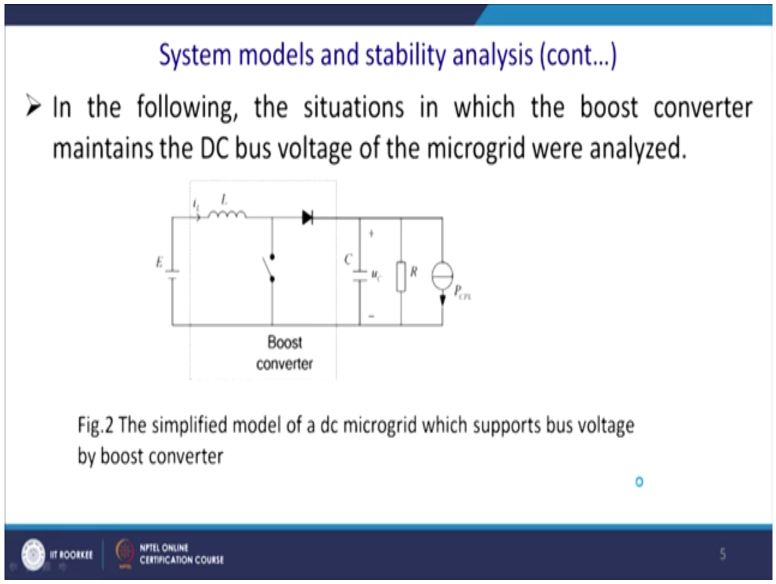

Now let us have a system model and we may have a boost topology in case of the mostly tracking solar MPPT and it in this case where it is replaced by your E it can be the solar panel. And thus what happened in the following situation energy boost converter maintenance the DC bus voltage of the microgrid we required to analyse it. And we have a constant power load let us see.

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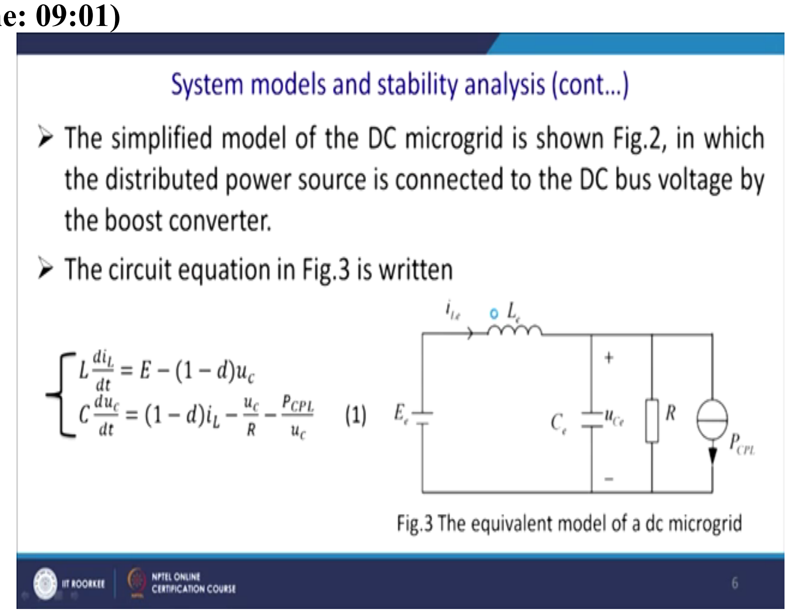

So, what happened we know that actual it has a two switchs when switch is closed and when switch is open and this topology are simplified DC microgrid is shown in the figure 2 with distributed power source is connected to the DC bus voltage by the boost converter. And the circuit equation is shown in the figure 3. And this is the equivalent circuit model of the DC microgrid when switch is off that means this switch is off and it does not when this voltage and this voltage same generally this switch is off and you transmit the power and losses across the conductance is zero.

And thus if you say that switch is off and duration is d and when you are circulated that value will be 1 - d for this when switch is off this equation is written L d i L d t equal to E - 1 - d into U c, U c where is the voltage across capacitor. Similarly the this will be C du c dt or C du c dt equal to 1 – d into i L – u c by R + since this point voltage is U c as system 1 cent here so the current drawing why this cost and power load will be power of the CPLD by the voltage of U c.

