**DC Microgrid and Control System**
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**Lecture-34**
**Stability in Microgrid**

Welcome to our lectures on the DC microgrid and control system. So, we shall first take out that remaining portion of the previous lecture that was the energy park and the hybrid charging system. Thereafter we shall discuss in detail about the stability of the microgrid. Now the remaining portion of the previous lectures that is the renewable energy park.

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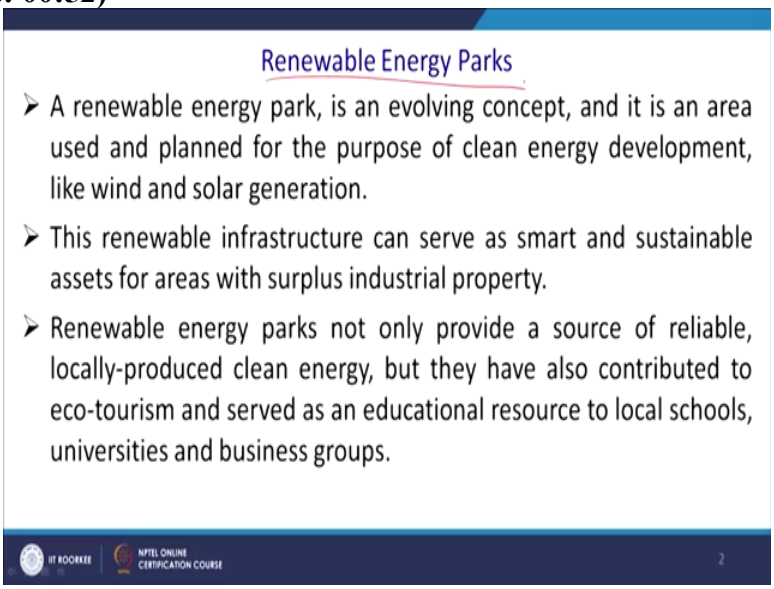


The renewable energy park is an evolving concept and there is an area used for the planning generally. It will be now when you go for the city planning there will be a park inside the city also. Previously what you used to do we require to put our power generating unit outside the city since it is causing a pollution hazards. And it just reverse happens here it will be a centre of the city and it will be a tourism attractions and you will also generate energy.

So, used for the plant for the purpose of the clean energy development like wind and the solar generations. This renewable infrastructure can solve and conserve smart and sustainable asset in areas of the surplus industrial property. So, once you were places where agricultural land or you have a sugar for example in Uttarakhand I have visited so many sugar factories they have a plenty of disposable land. So, there they can put the solar panel ultimately and they can use it as

a solar park so that is also the possibility.

The renewable energy park not only provides source of the renewable locally produce energy but they can also be also be contributed to the ecotourism. Because you require to since you are generating that place will be clean and all such other educational source because you can take them to the excursion to the students. So, that see that how does the modern concept of the technology works universities as well as the business group.

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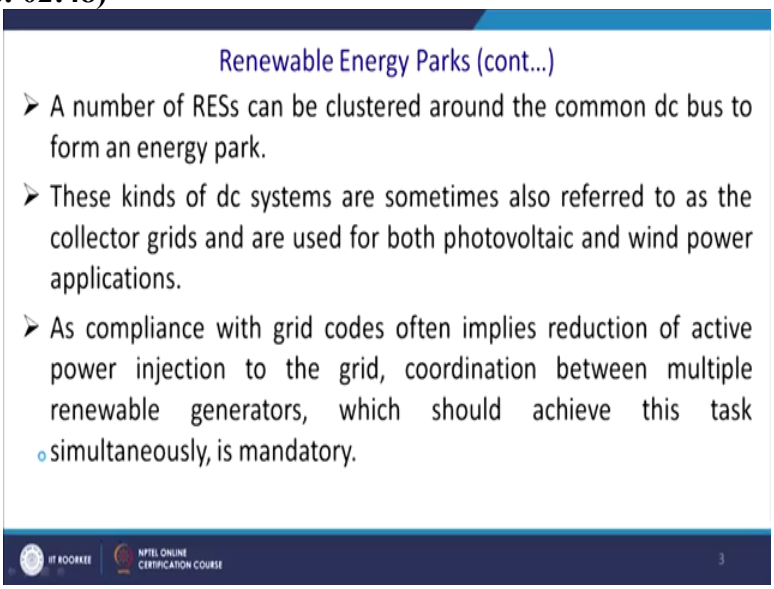


So a number of the renewable energy park or renewable energy storage system can be clustered around the common DC bus to form an energy park. So, you will put your all the solar entities and all those things with the power back up maybe into the close vicinity. So, that your conduction losses will be reduced and this kind of the DC systems are sometimes referred to as a collector grid and are used for both photovoltaic in the wind power applications.

As appliances with the grid codes often implies reduction of the active power injection to the great coordination between the multiple generation which should be achieved its tasks sustainably and the monetarily. So, that is the one of the constraint that we will put to the energy renewable box.

