DC Microgrid and Control System
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Lecture-38
Microgrid Stabilization Strategies
(Impedance/Admittance Stability Criteria)

Welcome to lecture on a DC microgrid and control. We are discussing in previous class on the passive damping of the microgrid simulation. Now we shall discuss about the impedance and the admittance criteria for the stability of the microgrid. Now, this small signal stability where it is related to the small perturbations of one entity or various entities.

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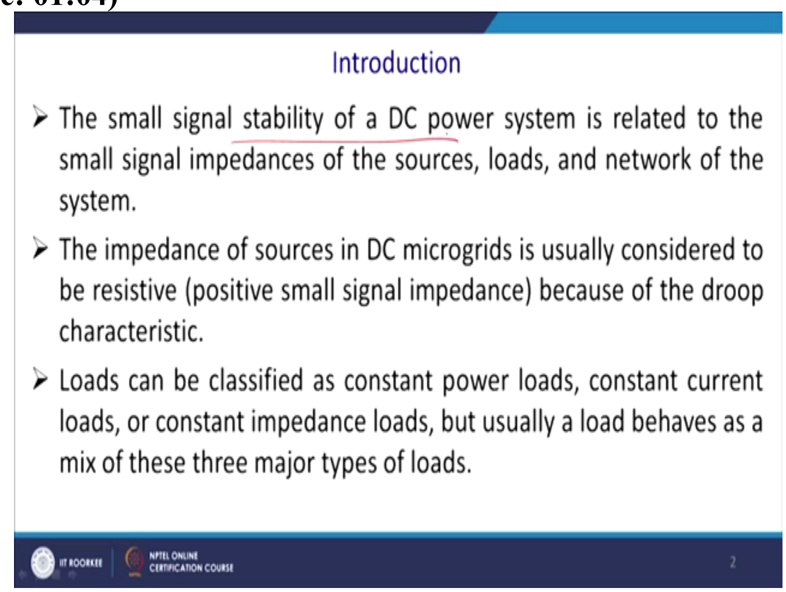

Small signal stability of a DC microgrid system is related to the small signal impedance of source loads and the network systems. So, these all entities will cover once you have small changes in an irradiation level it effects impedance level and monitor change and load we also change little bit, you changed a load of course it will come under large stability at large and loads and all the system has to be considered here.

The impedance of the source in DC microgrid is usually considered to the resistive. Because inductance does not have effect here and unlike the conventional grid varying R ratio is around 7 so predominantly have the inductance. But in case of the DC microgrid you do not have any inductance. Inductance is shorted and for this reason predominantly what do you mean by this impedance is resistance.

And the positive small signal impedance because of the group characteristics and when finally load increases you will find that the bus volt is drops, For this reason you have that group characteristics and also load can be classified as discuss several time before also constant power load this is quite nasty and load and also constant current load it tactics constant amount of current is respective of the battery charging kind of applications maybe and the constant impedance load.

And that is the good load, why? If we change the voltage and current drawn it will be different and if you have increased the voltage, current will be more and thus to try to stabilize the DC bus and the reverse will happen. It will take less current and that is it will try to stabilize also that this DC bus. And generally but what you can say here is but usually a load behaves as a mix of this three types of load. And in a microgrid to see which load dominates and if severely dominates then control has to take care of it.

And if the impedance load dominates, you have a little leave way. So, control will not be that challenging.

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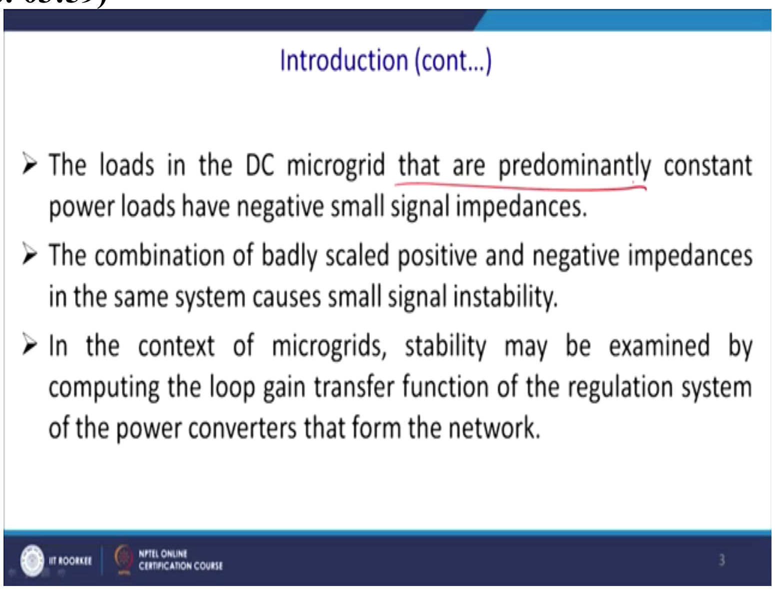