So, ultimately the current drawn entity will be totally depending on this a voltage of this boost rectifier.

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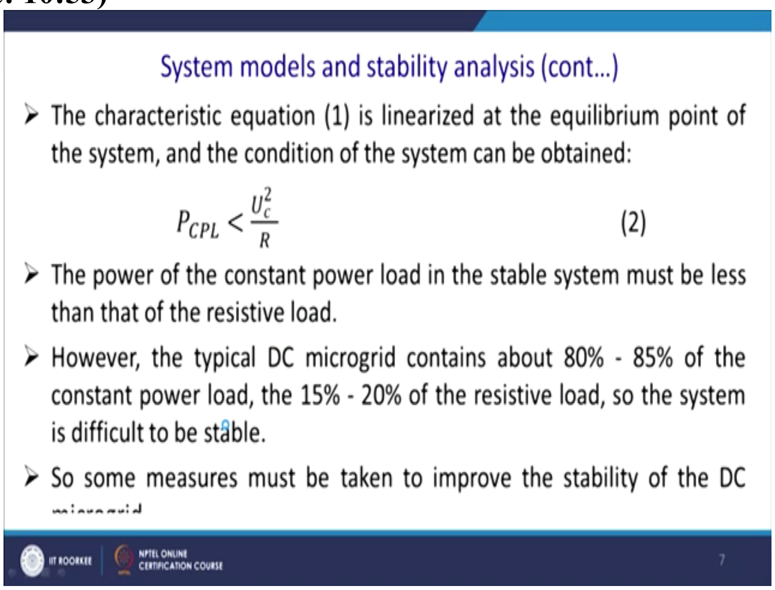

And please understand there is a challenge. Please refer back this characteristics equation one that is this is linearised to make equilibrium point of the system and the condition of the system can be obtained you know that the load that is constant power load should be more than U square by R see that what is R? So, this is your R. So, this is you R. So this is the power dissipation across the resister normal resister.

So, what happened power of; so the power of the constant power load is stable system but must be less than that of the resistive load then only it will work fine. However in a typical DC microgrid contains about; this is a one of the challenge that 80 to 85% of the constant power load you have a huge constant power load ultimately all your SMPS in your laptops, desktop are constant power load then only 20% to 15% that is heating load are resistive.

So, that it will face a lot of challenge in the stability. So, for this reason we required to take some measures to ensure the stability of the microgrid.

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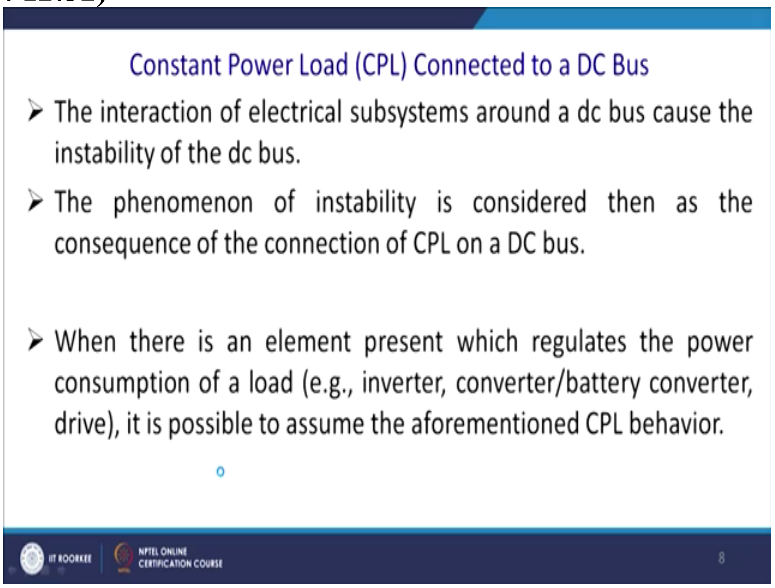

The interaction of the electrical systems around the DC bus causes the instability in the DC bus that is also one of the observed phenomena. So, electrical substance its Impedance Matching how it will work this also forms a localisation problem. And the phenomenon of instability is considered then as the consequence of the condition of the constant power load in a DC bus. When there is element present which regulate the power consumption of the load?