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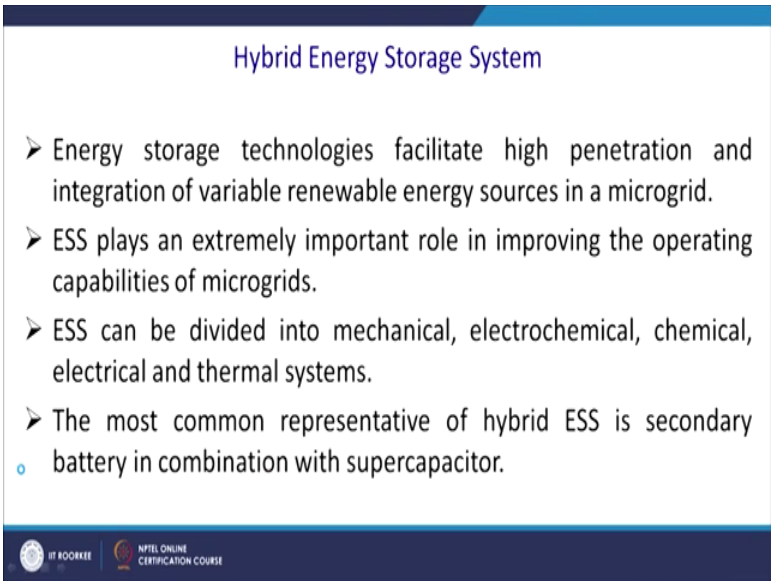


Now let us come to the next topic that is a hybrid energy storage system. So, we may have we required to put in this modern DC microgrid hybrid energy storage system that energy storage technologies facility high penetrations and integration of the variable renewable energy sources in a microgrid. ESS plays an extremely important role in improving the operating capabilities of the microgrids.

ESS can be divided into the mechanical, electrochemical, chemical electrical and the thermal system. So, you can have a different way to but generally it is electrochemical mainly it is batteries. But you may have a fuel cell hydrogen all those things we have seen in our previous lectures. The most common representative of hybrid ESS is a secondary battery and the combination with the ultra-capacitor.

Ultra-capacitor only take out the energy in seconds 90 second 100 seconds something like that. And generally if there is a energy mismatch in hours that has been taken by the batteries.

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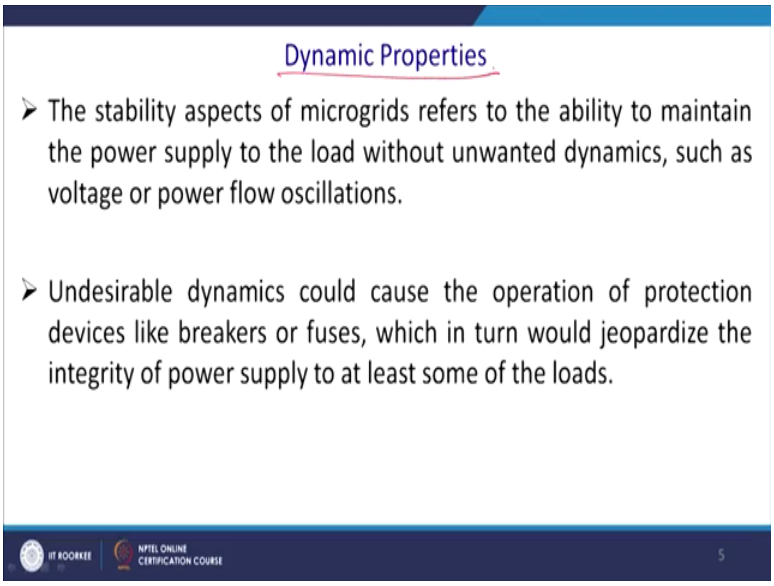


The capability aspect the stability aspects of the dynamic properties now, so the stability aspects of the micro grid refers to the ability to maintain the power supply to load without unwanted dynamics. Such as the voltage and the power of solution you should not once load change occurs or something from perturbation occurs into the system. Oscillation should not be sustained because you have a strain inductance in the DC microgrid.

And you have within the bus and the ground and within the two bus depending on the kind of architecture whether it is a unipolar or bipolar you have got a capacitance. And that is whenever the whenever there is an excitation reactions occurs and that leads to the oscillations of the voltages since if it is not damped properly. So, we required two damped those oscillations and there we can do the passive damping by connecting the resistance between these two buses.

And all those but that will be the lousy and instead of that we can actively damp out. So, by controlling the current flowing to the different point we can actively damp out these oscillations. And that is one of the requirement of the smart micro grid and that is increased efficiency. Unreasonable dynamic could cause operations of operation of the protections devices or the breaker fuses or it may be the transient and in my oscillation is sustained and it may be detected as a fault by your protection devices until relay will trip and ultimately throughout the rest of the microgrid in a no power choke.

And thus it will turn this which will turn into jeopardise the integrity of the power supply to the list of the some of the nodes. So, that is something it is not acceptable use a sustained oscillation is there those protection devices may activate and there will be a loss of power maybe in a some

portion of the microgrid unnecessarily and thus we require to prevent it.