The load in the DC microgrid that are predominantly constant power loads have the negative small signal impedance because once it is voltage decreases, current increases. And thus, you know dv di is negative. For this reason you had a problem that is the negative small signal impedance. The combinations of badly scaled positive and negative impedances in the same system caused are small signal impedance.

You may have a load which is of positive impedance coefficients and another due to the CPLD you have the negative impedance. And there we interact and thus it closes the system out of gear. In the context of this microgrid, stability may be examined by computing the loop gain transfer functions of the regulation system of the power converter that forms the network.

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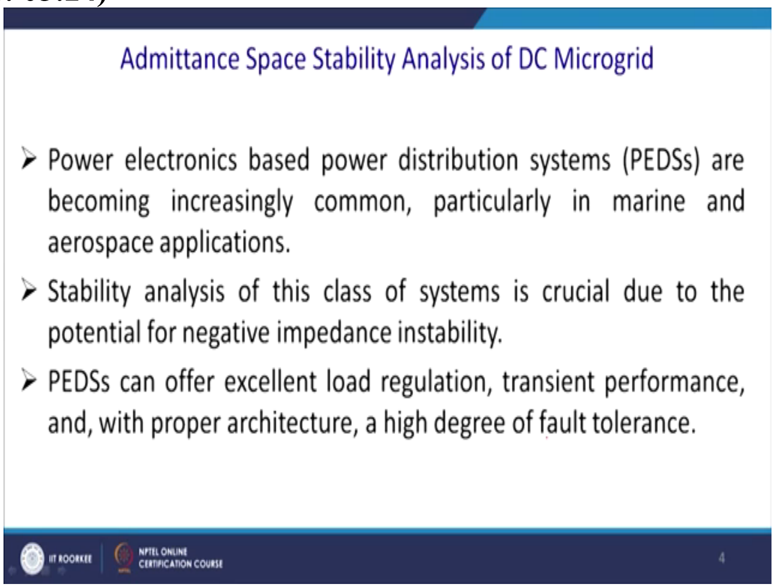

The power electronics based distribution systems in abbreviation we say that is PEDSs are becoming increasingly common, popularly are the marine and the aerospace applications. We have a submarine that required DC propulsion and all those things in submarine it can be visualised because it has a huge battery bank. So it can visualise itself another DC microgrid; same via spacecraft sorry an aircraft that can also be visualised as an isolated DC microgrid in high landing more when it is flying.

So their stability are the very big challenge these two entities or the ship. The stability analysis of this class of systems is crucial due to the potential negative impedance stability. So CPLD is the hazard. And thus what you required to do is Power Electronics distribution systems can offer excellent load regulation. So we required to manage this thing by this power electronic features and transient performance and the proper architectures a high degree of fault tolerance.

Because CPLD has to be there then, it should cause the negative impedance to come into the pictures and since voltage goes low and that is it will track more amount of current. And there for this reason restrict into those we require these power distribution systems.

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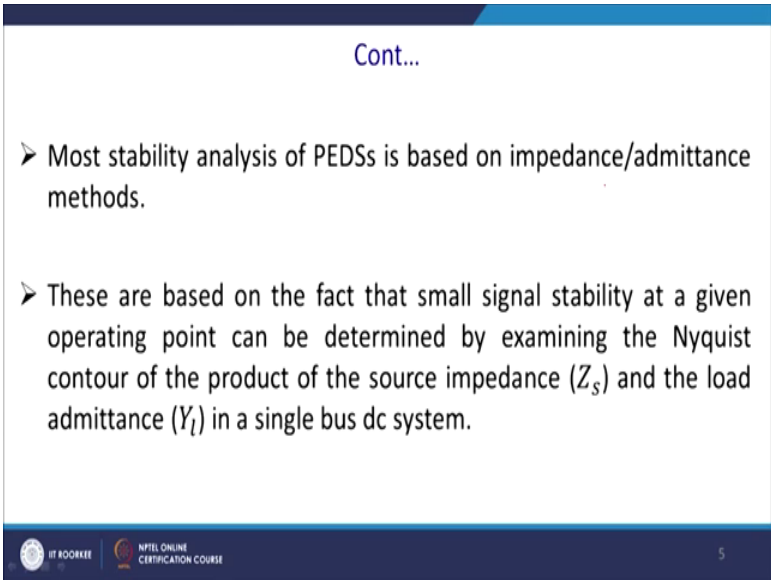