For example you are inverter your converter battery etcetera. It is possible to ensure you have this load aforementioned load having constant power load behaviour. And also behave like a constant power load and for this reason in a microgrid CPLD constitute 80% of the loading.

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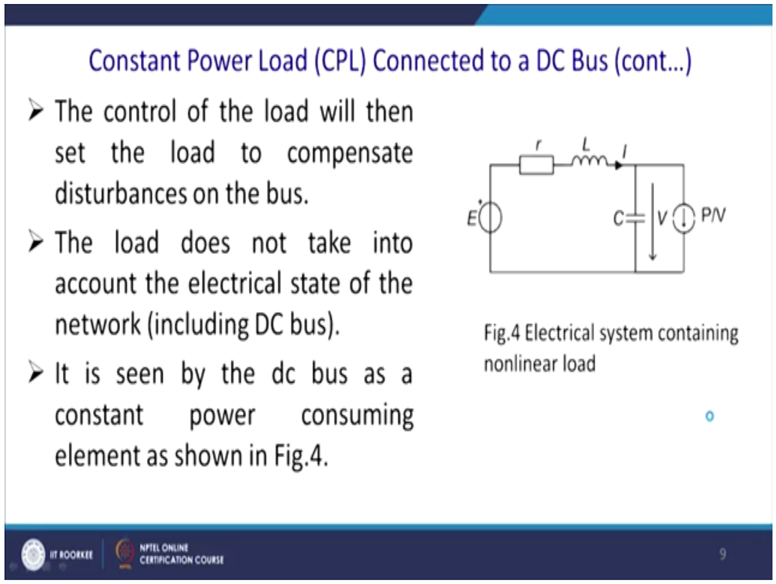

So, what happened then when you connect a CPL or D the device connected to the DC bus then we required to understand that the control of the lot when will be the control of the load will then set the load to compensate the disturbance of the bus. When there is a voltage drop since CPLD takes a constant amount of power then it will take more amount of the current from the system and that it will put on the voltage level further.

So that is a one of the greatest challenge in the CPLD. On the other hand only a worth full load and you have little bit of; or you got a DC bus voltage and you want by bring it to come down the voltage level. Since it is you CPLD and your voltage level is high and current will be drawn less and thus it will further push up the voltage. So, in the language you can write like this load does not take into account the electrical state of the network including the DC bus.

It is seen by DC bus constant and power consuming element as shown in the figure. So, it is just P by V P is constant. So, this is the electrical system that containing non linear load.

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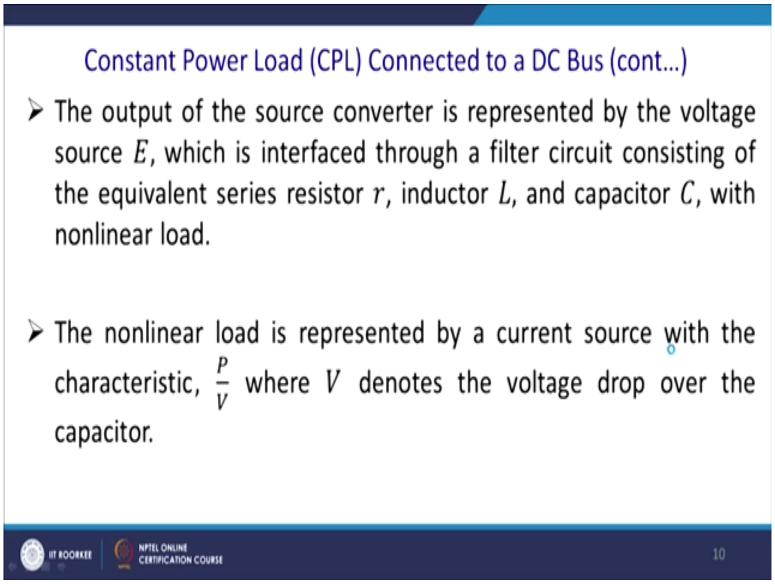

And output of the source converter is represented by the voltage source is here please refer back the figure this output of the source converter is considered as a voltage source it is E which interface with the filter circuit mostly you have high frequency ripples of the switching and you got to eliminate those ripples consisting of the equivalent series resistance and inductor and capacitor with a nonlinear load.