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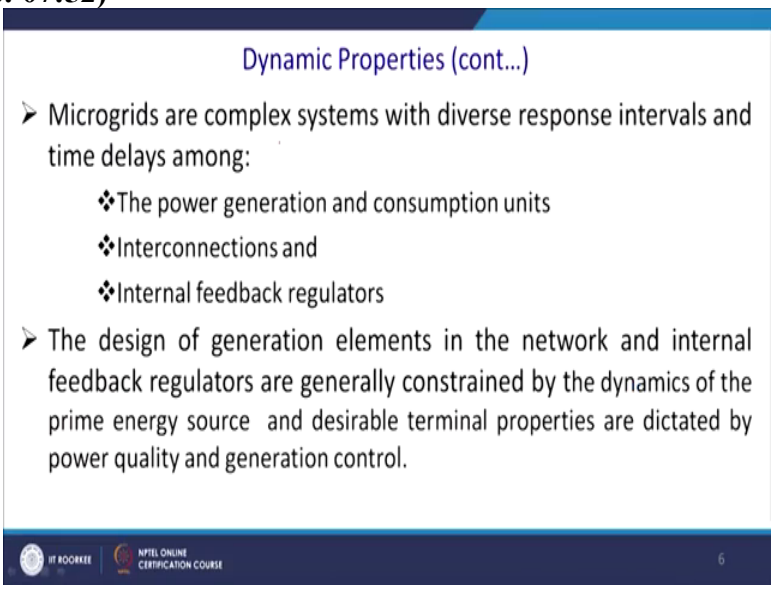


So, dynamic properties microgrid are the complex systems with diverse response interval and the time delays among this different coordinated control. It may be connected to the high frequency communication channel as there is a delay in memory communication some element will be communicated to the low frequency communication channel. And there is a switching delay there is a response time of a different kind of systems.

And thus based on that we can categorize that the power generation and the consumption unit will have some delay so we have to incorporate it, there is a interconnections between two power generating unit required to have a coordinated control. And internal feedback regulators so you have to have a feedback what it is given its PDT required to be checked. So, whether the census gives you the right value or not the fidelity of the sensors required to be check regularly.

And you require to provide some kind of redundancy. The design of generation of the element in the networks and the internal feedback regulators are generally constrained by the dynamics of the prime sources. So, these had something we required to understand that so we have the feedback and the regulator will put on restrictions on the primary energy sources. And that will then decide what should be the DC bus voltage something like that.

And desirable terminal properties are dictated by the power quality and the generation control. So, power quality is something we have to taken into the account if you have a solar is more or something if you have a good amount of power if you have your if you have a good amount of

power is available to you then you can inject power to the grid. While injecting the power to the grid you have to maintain the desired power quality that is the THC has to be less than the something the value which can export power to the grid.

As well as you require to have a power factor to be close to the unity 0.95 those constraint has to be put into the place then only you can walk with the grid.

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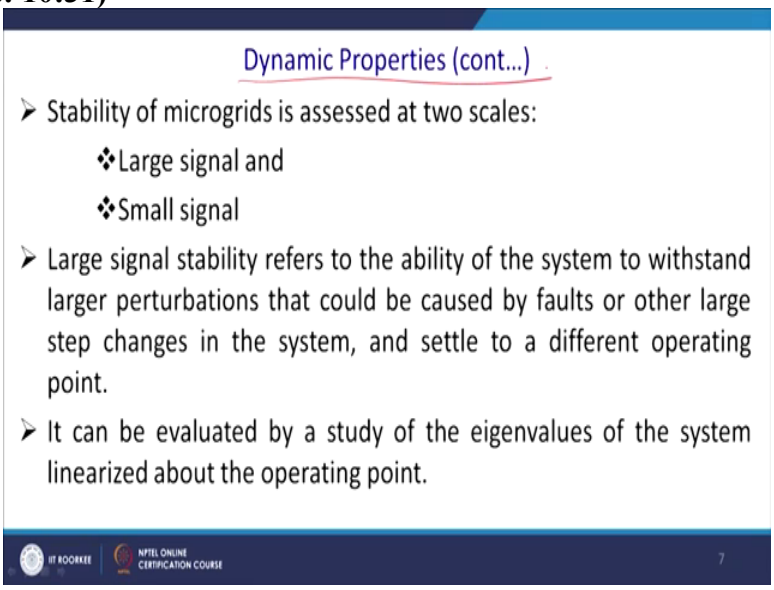


Now stability; stability is thus it is an important aspect of our DC microgrid or any system rather. So, it is a part of our dynamic properties. So, stability of the micro grid required to be assessed one is large signal another is small signal. So, if it is a huge load change or a sudden phenomena that cause havoc to the microgrid for the large signal and the small perturbations are called the small signals. We analyze, we require to analyze both the stability then only you can find it out whether it is robustness of the system.

Large signal stability refers to the ability of the system to withstand larger perturbation. Now how you define larger, so if you have an if you are running the load at half of the load maybe all of a sudden you go to the 100% loading and you can say that is a large disturbance or large perturbation. So, that could be caused by the and also by the fault or other rather large step change of the load on the system and settle to the different operating point.

May be that the once you have 100% loading you fix the DC voltage at 48 volt once you are overthrown 50% of the load and in want a generation maybe you allow maybe 48.5 volt is a new settling point and that is allowed. So, you operate you stabilize in an another settling point

depending on your convenient and within a band of band of the control which you have accepted and vice versa.