Now we shall discuss what is our content is today? The more stability analysis of these PEDSs is based on impedance, admittance methods. So we prefer generally impedance method is a part of the single DC bus system analysis and also we may have admittance method we have parallel zones. This method based on the fact that small signal stability at a given operating point can be determined by examining the Nyquist contour of the product of the source impedance status.

And the load admittance that is Y l in a single DC bus system. Of course these things become quite complicated once we have studied about the different kinds of architecture of the DC microgrid and that is a different area. And we will take a simple case that is a single bus system.

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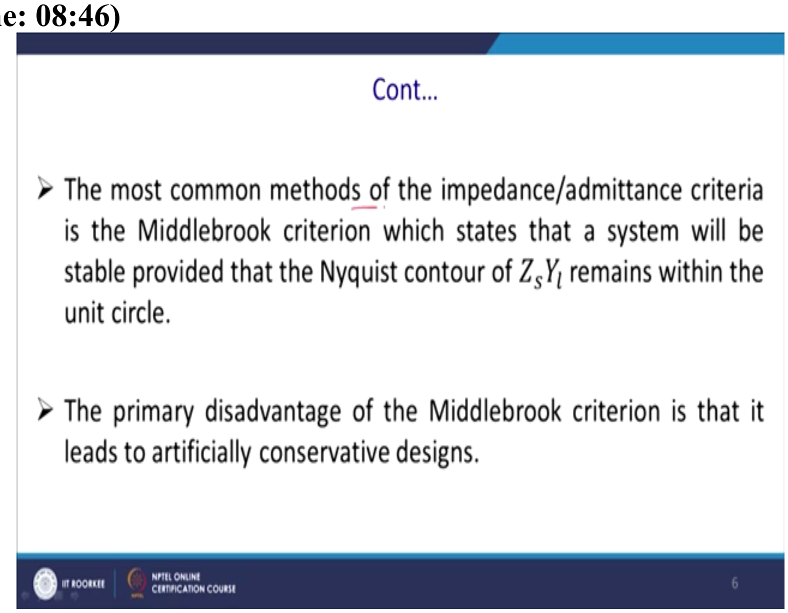

The most common methods of the impedance admittance criteria is, we have referred this Middlebrook criteria in our previous discussions also. It states that the system will be stable provided that Nyquist contour that is Z s, Y 1 remains within the unit cycle that is the one of the requirement. And to satisfy that what we are required to do is the primary disadvantage of the Middlebrook criteria is that it leads to an artificial conservative design.

So you will find that you are unnecessarily you are quoting extra damper to ensure the stability and efficiency will be poorer and we are required to revist this criteria.

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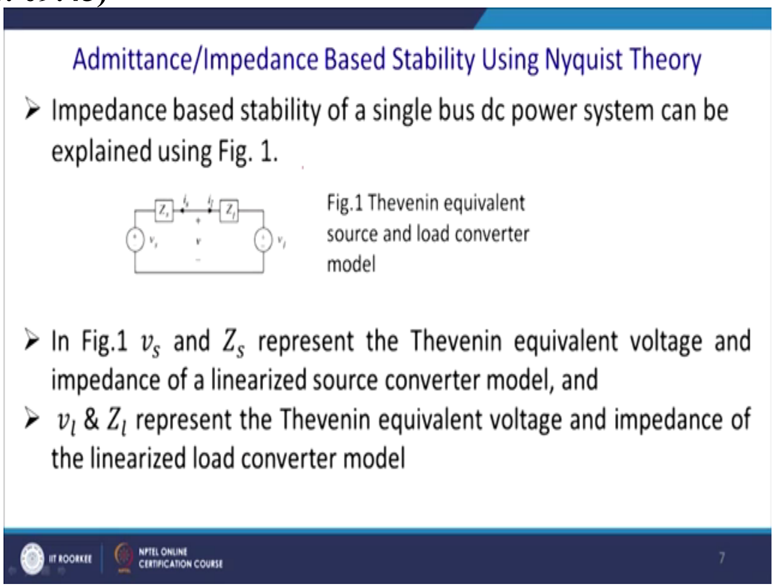

