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

Lecture-37
Microgrid Stabilization Strategies
(Passive Damping Method)

Welcome to our NPTL lectures on the same microgrid and the control. We shall continue to do our discussions on DC microgrid simulation strategies. We shall today see that the passive damping method and in subsequent classes we shall discuss about the active damping method. Now as we have seen in previous lectures there are so many power electronics converters and their impedance matching is an issue.

And thus from there we required to do a lot of fuelling. So, for this reason power electronics converter at the; we have already told it several time that a power electronics converter at the basic building wall of this microgrid and especially this renewable energy based DC microgrids.

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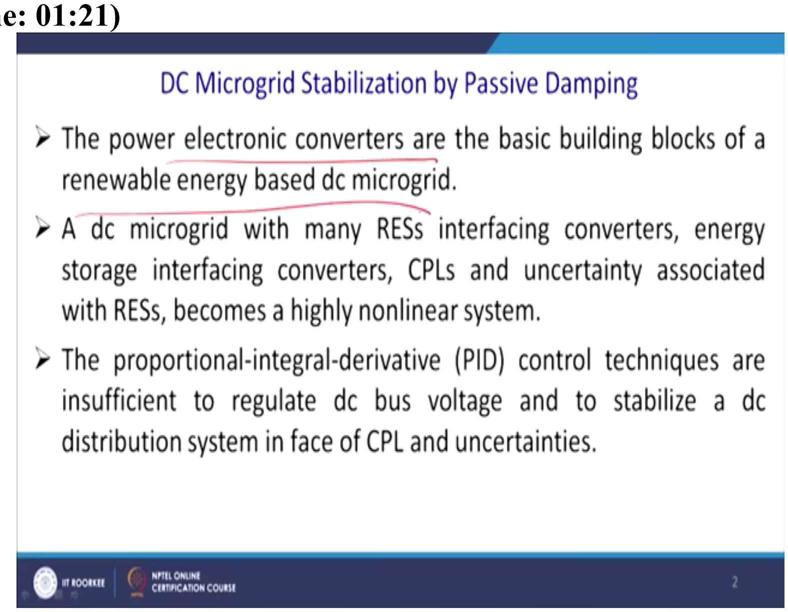

This DC microgrids mainly this energy resources that consisting of the renewable energy and the storage element interfacing with the converters and the energy storage interfacing with the converter and the constant power loads and the uncertainty associated with this energy resources because of the varying natures of these renewable energies. And this system becomes highly nonlinear. All of a sudden load may change that was a problem in case of the typical power system.

Now you have a problem with a battery is voltage balancing. You have a problem with variable irradiation and the temperatures and the wind of the solar. So, these are many parameters which has to be catered in to the microgrid and thus system becomes highly nonlinear. And of course we can rightly denote the average model once we because you have a power electronics converters and you have a one switching state and another switching state and based on that we can write it down that average one.

And when you have an average model then you imply it a linear control technique and that will means most preferred solution will be the PID controller. So, the proportional integral derivative controller techniques are generally applied while considering the linear model are insufficient to regulate the DC bus voltage because system is highly nonlinear and when you make it average model PID controller does not gives you satisfactory results.

The DC bus voltage to stabilize the DC distribution systems in interface with the constant power load and the uncertainties, so we required to, design the controller taking all those non-linearity into the account.

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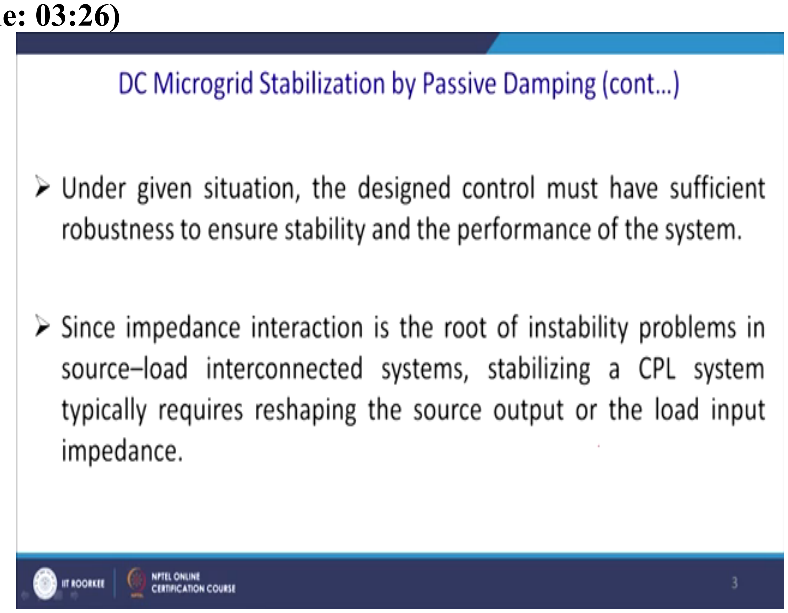

And thus under this situation the design control must have sufficient robustness. Robustness means this system is very much stout in the any change of this one state to the another state, so state change will not affect its positions of the stability that is called a robustness and robustness to ensure the stability and the performance of the system. Since impedance interaction is the root of the instability problem.