In case it can be evaluated by a study of the eigenvalues so by the normal controller so you have to see that we have an eigen what are the values of the eigenvalue you get roots of the quadratic equations. If you have; you may have any order system ultimately whether model reduction technique you have to bring down the second-order system then only you can visualize the system better.

So, if you have a larger system and go for the eigenvalue and find it out that the eigenvalues positive or negative based on that you can go for the comment or you can apply any standard by method right now how is or anything because if you have a transfer function you can play a lot. Eigenvalue of the system linearized about the operating point because in nonlinear system so you have to linearize it.

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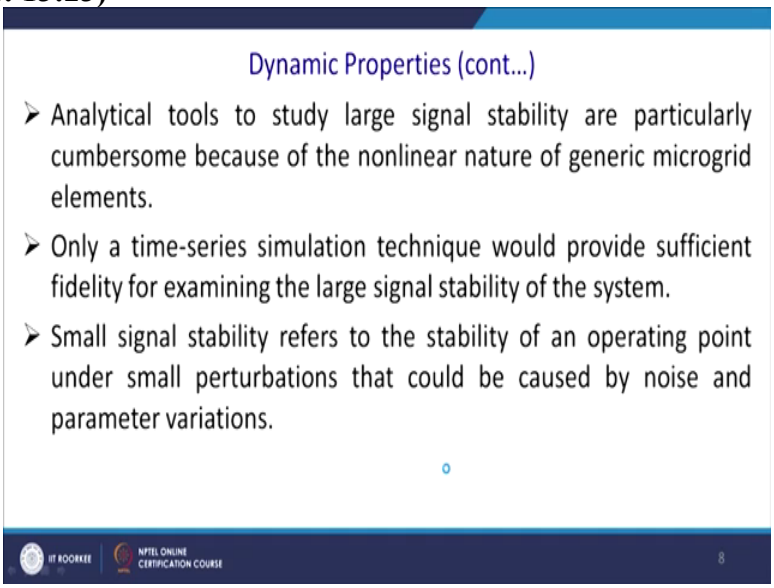


And analytical tools to study the large signal stability are particularly cumbersome because of the nonlinear nature of genetic microgrid element because essentially all the elements in the microgrid are comes with the power electronics element. Power electronics elements converts conversion of the power operation conversion of power electronics are nonlinear when you have one state there is a one set of state space equation.

Once it is off state is another state of state space equation and thus you come out of the average model. So, for this reason inherently those equations are nonlinear and thus when you put onto

the average modelling so you accept that some amount of linearization near the; it is operating point. So, that is what it is for this is in as time series simulation technique would provide a sufficient fidelity for examination of the large signal stability of the system that is something we may do that.

On the other hand the small signal stability refers to the stability of an operating point under small perturbations there are certain disturbances and that could be caused by the noise or the parameter variations, solar radiation change and all those things and how it system would respond generally it will settle down to the same operating point.

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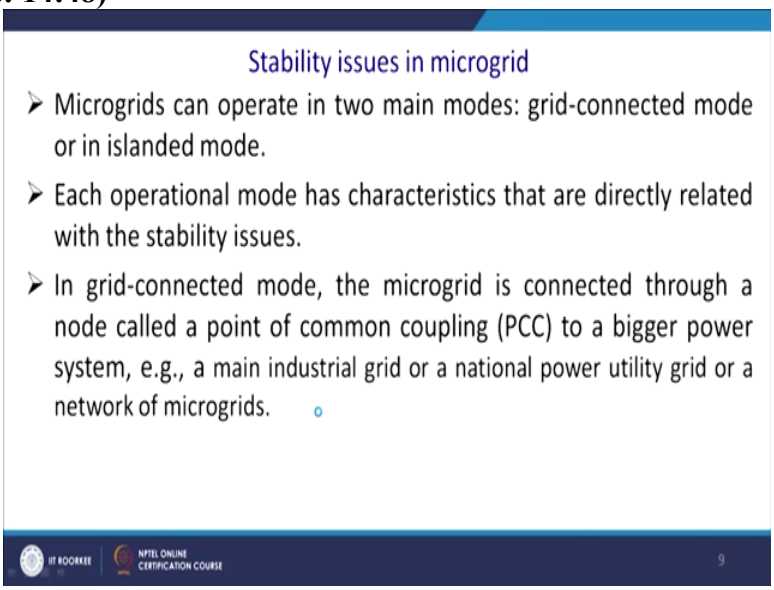


Microgrid can operate into the two main modes which we have discussed several times that is the grid-connected mode and islanding mode. Each operational mode has characteristics that are directly related within the stability issues. In grid-connected mode the microgrid is connected through a node called the point of the common coupling to a bigger power system main gate industrial grid or the national power utility grid or a network micro grid or anything.

In this operation what the dynamics is imposed by bigger power systems. So, ultimately the frequency will be determined by the external grid not by you. So, in case of the AC microgrid, since it is a DC micro grid so ultimately the entry point will be through the active, an active rectifier will set the voltage of your microgrid through a DC to DC converter.