The impedance based stability of a single bus DC power system is can be explained using figure 1 and this is Thevenin equivalent circuit and so this is the source impedance and this is the load impedance and this is voltage. Where in this figure 1 V s and Z s represents the Thevenin equivalent voltage and impedance of a linear source converter module and V l and Z l represents the equivalent voltage and impedance of the linearised load converter model.

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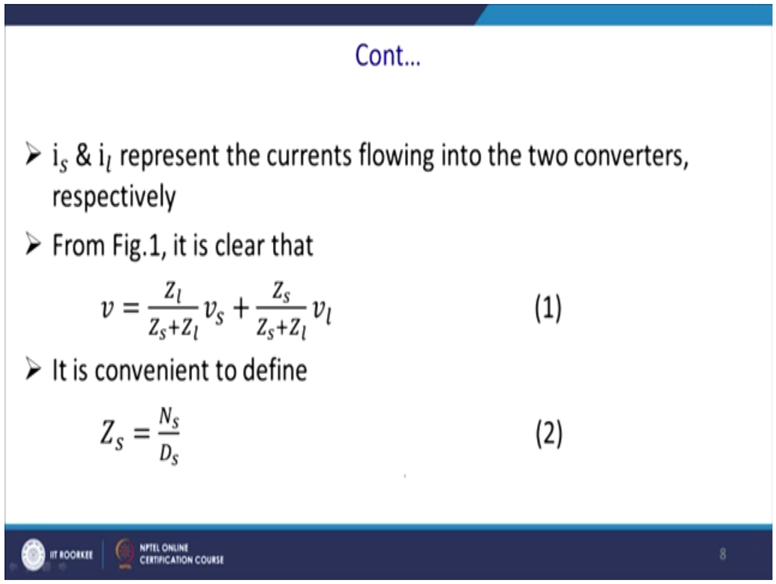

And this I s and I l represents the current following into the two converters respectively and we have considered single bus system from this figure we can write that V that is thermo equivalent voltage Z l by Z s clustered into V s + Z s+ Z s into V l so we mean to define let us say that Z s equal to in the terms of polynomial in the Laplace will be numerator and the denominator.

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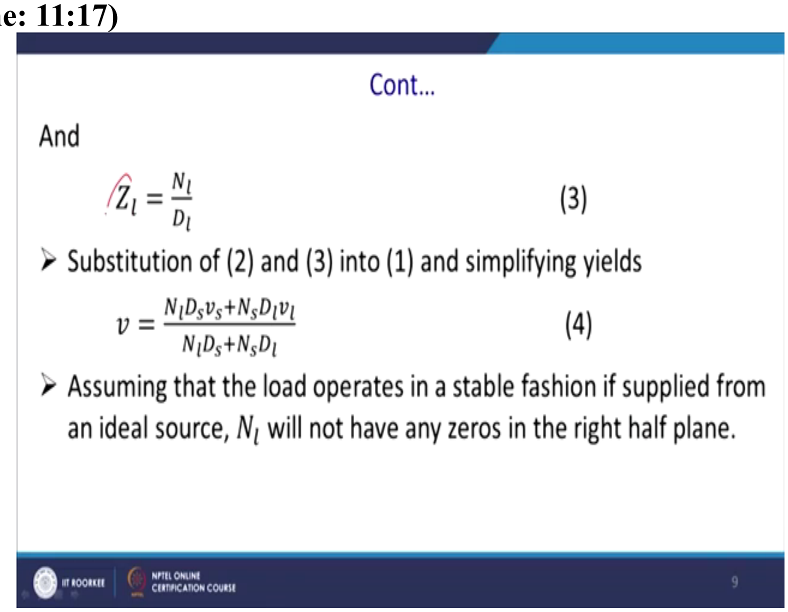

So again will be N l by D l so while substituting 2 and 3 in 1 so write and find out the N l D s into V s + N s D l into V l by N l D s + N s D l. Assume that the load operates in a stable fashion if supplied from the ideal source N l will not have any zeros and the right hand side of the s-plain and the system is going to be stable.