So that is a change of impedance because you are tracking the MPPT your voltage changes current changes and thus there is a change of MPPT and sometimes your load changes. So, thus the impedance interaction is the root cause of the instability problem in source-source interconnected system and stabilizing a constant power load because once voltage dips its current increases so it is quite nasty kind of entity.

So, CPL system typically requires a reshaping of the source output or the load-out input impedance so that you can control the flow of current into the system.

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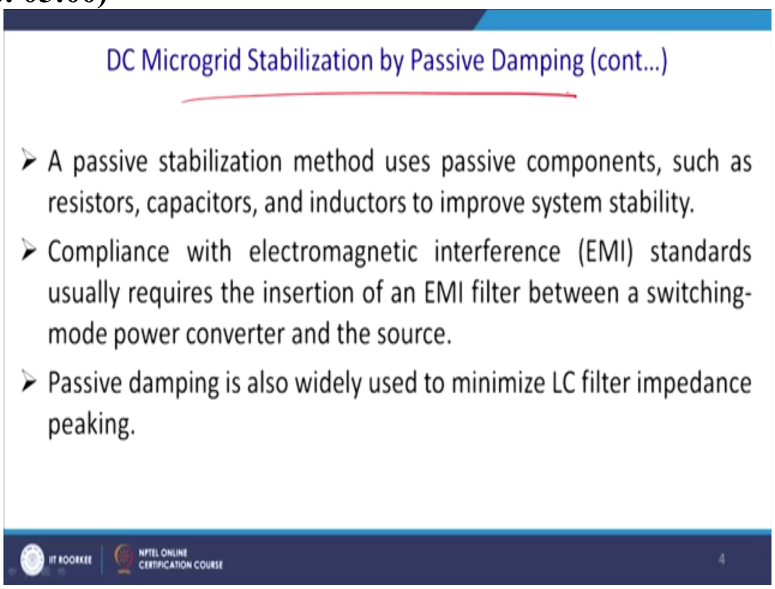

To ensure this you know we can go for that stabilization by the passive damping but of course it is a less efficient system let us see how it has been done. As passive stabilization method uses a passive component such as resistors, capacitors, inductor to improve the stability mostly required to damp out the oscillation. You require to make the system very we have to visualize the system as a second-order system by the reduced order model.

And thereafter you with the effect of the dominant pole you try to design to specify the oscillation by that by the proper damping. Compliance with the electromagnetic interference standard because there is a challenge you know once you are having this kind of issues so generally once your sustained oscillation then generally you have a huge problem of EMIMC. And what happened generally once you suppress one entity generally you will find that you have aggravated another entity.

So, you have to keep into the mind and while you are damping that it may increase your electromagnetic interference standard. Because what happen you know when a wave gets reflected when that will be the cause of the EMI what a wave electrical will be reflected when there is a mismatch between the impedance. So, for this reason this will you will find that more mismatch into the; once you are putting a passive damping you may introduce a little more mismatch into the impedance and thus it may aggravate the cause of the EMI.

But you have to keep in mind I tell you have to find it out the optimal solution and you have to see the standard of the EMI so that you can have a little flexibility here or not. This EMI standard usually required the insertion of an EMI filter between the switching power converter and its use. Generally you have different rate that itself is a big chapter telling you have a conducted emission and that will have a common mode noise as well as the and the radiated emission.

Generally conducted emission can be reduced by the EMI filter there is a XX filter that is for the common mode and therefore the differential mode is called XY and that filter will try to reduce your conducted emission. And also you will have a problem with a radiated emission that required to be addressed by lower dv dt and low di dt. So, passive damping is also widely used to minimize the LC filter impedance peaking.

So, that is something can be done you know so once you have introduced so a proper damping in a second-order system. Your peak overshoot will decrease and all those issues will pop in and thus proper designing of the LC filter will reduce the picking.

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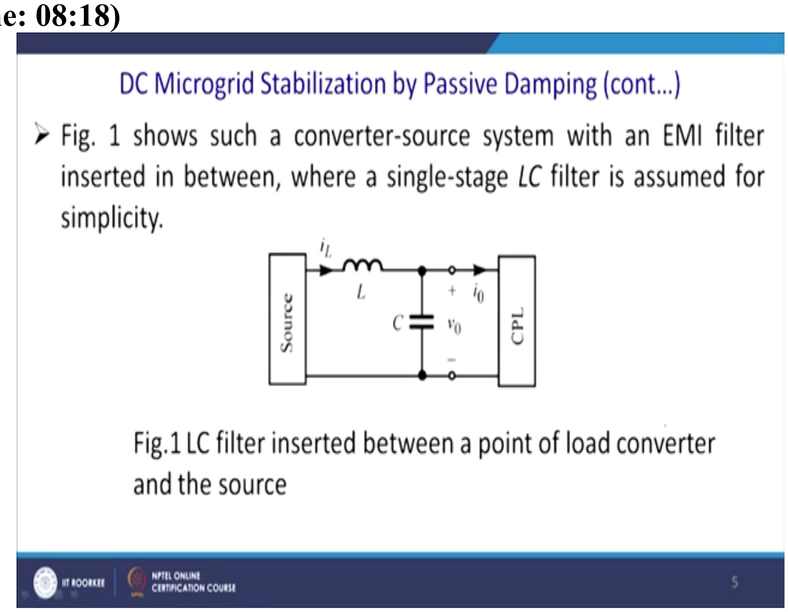