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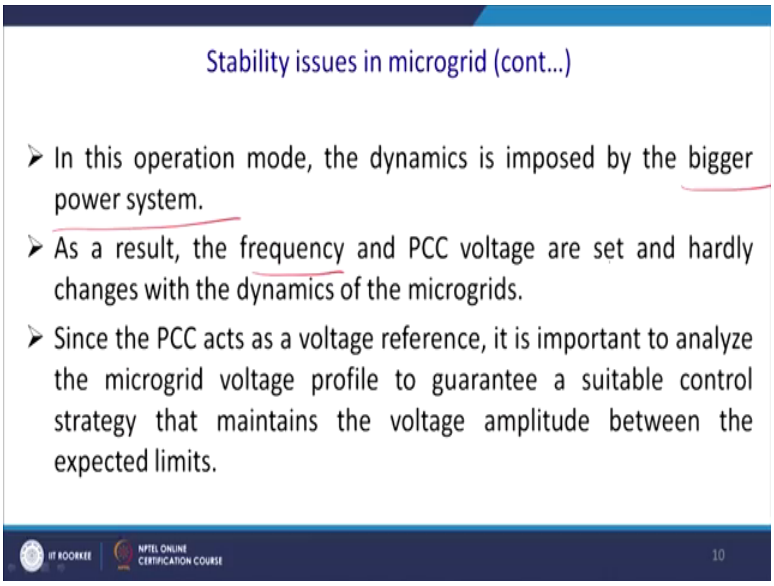


As a results if it is a AC microgrid the frequency and the voltage a voltage a set and hardly changes with the dynamics of the micro grid. Since your main grid is very rigid because think about the Indian grid we have only one great courtesy to the power grid Corporation of India it has got a huge inertia. And so sudden small change in the microgrid it is not going to affect anything in our main grid.

So, since the PCC acts as voltage reference it is important to analyze the micro grid voltage profile to guarantee the suitable control strategy that maintains the voltage amplitude within a expected limits. So, once you are exporting part you have energy surplus you will be in a one mode bus voltage may increase and if you are importing power they may will be energy deficit you will put this bus voltage in a different mode. So, the accordingly control will come into the picture.

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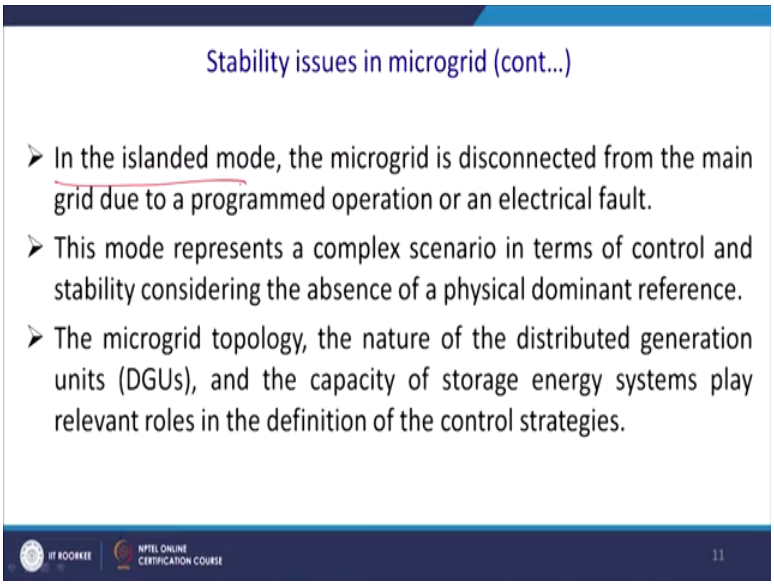


And once you have cut off from the grid that is quite important aspect. In islanding mode the microgrid is disconnected from the main grid due to programmed operation of the due to programmed operation it was something that you have; you want to; you do not know you may have this grid power is so costly that you want to manage by your own generations or the entry point to the grid has a fault in that case.

And these slit through our little complex scenario the mode of expresses a complex scenario in terms of the control and the stability considering absence of the physical dominance reference. So, who will set the voltage now that is something we have to keep in mind we have discussed in previous class that there is way their slack note and there will be a selfish note. So, who will be the slack note and that control has to decide.

The microgrid topology the nature of the distributed energy units and capacity of the storage system play relevant role in the definition of the control strategies.

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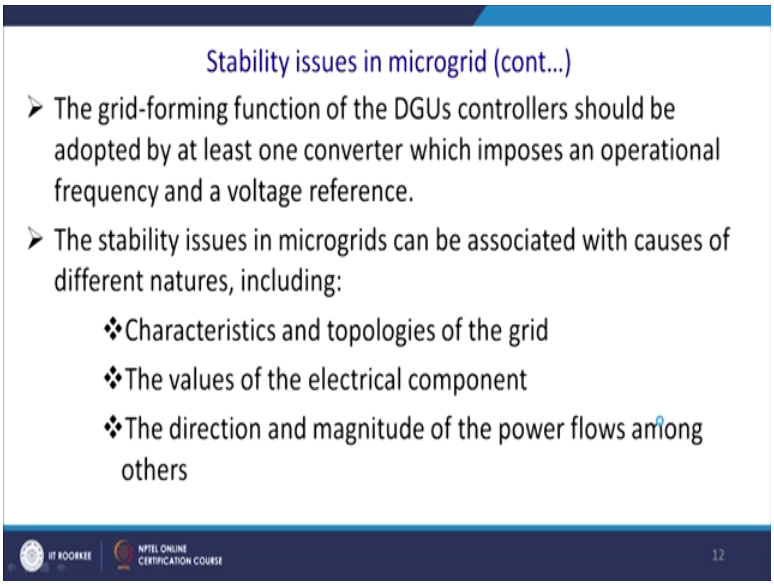


Now we are continuing with stability issues of the micro grid is required important aspect. The great forming functions of the distributed generated units that is the DGUs controller should adopt by at least one of the converter which imposes an operational frequency and the voltage level for the AC microgrid and for the voltage level for the DC microgrid. The stability issues of the microgrid can be associated with the cause of the different natures including characteristics and the topologies of the grid.