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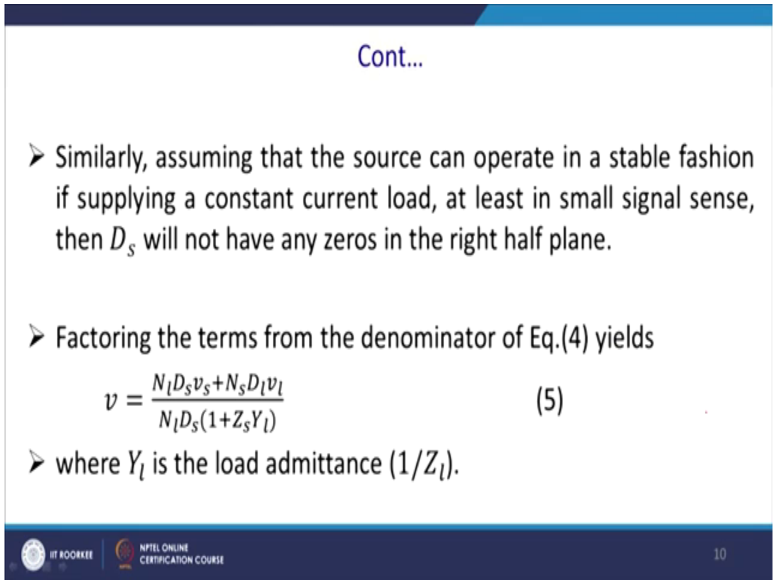

Similarly assume that the source can operate in a stable fashion if supplying a constant current load that is CPLD at least in the small signal sense then D s will not have any zeros as a right hand of this plane. So, factorizing is term in the V considering this criteria which we have stated right now so this equation 5 can be yields and thus we can write V equal to N l into D s into V s+ N s D l into V l by N s D s + 1 Z s Y l where Y l is the load impedance of 1 by Z l.

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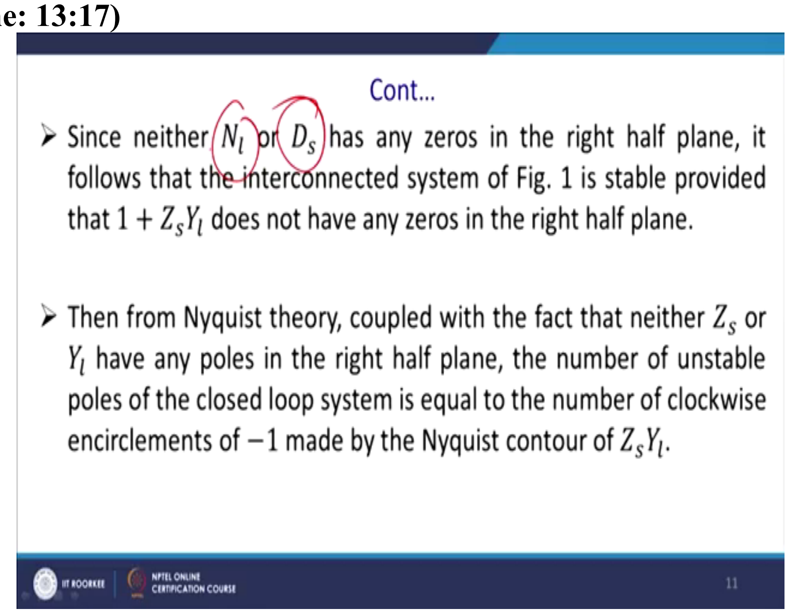

Since neither N l nor D s as any 0 in the right hand of this plane it follows that interconnected system which was shown in the figure 1 is stable and provided that 1 + Z s into Y l does not have any 0 in the right hand side of this plane. So, that is the criteria required to be fulfilled. Now then Nyquist theory coupled with the fact that neither Z s or Y l have any pole in the right half plane. The number of unstable poles of the closed loop system is equal to the number of clockwise encirclement that is the Nyquist criteria of at minus at the point equal to -1 Z 0 made by the Nyquist contour of Z s Y l.