In non linear load is presented by the current source and having a characteristics P by V, while V denotes the voltage drop over the capacitor. So this is the voltage across the capacitor.

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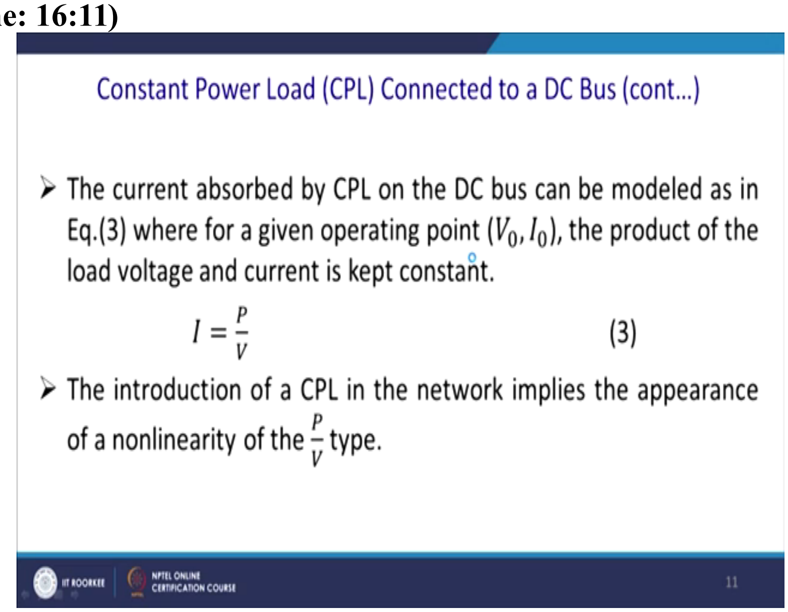

And the current observed by this constant power load on the DC bus can be modelled as shown in equation 3 that is P by V were for a given character; for a given operating point this is I 0, output of the voltage and the current are kept constant. The introduction of the constant power load in the network implies that appearance of the non linearity of this PV type. So, it is not V square R kind of load. It is P by V kind of load if voltage increases current will increases and if voltage decreases the current will increase.

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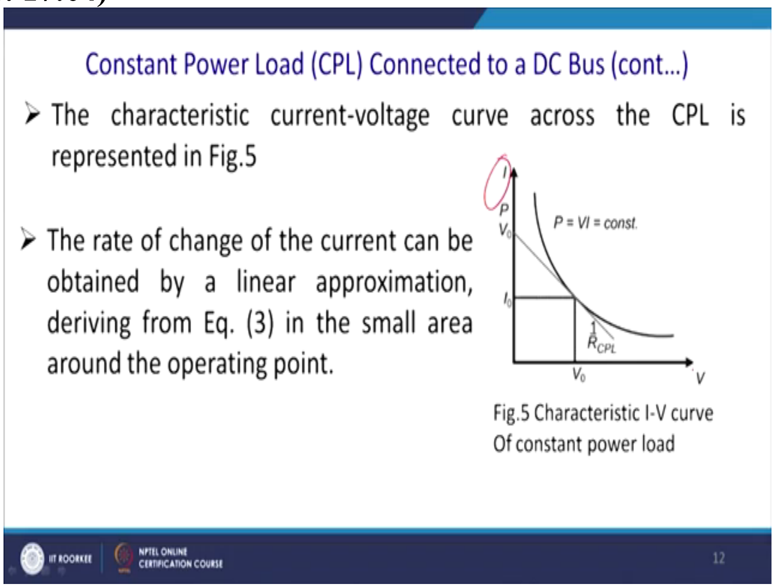

And thus this is a characteristics of and it will be a rectangular hyperbola and this is the operating point that is the I 0 is a maximum current and the V 0 will be the optimal current, optimal voltage and you are supposed to operate here if you go here you will have a; that is a problem here also because you are more voltage less current and here if you go you have less voltage more current. And operating here it will be detrimental because you are not operating at this point you have shifted to this point and it will cause huge amount of instability.