Value of the electrical component so that is something we have to think of. So, how fast how the dynamic response and the stability are generally conflicting in nature. So, you have to choose accordingly its dynamic characteristics and the topological aspects those issues power handling capability if it is isolated DC to DC converter then how much overloading is possible. So, these are the entities are the topological aspect that has to be considered.

So if it is operating little bit overloading condition what will be the losses so those all comes into the pictures. The value of the electrical components their rating has to be comes into the pictures while taking; giving into the some kind of loading and direction and the magnitude of the flow of the; among the other. So, there it is taking power giving power so we have seen a different kind of mechanism in a coordinated control.

So, accordingly direction of the park flow also will be decided by the DC to DC converters and that also play an important role deciding the role.

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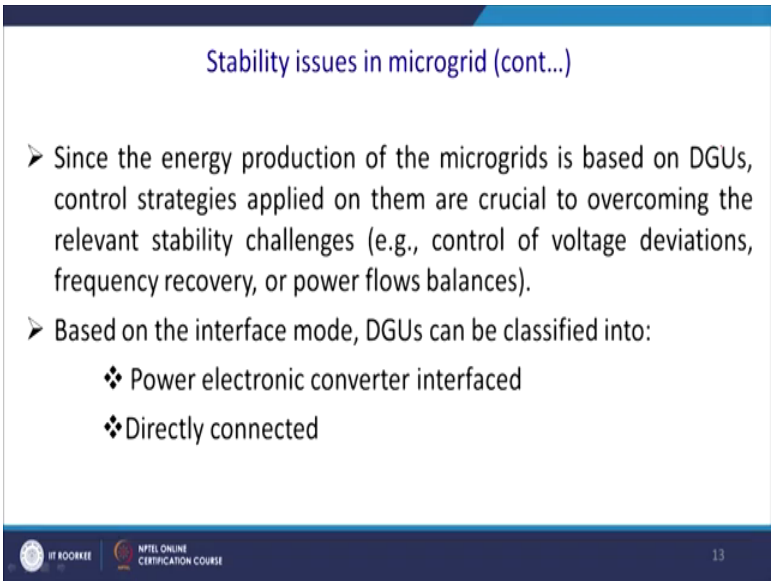


Now since the energy productions in the micro grid based on the distributed generation use it the control strategy applied on them are the crucial to overcome the relevant stability challenges. So, that is something we require to understand very thoroughly. For example control of the voltage deviation so how much a tolerance you only allow for the bus voltage to vary. And in case of the AC micro grid or hybrid microgrid the frequency recovery.

And the power flow balance what we are consuming what you are generating ultimately results may be transient features where we come from the ultra capacitor or the first response devices. Well ultimately you require to balance the power gradually and the grids worsen in case of the; you have many number of the CPLD that is constant power load. If you have a constant voltage of the loading then what will happen generally if you are more loading little bit voltage will sag down and thus your consumption will decrease and it will help to stabilize.

But in case of the constant power load once your load; once your bus voltage deeps since it continued to consume the same amount of the power it will attract more and more amount of current and thus things worsen. Based on the interface mode the DG's can be classified into the power electronics converter interface and directly connected. So, generally we will find that most of these are electric a power electric convertor interface because the bus voltage and the application voltage does not match.

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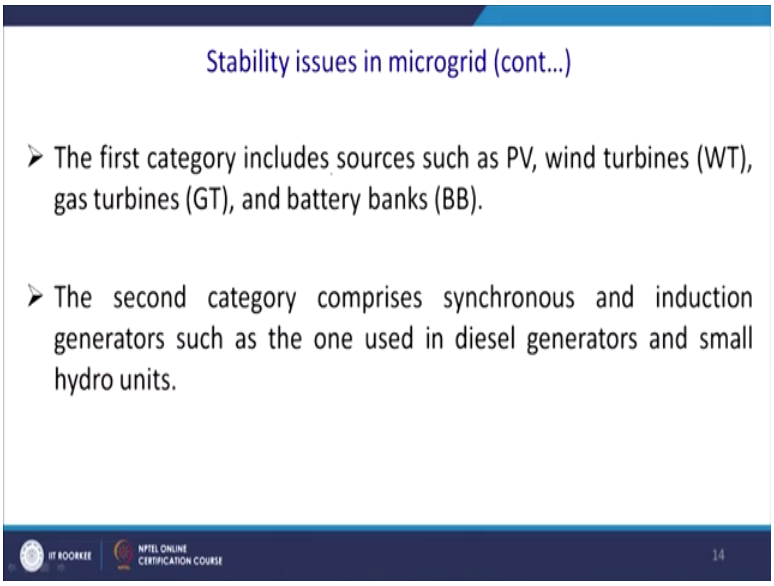


The first category includes the sources are as the PV panel, wind turbines because wind turbine is essentially a AC we required to convert into the DC and we require to both the cases we require to track the maximum power point and for this reason we require to have front end power convertor. The gas turbine and the battery banks, battery banks we require to charge in a different mode because it has to; because you cannot; because ultimately it is a chemical reaction.