So, let us consider this figure one and it shows a convertor source system with an EMI inserted between where a single stage LC filter is assumed for the simplicity. Now you have a source you have a CPL. Now what happened this is the filter and since it is assumed that there is no resistance here. So, any step change or any change will have a sustained oscillation into the system. A thus we require to provide the proper damping.

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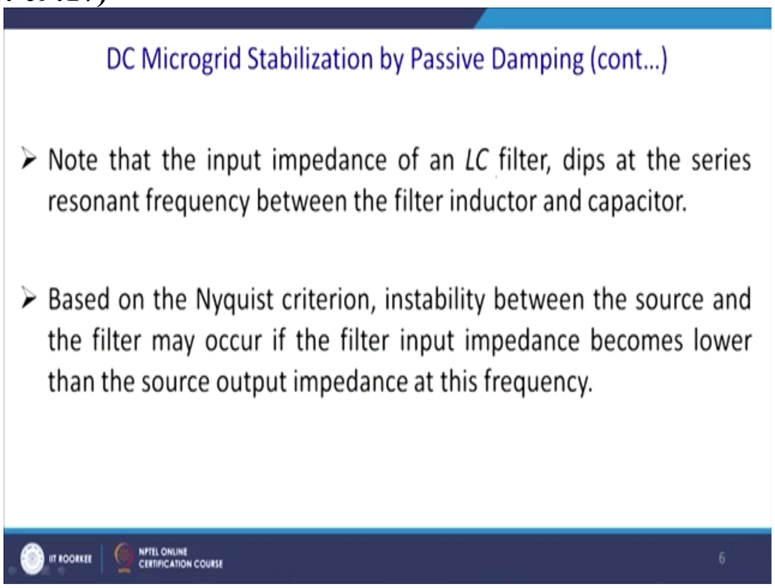

So, what; so please note that the input impedance of the LC filter dips at the series resonant frequency between the filter inductor and the filter capacitor you know the Q factor and based on the Nyquist criteria instability between the source filter may occur if filtered input impedance becomes lower than the source output impedance at this frequency. So, this is a cause of instability. So, you have to keep in mind this is a very one of the thumb rule of designing the filter.

So, you have chosen a particular switching frequency and so you may one layman kind of question some type asks, so what is the frequency in a DC microgrid? Because all these DC to DC converter are switching device that is it has got a operated a particular switching frequency. And you are required to filter out those high frequency. And while designing the filter you require to remember this Nyquist criterion very well.

So, the filter may based on this Nyquist criterion instability between source and the filter may occur if the filter input impedance becomes lower than the source output impedance of that resonating frequency.

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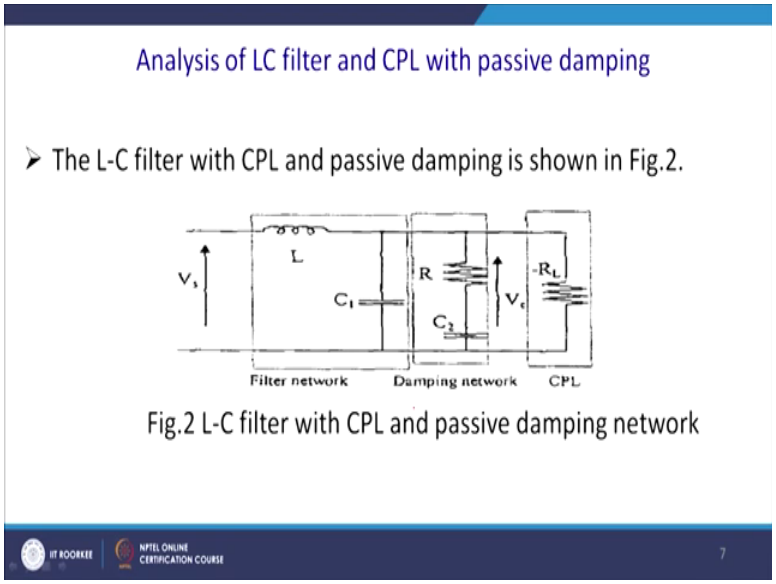

And if the switching can see because there is not it anybody then there is a great hazard. So, for this reason the LC filter with a constant power load and the passive damping it has been shown. So, this part is a CPL and this part is filter and since you may not have fulfilled that criterion. And for this reason you have added one RC network to damp out the oscillation. And that is what happen this is called a passive damping.

Since some amount of current will be sinking here so efficiency of the system will be lower but you will be get rid of the effect of the instability. So, and assume please go back to the figure this is c1 that is a filter capacitor and this is a damping capacitor c2.