The rate of change of the current can be obtained by the linear approximation of this equation 3. Please go back to this equation and a small area around the operating point let us say this neighbourhood. And here you are supposed to operate the CPLD.

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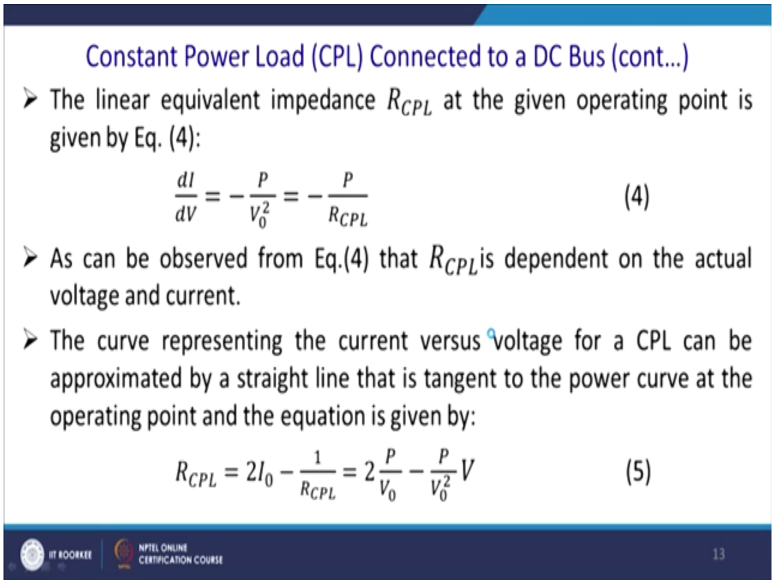

The linearity equivalent of this resistance of the CPLD are given operating point of this equation 4 so just you have this curve and thus you get a derivative of it. Once you derivate it will be you get V square and you can replace this thing by V 2 by R and thus you get P by R CPL while R CPL is it may be observed from the equation 4 that R CPL depend on the actual voltage and current. So, it will be a changing depending on the voltages and currents and this is your curve.

So this point we have a different tangent this is different tangent essential this gives dy dt characteristics. This curve represents the current measure voltage for CPL and can be proximate by the straight line and it is tangent to the power curve the operating point and equation can be given as represented by constant power load resistant is 2l 0 – i by R CPL is 2 PV P by V 0 – P by V 2 into V this will be overall equation of the resistance.

Since the power is constant ultimately this resistance depends on the output voltage of this DC bus voltage.

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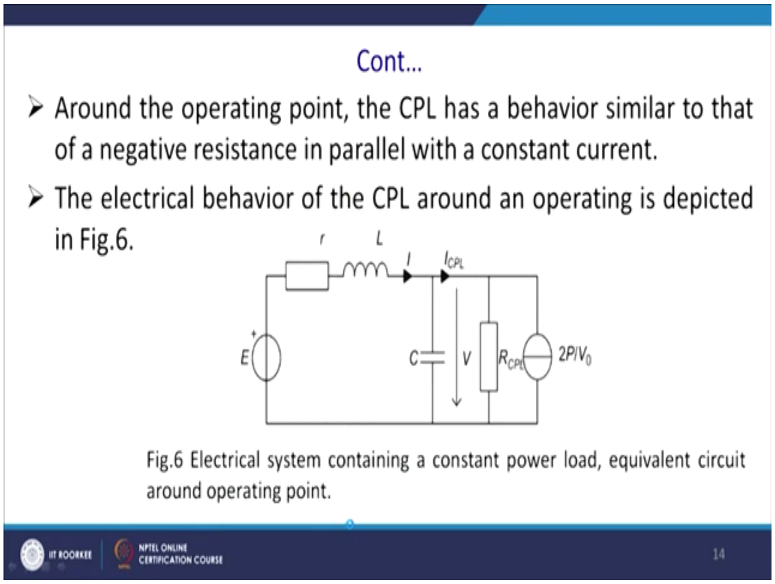