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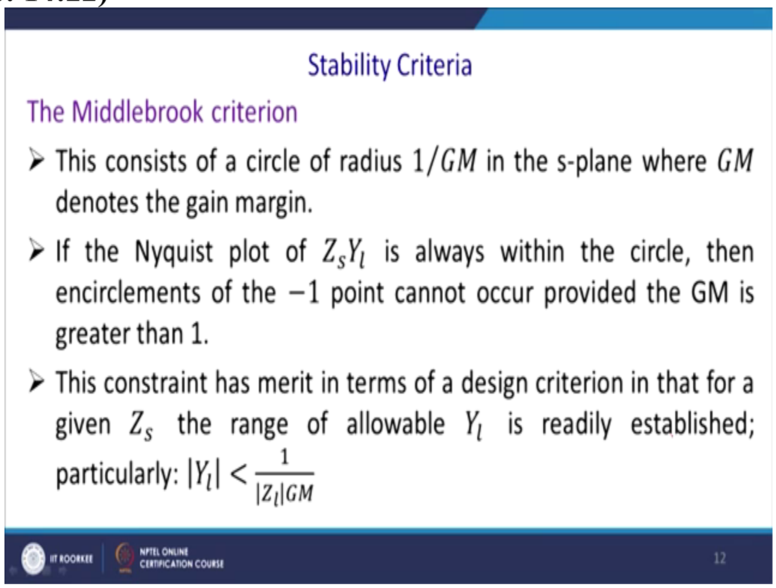

So, let us revisit that Middlebrook criteria one second so we have qualified and satisfied by the Nyquist criteria and this Middlebrook tells it consists of a circle of radius 1 by GM in the s-plane why GM denotes the gain margin of your bode plot. Please understand what we are saying today all on average model. So, we cannot cover the nonlinear integral nonlinear control but student are requested to first introduce the linear control and see the stability.

And if it is works fine if you can design the system PID controller based on these average model that also works fine. So, there after we can investigate nonlinear control and find it out that what are the advantages of nonlinear control? But for timing our concentration is totally on the linear control. And you know that there is a different issue of the system gain margin phase margin. if the Nyquist plot of Z s Y l it is always within the circle then encirclement at the point – s Z 0 that is -1 cannot occur provided that this gain margin is greater than 1 that is something we require to keep it mind.

The constraint has a merit in terms of the designing criteria in that for a given the source impedance. The range of the allowable not impedance load admittance this Y l really established and in particularly the load admittance that is the mod value should be less than 1 by Z l into GM that is something we required to consider and required to be established.

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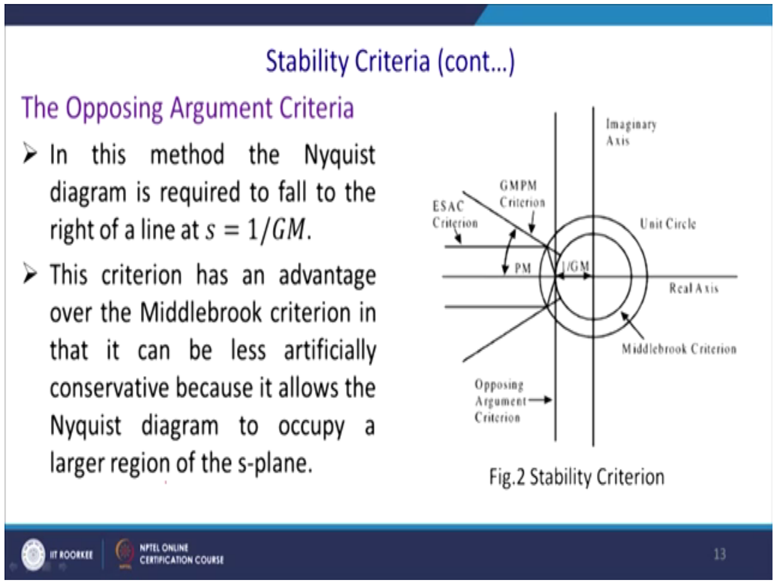

So, this is the stability criteria and this is unity circle and this is the sigma axis and this is the G omega axis. Now in this method and opposing the augmenting criteria and say that in this method the Nyquist diagram is required to fall to the right side of the these line that is equal to 1 by GM gain margin. This criteria has an advantage over the Middlebrook criteria. What is it? The criteria in that it can be less artificial conservative because it allows the Nyquist with diagram to occupy larger region in the s-plane.