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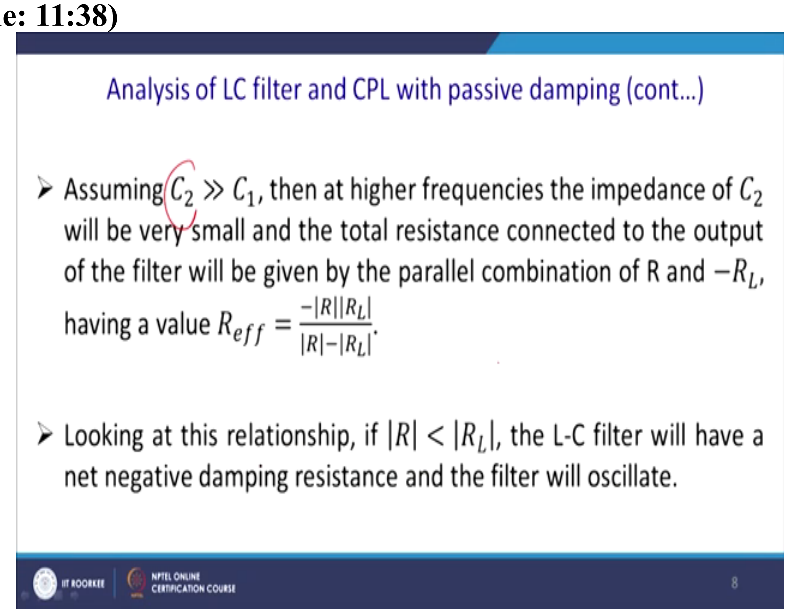

Assuming that c2 is much lesser than c1 and higher frequency the impedance of c2 will be very small and the total resistance connected to the output of the filter will be given by the parallel combination of R and the CPLD node that is RL and thus having effective R will have minus sign comes from the CPLD. So, R into R L minus this one, so, looking at this relationship if RL is much, much greater than R.

The LC filter will have a negative damping resistance and the filter definitely will oscillate. So, that is the challenge here so this will have a sustained oscillation.

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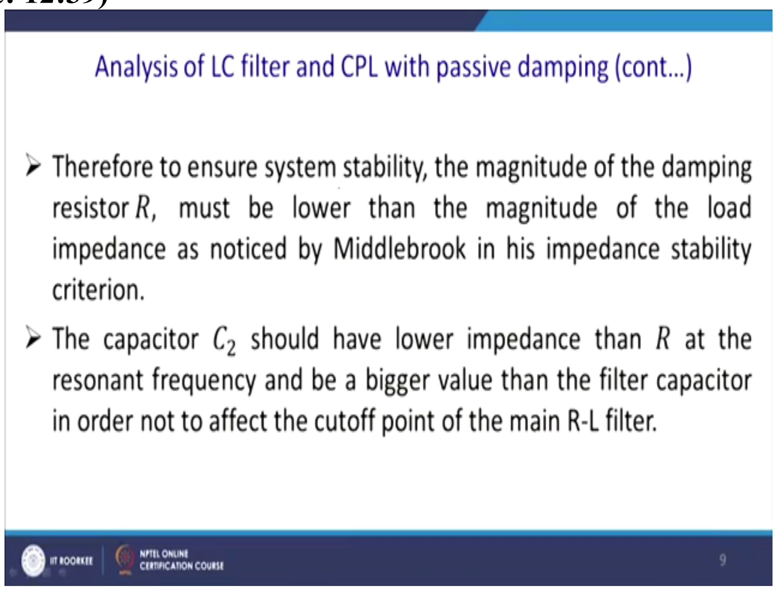

Now for this reason R therefore to ensure the system stability the magnitude of the damping resistor must be lower than the magnitude of the load impedance as notice by the; by this person Middlebrook in this impedance matching criteria or the impedance stability criteria. The capacitor c2 should have lower impedance than R at the resonant frequency and we bigger value than the filter capacitor in order not to affect the cut-off point of this RL filter. So, that is another criterion of this Middlebrook's impedance.

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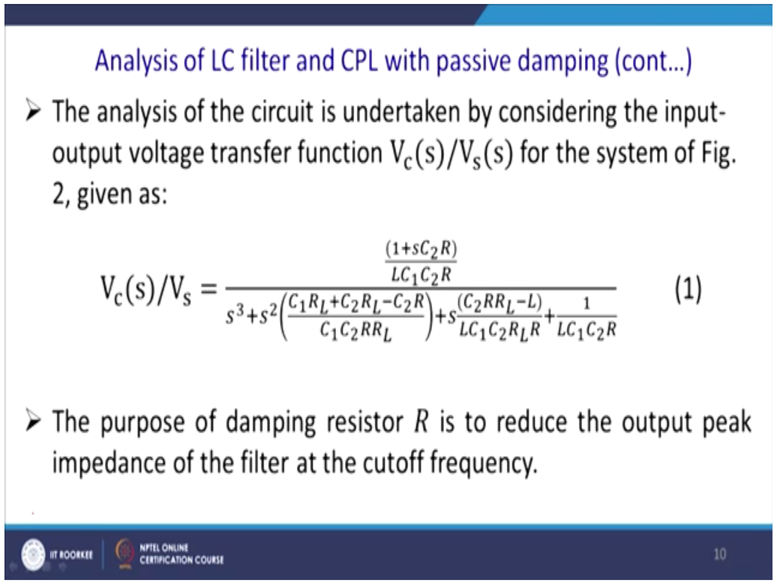