Chemical reaction charging current should be such that it will simulate the faster chemical reaction. Once you start this process chemical reaction goes and picks up its peak after that it will gradually decrease. So, accordingly the charging pattern also required to change otherwise more hooding will be taking place. So, for this is a charging pattern has to be done with the in conditions with the; it is property of the material and accordingly the charging current required to be set.

The second category compromises the synchronous and the induction generators such as such as used one used in a diesel generator or the small hydro units. So, these are can we directly connect it to the DC bus voltage but field can be controlled by the field excitation. Now let us talk about little bit small signal stability and that is very important and we require to; and if it is not stable that it will have a sustained oscillation. And sustained oscillation we will may trip some relays and all other entities.

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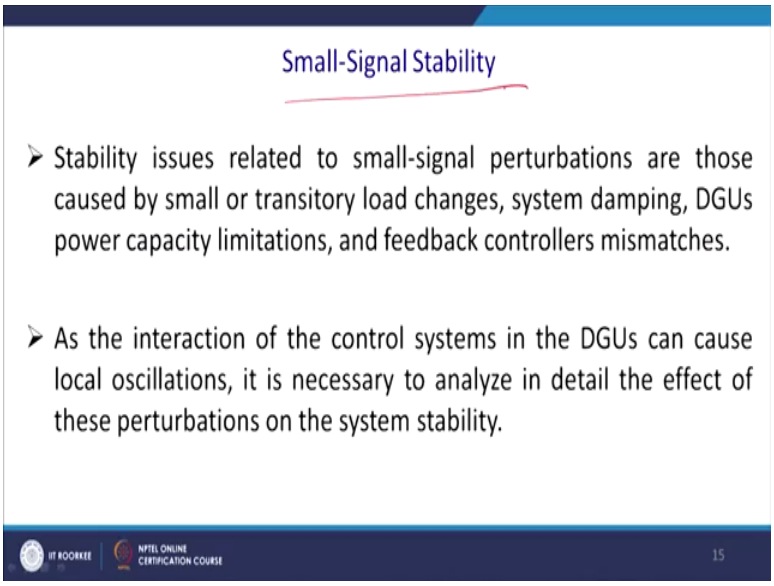


Stability uses this stability small signal stability uses a relatively small sing; a small perturbation those are called the small and translated load changes system damping. The distributed generated units power capability limitations and the feedback controller mismatch. So, there might be issues with the fidelity of the senses. All may be put into the; into the into this actually small signal stability problem.

It may be working very fine but your senses may be capturing little wrong data. It may be so that you find that your irradiation is such an unfortunately irradiation is been measured by the sensors that that tilted angle is not properly place to track the Sun radiation. And that there is a mismatch so you predict that something will come and ultimately you find an error. So, the impurity tracking will be irradiation.

All the interactions of the control systems in the DG's can cause local oscillations. It is necessary to analyze in detail effect of this perturbation on the system stability these are few aspects of the small signal analysis.

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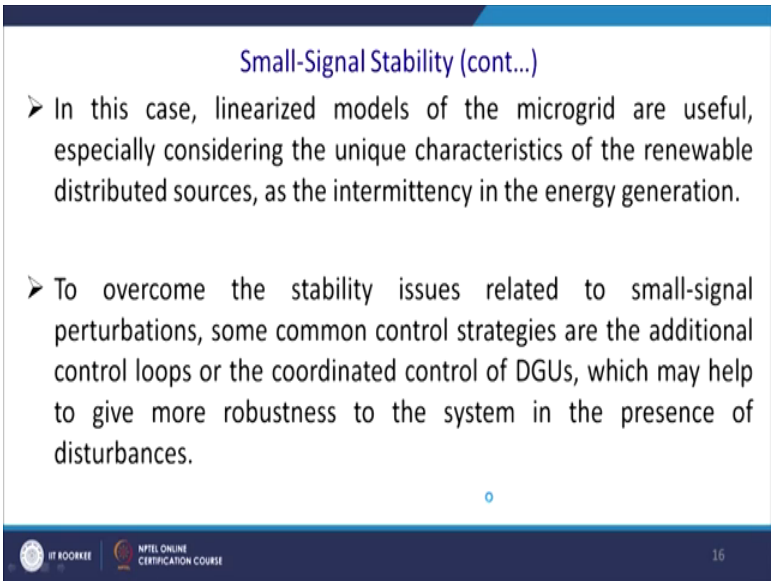


Now in case of the; because we require to; since we have a set of the differential equations and thus we write at state space model and test space model we use all those power electronics devices. So, you have on state and off state and thus we required to have average modelling. And average model is essentially a linearized modelling. In this case linearized models of the microgrids are useful.