So this one this lowest circle you know is lower circle is your Middlebrook criteria and this one is ESAC criteria and this one is your gain margin and phase margin criteria and you can see that you can very well operate this is a Middlebrook criteria is little conservative approach of the stability you can very well operate this above cycle with their encirclement and having your stability criteria satisfied by the gain margin. So, by the; bode plot only we can ensure proper stability of the system.

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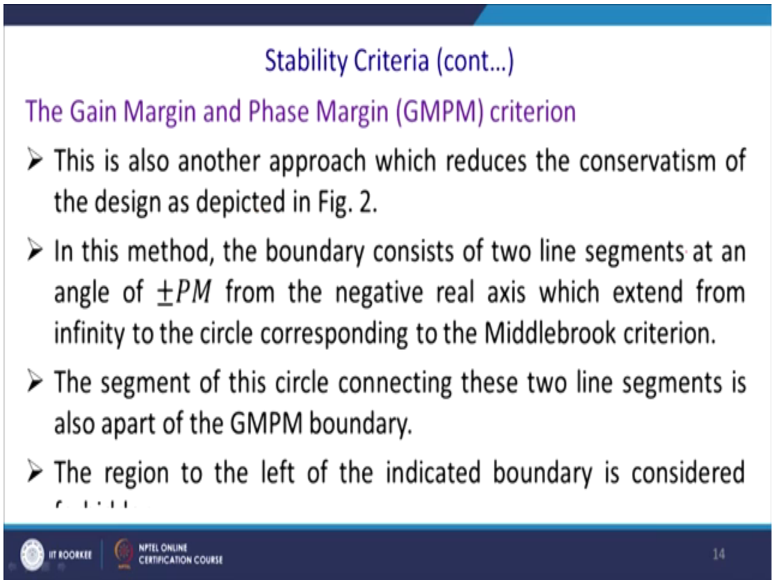

Now gain margin and phase margin criteria let us visit that students are requested to revise your basic Control Theory to understand it better. This is also an another approach which reduces the conservatism of this approach Middlebrook was restricted. Now this is the design as depicted in the figure 2 that is Middlebrook approach essentially. In this method boundary consist of two line segment at an angle of + and – P please refer to the figure number 2, this is figure number 2.

So, this is the plus minus here, +- PM from negative real axis which extends from the infinity to the circle corresponds to the Middlebrook criteria. So, students are requested to take snapshot or screenshot of this figure number 2 so that they can correlate this statement better. These segments are the segment of the circle is connected; these two lines segment is a part of the gain margin and phase margin of the boundary. The region of the indicated boundary is considered as your controllable boundary.

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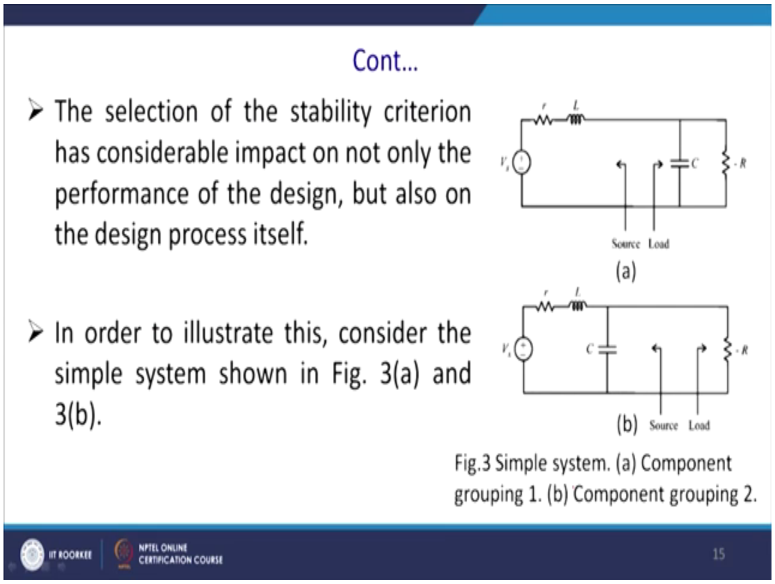

And thus what we can say is that selection of the stability criteria has considered has as considerable impact on not only the performance of the design but also the design process itself. If you look from this site is your source side and then it will be the load side and now what happened we have grouping the component. So, have transfer this capacity of this site and see that what will be the changing occurring.