And now let us come into operating point issues. That is the operating point of the CPL has the behaviour similar to that of the negative resistance in parallel with the constant current and that has been shown here. So electrical behaviour of the CPL amount operating around and operation point or operating point is depicted in the figure 6 this E you have a filters. And ultimately this is the; to balance out of instantaneous power balance you have a capacitor not only filtering.

Because sometimes if the load may take little bit more power or less power so that something transient has to be fit this capacitor. So, you got you can module this has 2P by V plus this resistance.

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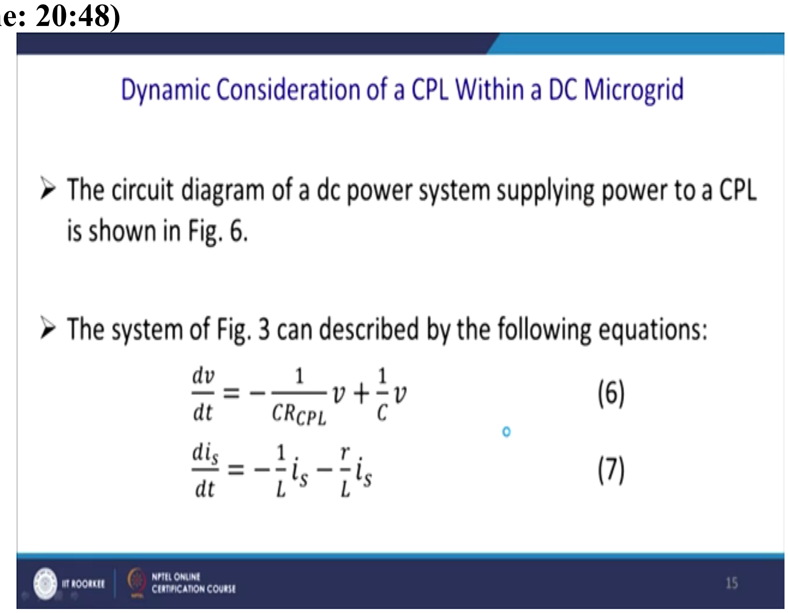

And thus the circuit diagram of this figure 6 which is shown in the figure 6 can be represented as the dv dt equal to - 1 by CR CPL V + 1 by CV and di dt equal to - 1 by L S - r by L S.

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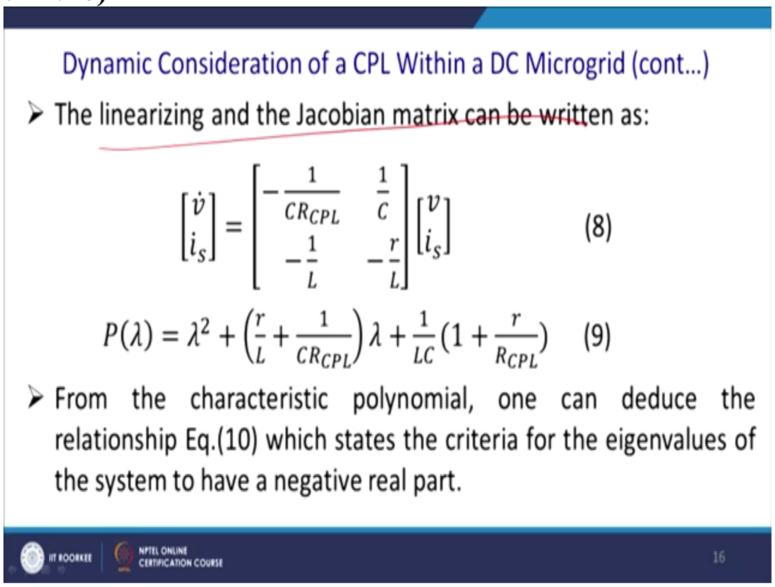

So, linearising the Jacobian we can rewrite this equation in a state space form and ultimately V i and I i will be have a this resistance which you have mentioned here and capacitor by inductor and other. And let us form the polynomial and you have a study over your eigenvalues. And thus you have this eigenvalues. So, from this characteristic polynomial we can reduce the relationship in a next equation 10 which state the criteria of the eigenvalues of the system for the negative real part.