Now let us see that analysis of this LC filter with the; we have to refer back to this figure. So, figure 2 viewers are requested to refer that figures by sliding this. So, this is analysis of the LCL filter with the CPLD passive load damping and to analyze the circuit it undertaken by considering the input and the output transfer function that is your we V c S by V s of this figure 2 and thus what you can write this transfer function.

You can see that it is a third order but you can reduce in by a second order by the dominant pole method. So, you have overall transfer function like this. And the purpose of this damping resistor R here is to reduce the output peak impedance of the filter and the cut-off frequency. So, thus it will be flattened so that over shoot will be reduced.

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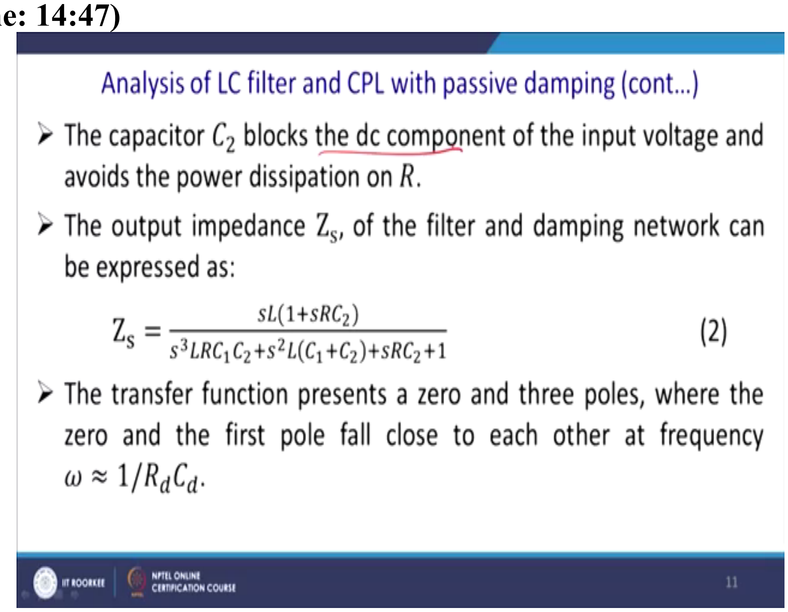

The capacitor c2 generally it blocks this DC component or the low frequency component of the input voltage and avoids the power dissipation on R. The output impedance Z s of the filter and damping network can be expressed as Z s equal to SL 1 + S RC 2 by s 3 L R C 1 C 2 + s 2 L C 1 + C 2 + s RC 2 + 1. The transfer function represents a 0 and 3 poles. So, here you got a 0 and you got a 3 poles where the 0 and the first pole goes to the each other to the frequency what it is given by that is an Omega that is 1 by R d into C d. Please refer back here in the figure number 2.

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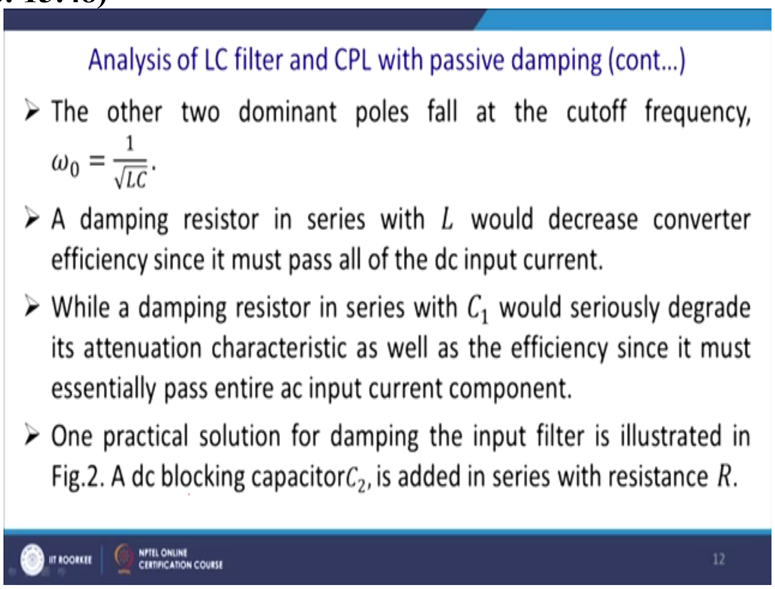

So, the other two dominant pole, will be at its cut-off frequency and that is your natural frequency oscillation of this filter that is under root of LC. The damping resistors with the series L if you connect then efficiency will be the catastrophe would decrease the converter efficiency. Causalities will be the efficiency because series current will flow. Since it must pass all the DC current so they were lost, so you cannot add in a series you require to add in parallel.