And in order to illustrate the above statement considered the 2 system that is source side impedance and load impedance a and b the first is the component grouping first component grouping resource and the capacitor is a part of the load and here capacitor is a part of the source.

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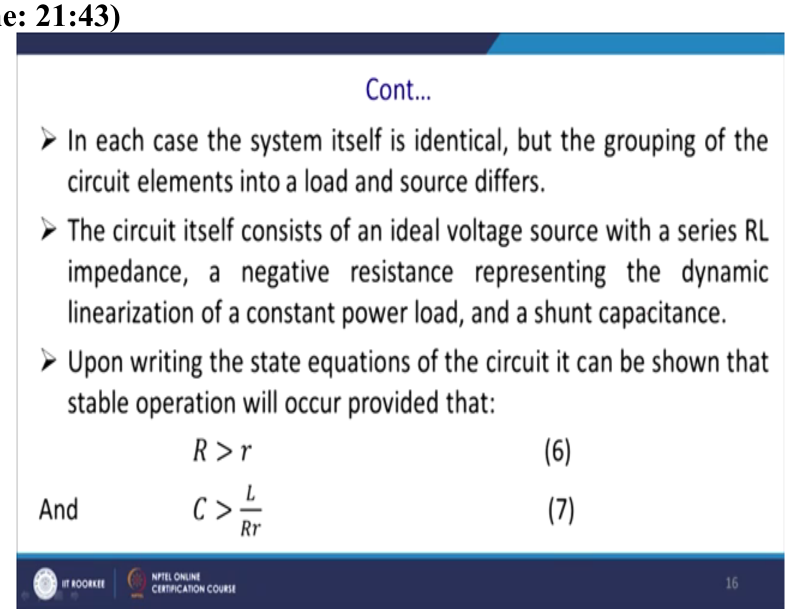

Now in each of the case system is identical but grouping of the circuit element into the load and the source differs essentially capacitor is separate in between the two entities. The circuit itself consists of an ideal voltage source with the series RL impedance and negative impedance representing the dynamic linearization of constant power load and the shunt capacitors that is something we required to do.

And that is what happened upon writing the state questions of the circuit it can be shown that stable operational occur when capital R is much greater than smaller r and this C is much better than the time cost and that is L by Rr so in that case you will consider it like that. So, what happened here let us revisit this condition once again. This is the sources resistance and this is the load resistance and our condition is that load resistance will have a negative type because of the; it is the CPLD.

And our consider vision is that load resistance is much, much greater than source resistance and this capacitor value what you have this value this ratio L by R into r is it should be greater than C and if you do that condition then what happened in this configuration so then this interchangeability is possible. For this reason in each case itself even though it is identical but if this condition was not satisfied then we cannot consider this case to be identical.

Grouping of this circuit element into the load and the source here it will differ. And another point also here the circuit itself consists of the ideal source that is that you also your to keep in mind but in case of the mostly in case of this; in case of the Microgrid that kind of situation does not arises because ultimately you have a solar entity and thus you are have a DC to DC Converter and it has got on impedance.

So, it is a over simplified model but in the over simplified model if this criteria is considered then this gain margin and phase margin model will be satisfied and what you have done in case of this Middlebrook approach that is a conservative approach you required to operate your model with this inner circle instead of that you can go to the outer circle if you consider your system for the gain margin and phase margin model.

This is the one of the way of analyzing it and of course this model is totally linear and it has got lot of approximations. And we have considered only the load to be here negative does it is a constant power load and this analysis may change or differ if you have a cost if you have a constant current load or the constant impedance load. But since more stringent condition arises once you have negative resistance.

For the session this example is chosen and where you have CPLD and students are requested to validate this whole system of PM this is phase margin inversion method by other kind of constant loading and you see that whether this control bandwidth increases or not that is something we required to once we have online forum and all those discussion will take out this issues.

Because we cannot cover in the 20 hours all those aspects of the control so students are welcome to revise all that all this control aspect otherwise they will find it difficult to understand this part of the microgrid, thank you. Thank you for your attention we shall carry forward or discussion of the control applications of the microgrid, DC microgrid, thank you.