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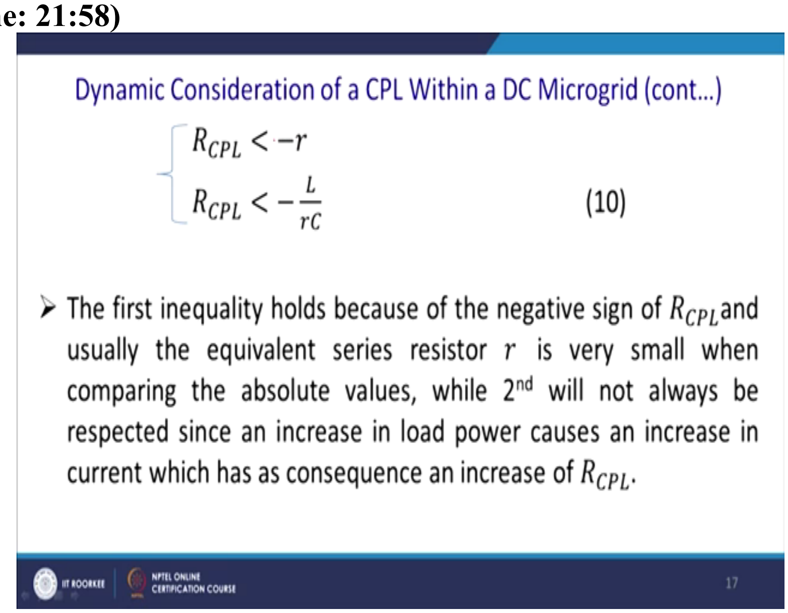

Thus from this condition we can get this is essentially nothing but your maximum power transfer theorem you get this calculation so R CPL equal to - R and this one this should be less than - L by RC and that is what we can say if the first inequality holds because the negative sign of the of this because you do you know that it is a negative resistance region. So, this R CPL and usually equivalent resistance R is very small when compared to the absolute values.

While second will not always be respected since increasing the load power causes the increase in the current which has a consequence or increasing the; if the value of the; this RCL.

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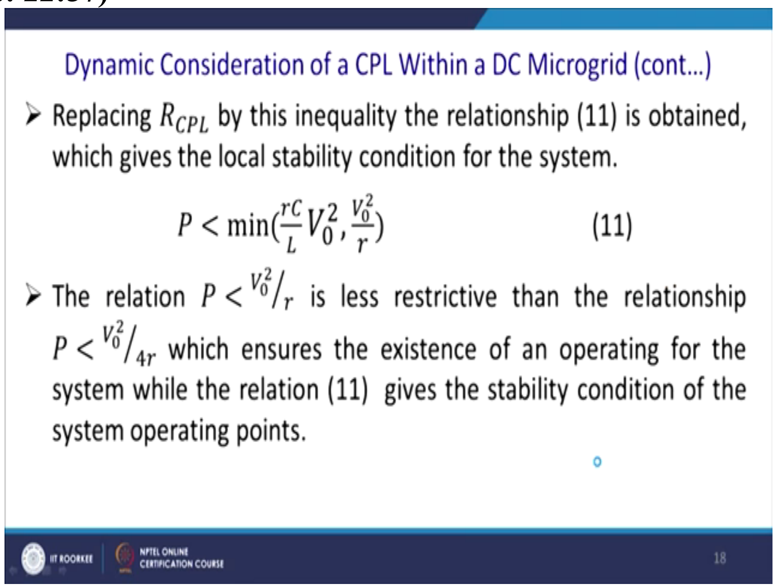

Thus by replacing this R CPL by inequality relations which have shown in the equation Number 11 is obtained. And which gives you the local condition of the power stability and that is what happened that P should be minimum of rC by L V square V square by R this should be the power and equity square important thing that is very simple the relation P is less than V square by r is a resistor is less restrictive than the relationship that have a; you got it in case of the maximum power transfer theorem please remember that is your power should be less than your V 2 by 4r.