While damping resistors in series with c1 will seriously degrade the attenuation characteristics as well as the efficiency since it must essentially pass enter AC current to component. So, ultimately filtering effect will be a catastrophe THD will be a catastrophe if you add a resistance is c1. And for this reason what we do we add one practical solution for damping for the input filter as illustrated in Figure 2 that DC block capacitor c2 is added in series with the resistance so that is this case.

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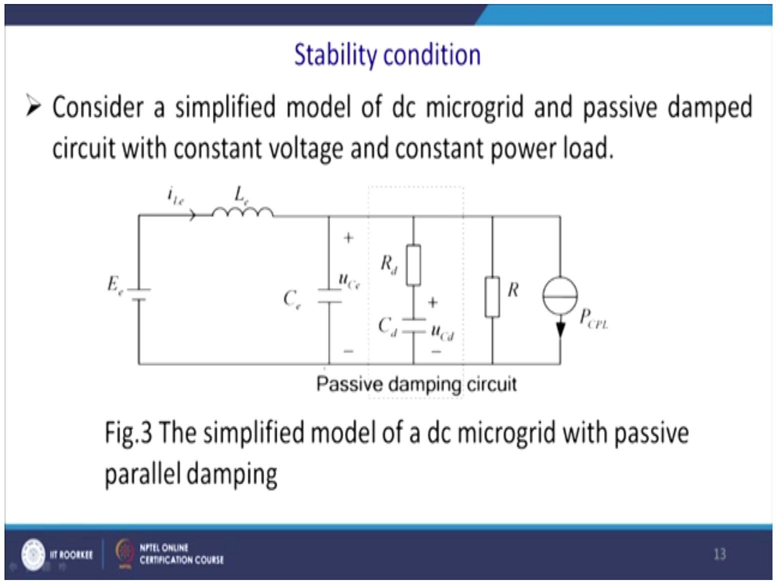

So, consider a simplified model of the DC micro grid and the passive damp circuit with the constant voltage and constant power load that is the CPLD and this is the filter part of it and you will add extra damping resistance to damp out the oscillation that is R d C d and the simplified method of the DC microgrid with the parallel damping.

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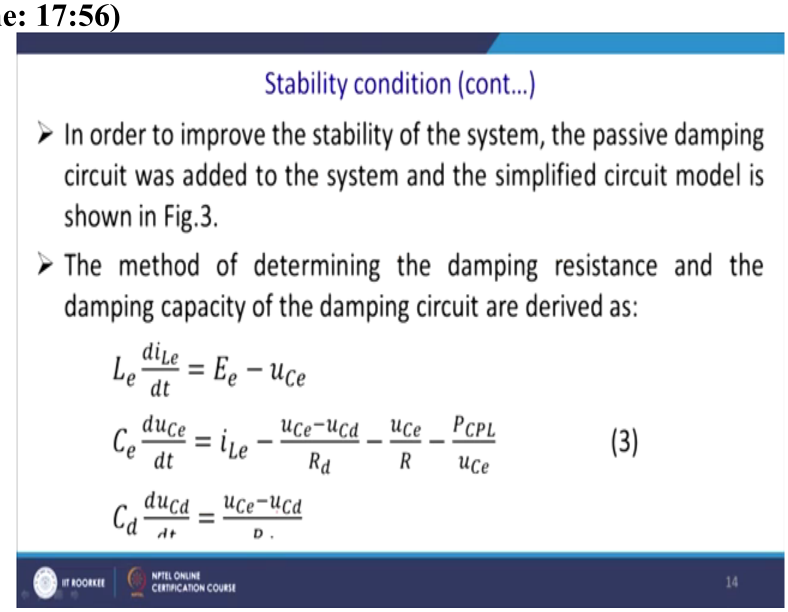

Now let us now come to the stability condition once you are damped it of course you expect that stability will be improved. In order to improve the stability of the system the passive damping circuit was added to the system and simplified the circuit model as shown in the figure that is the figure 3 this one. The method of determining the damping resistors and the damping capacitor can be derived as follows.

So, it is L di dt is the voltage across this inductor this please refer to this figure you know this element before the filter we say it is the source E c. So, you write this equation here so L e L di dt equal to E c - the voltage across the capacitor that is u c. Again the currents sinking into the capacitor is dv dt C dv dt that is C e du ce dt equal to L e minus this difference u ce - u cd by R d and since the high frequency we assume that higher capacitor is shorted value of the C 2.

There you have to use u ce by r - CPLD by this capacitor voltage ultimately what you can have is your C dt u cd equal to u ce - u cd by R d. So, this is the equations what you have.