Especially considering the unique characteristics of the renewable energy, renewable distributed sources as intermittency in the energy generation so you might it may change all of a sudden. So, solar irradiation may change wind may change state of a HFC of this battery may change and thus to account this intermittency comes into the pictures and that can be well captured by the linear model.

To overcome the stability issues related to the small signal perturbation some common control strategy very simple PI controller or any or PID that will work fine or additional control loops and are coordinated control of distributed generations are being preferred. Which may help to give us the robustness of the system in presence of the disturbance so closed-loop control only ensure that this disturbance has been mitigated at a damping can be possible sustained oscillation will be damped.

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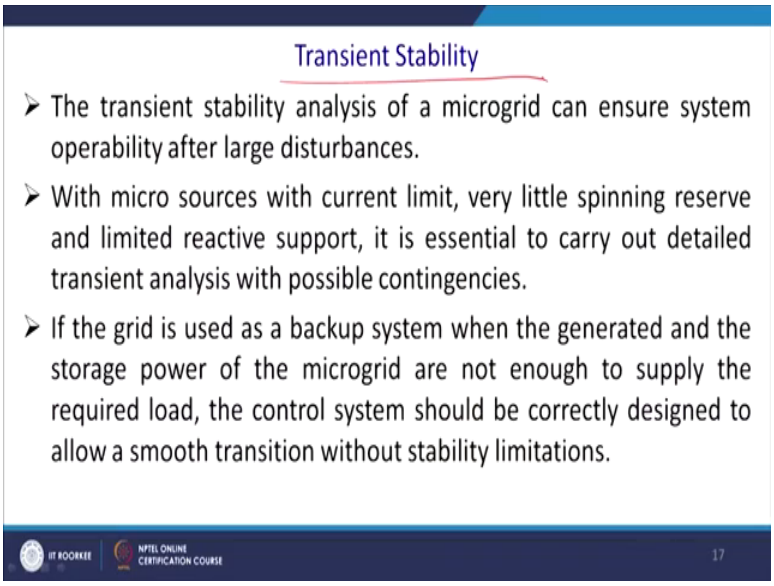


So, another aspect is a transient stability that is quite an important aspect of it. So, we have a sudden load change we have a sudden state transitions from on grid off grid. All those leads through the transients and that is we required to analyze this transient stability in detail. The transient stability analysis of the micro grid can ensure the system operatability after the last disturbances. Generally this is caused by the large change in the system.

With micro sources or the current limit, a little spinning since you have put that a current limited in every places very little spinning reserve and limited reactive support where voltage cannot be boost by the reactive support in case of the AC microgrid. It is essential to carry all that this detailed transient analysis with possible contingencies with the possible limitations. If the grid is used as a backup system when generated and the storage power of the micro grid and not enough to supply the required load that may be the; your point of action.

The control system control system should correctly design to allow smooth transitions without the causing the stability problem upgrade to one grid to other and vice versa.

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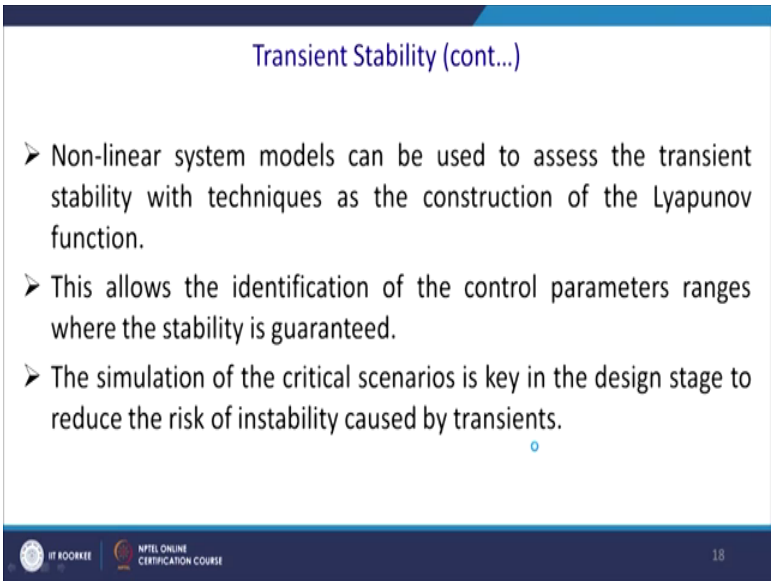


On the other hand nonlinear system model can be used to assess the transient stability. So, we require to understand that this system since it is a large load change your operating point will change and the system is totally nonlinear the average model will not work. And that is transient stability technique as a construction of the; we require to as put it as an energy functions that is Lyapunov stability functions. And we analyze that how energy goes down so that the system will be more stable.

This allows the identification of the control parameter ranges where the stability is guaranteed there it is a Lyapunov stability at large that is something we are trying to conclude. Sometime we simulated but we he required to do a proper simulation tool for it. The simulation of the critical scenarios is key that is called the Monte Carlo programming is key to design the stage to reduce the risk of the instability caused by this transient.

So, that is something we require to be designed for the contingencies. So, the transient can you taken care of nicely by your control system. Thank you, thank you for your attention we shall continue with more applications of the DC microgrid in our next classes.