And which ensures the existence of an operating point of the system when the relation 11 give the stability conditions of the operating point this is the stability conditional operator point so you have to operate within this ratio.

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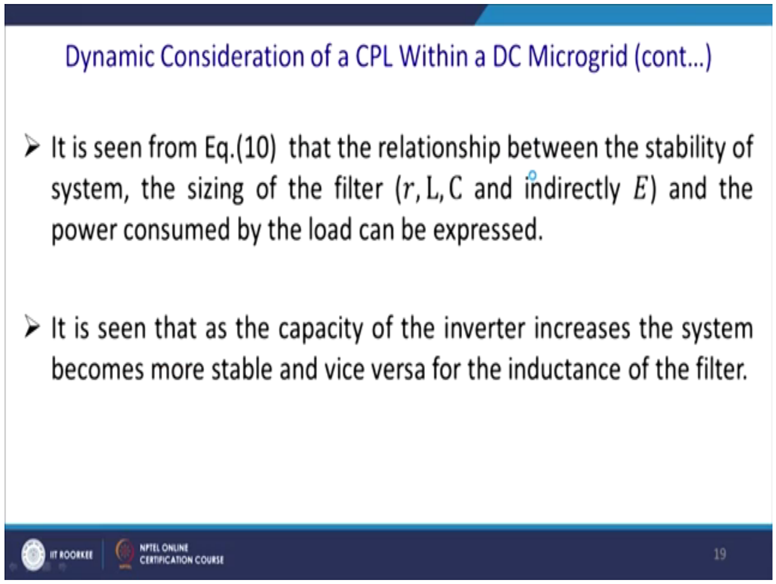

So, while going to this analysis what we can say that this equations 11 is quite important and it quite to be satisfied while you are designing CPLD. Now as we can see that the dynamic condition of the CPLD with the microgrid. So, it can be seen in the equation 10, this is your equation 10 and this is your constant you have put that is R CPL should be less than –r and R CPL should be less than L by rC. So, these are the two constraint you have to put it into this condition for deriving stability.

So, it is seen from the equation 10 that the relation between the relationship between the stability of the system and the sizing and the sizing of the filters the r L C and also the source voltage of the converter. And the power consumed by the local load can be expressed. So, what load this CPLD will deliver ultimately all have a say on it and to transfer this maximum power you want definitely want to be; system has to be stable as well as your efficiency should be high.

So, all those parameter has to be designed properly then all this parameter has a huge say. And that is it has been seen that the capacity of the inverter generally this inverter comes into the picture for the active rectifier. If you are taking power form the grid or you are sending back to the power to the grit when it is in an inverter mode increases the system and becomes more stable and vice versa for the inductance of the filter.

You can make it also converter for DC to DC conversion in applied both for the AC microgrid. So, what happened it can be seen that this is a criteria where maximum power required to be transfer and stability because this is the criteria of maximum power transfer. And please see these two equation and compare and see that it is it is it is there already. And thus we can conclude that while the limitation puts by this equation.

While this eigenvalue as the real negative so all those put into the consideration we can design a proper value of the systems and in that we can calculate the proper parameter. And with high CPLD in DC microgrid we should be able to control and appropriately work as per the requirement in case of the transient as well as the stability as a large. So, this is something quite important aspect little deviation from the normal grid because of the less resistive load.

If you have a resistive load it is itself has leeway voltage decreases then you will consume less amount of power though but current also get reduced ultimately you overcome this problem easily. On the other hand once your voltage is more than you are going to increase your current and as you are going to consume amount of power and you will have to bring down this mismatch.

But here the CPLD worsened and for this is reason stability study quite important and we required to, map that properly. Thank you thank you for attention we shall carry or discussion on the stability of the microgrid in our next class.