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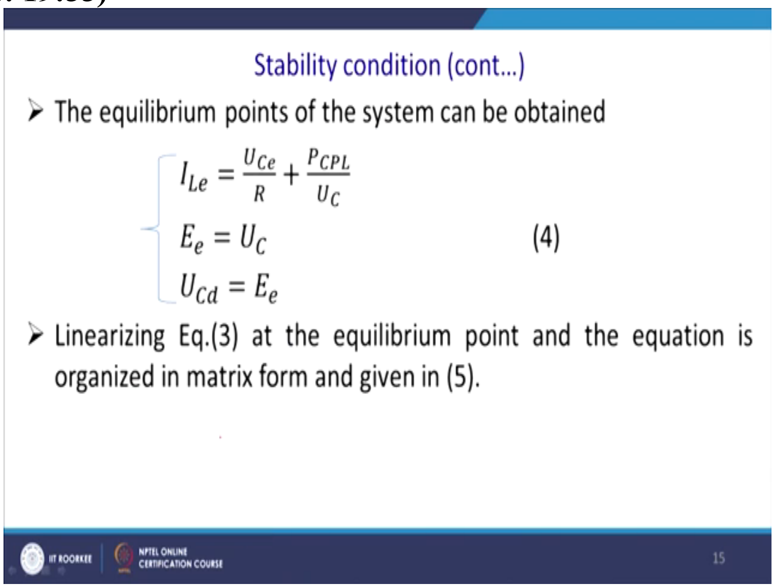

And thus from the equilibrium point of view we can find solving those equations that Le equal to U Ce by R + P cl by U c and E e equal to U C and Ucd equal to E so linearizing this equations at the equilibrium point and the equation is organized in a matrix and matrix form and given in the 5.

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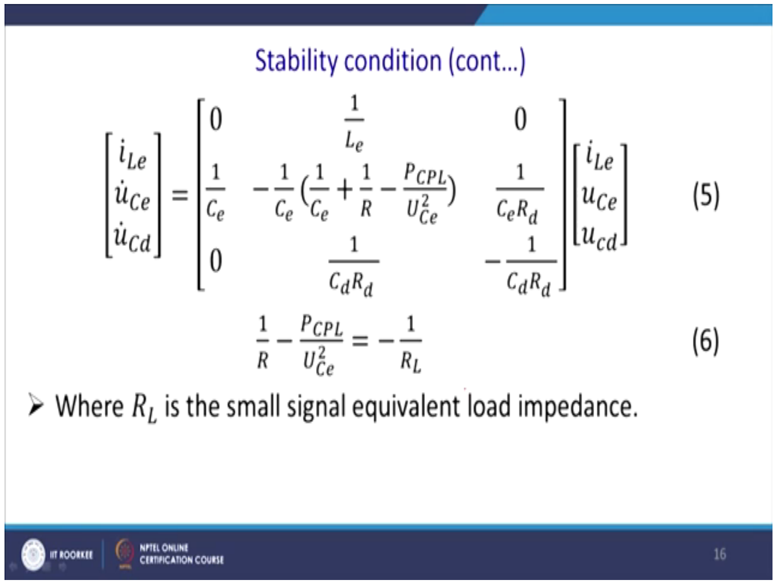

So, this is the overall transfer function with this filter with that damping network. So, these are the state variable that is the current to the inductor. There are after you have the voltage across the capacitor differentiation of the voltage rate of change of voltage across the capacitor of this filters and rate of change of voltage of the capacitor across this damping resistor. So, what you can see you can write it down the state space equation.

And where 1 by r - CPL by U c square equal to 1 by R L, so this is one of the constraint. And this R L is the small signal equivalent load impedance. So, that is something we take it as a R L load impedance.

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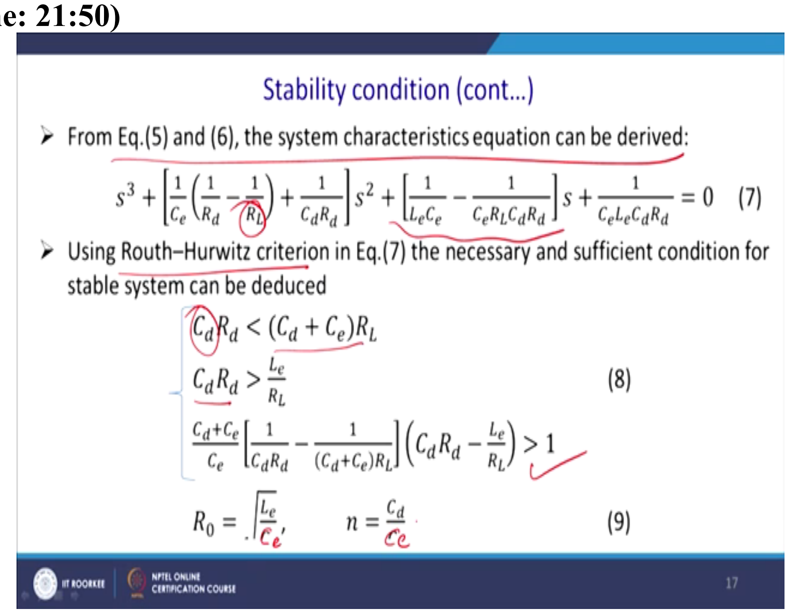

Now while the stability analysis so we can spread these equations from this state space equation we come to the transfer function model. And thus we get this is the characteristics equation this is the denominator essentially this is a characteristics polynomial and we have to analyze the stability analyzing this characteristics polynomial. So, it is s 3 + 1 by C e 1 by R d – R L please note that R L is quite small we have to 1 by C d + R T into s square + this is the damping part.

Since it is a coefficient of s so L by C is a + C into R L C d into R d and that into s thereafter this will be essentially the damped oscillation part Omega d and thus we apply a simple criteria that you have studied in your called basic control system in your B.Tech level that is the Routh-Hurwitz criteria in equation 7 and the necessary sufficient conditions will be the sign change in the Rho and thus we rewrite the Routh- Hurwitz criteria.

So, what you get here C d into R d should be less than that R L into C d into C to having a stability criteria to be fulfilled C d into R d should be greater than le by R L and also you have Cd + C by C in bracket 1 by C d R d - 1 by C d R d R L into C d R d- l e R L it should be greater than 1 that is equation number 9 and where R 0 will be under root of L by C and this n is a ratio of the C d by C e.

So, that is something the notation will be followed and based on that we have to have this criteria and based on that you will design the value of the C d and the R d. So, you fix up the city because generally what happens Cd comes in a some numerical values 47 microfarad or some other values.

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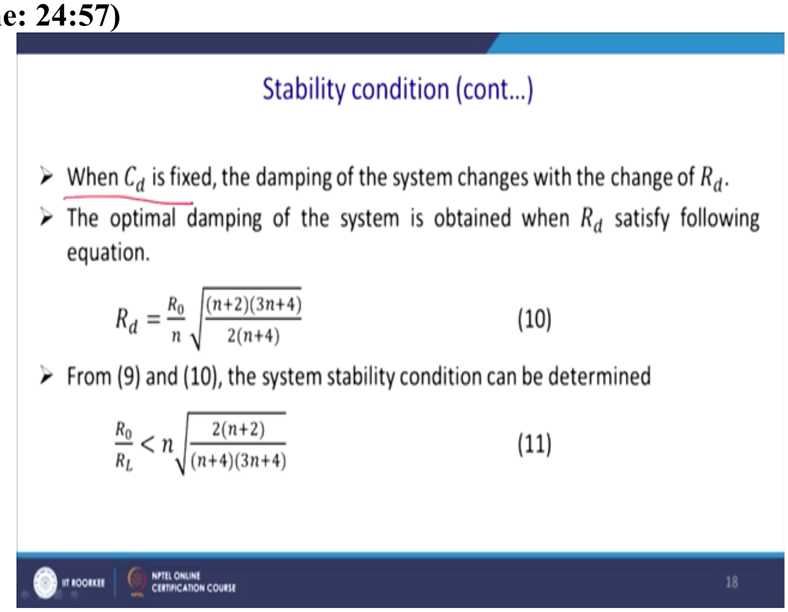

So, then what happened since we required to fix the value of this Rd and thus you get a little range extremely sorry first you fix up the value of the Cd once you fix up the value of the Cd range of Rd and it is your task in a in simulation also you put that values of the Rd and check because in a real hardware setup you may not do that heat and trial. And for the reason you take a range of the R and you swap out the value of R and see that where it gives a best response.

But of course your theoretical aspect will mismatch there is a lot of parasitic entities that will come into the picture but you know then we have to take care of this eliminate or account those parasites in your hardware. So, that what I can say is that the damping of the system changes with the value of Rd the optional damping of the system is obtained by Rd satisfying the following equation that is Rd equal to R 0 by n under root of n + n 2 n + n 4 by 2 n + n 4 where n is a ratio of Cd by C.

And thus this is the value of the Rd you will get and from this 9 and 10 we can derive the condition of the stability that is you know R 0 by R L this ratio should be less than a n into so you can take this 2 equations and combine. so 2 into n 2 into n + n 2 by n + n 4 into 3 n + 4 this is the conditions while choosing because you have chosen a filter based on the switching frequency so your value of le and C are fixed.

And so steps will be the once you have fixed then you come across this relay then you will fix up the value of the Cd. If you have chosen that capacitor voltage to be maybe actually .47 micro farad and you choose this capacitor as 47 micro farad so it is actually 100 times higher so, I in value 100 snd accordingly you will have Rd and thus you come into the conclusions C and e required to design properly what should the other.

Please note that these cap this capacitor C d should not interfere and it that should be around 50 to 100 times higher than the value of your the filter capacitor C then only this will work fine. Thank you, for attentions and what I can say in here that this characteristics you have to write it properly. Thereafter this is the steps again I am reiterating this is the step. Thereafter you come to the transfer function students should be very much aware of converting your stage space into the transfer function.

Then you get the transfer function and thus you get the criteria and you see that what should be the stability of the system by equation number 11. So, thank you for your attention and in next class we shall see that active damping may be and some other cases of the passive damping thank you for your attention, thank you.