DC Microgrid and Control System
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Lecture-40
General Summary of DC Microgrids

Welcome to our last lectures on the DC microgrid control. Today we shall summarize our course content and its advantage and what are the challenges available so that research scholars or the practicing technician practicing engineers like you people can address those channels. So, this is a; we shall discuss about the general summary of the DC microgrid. So, we have; please refer to our introductory classes we have discussed why microgrid, what is microgrid and all those.

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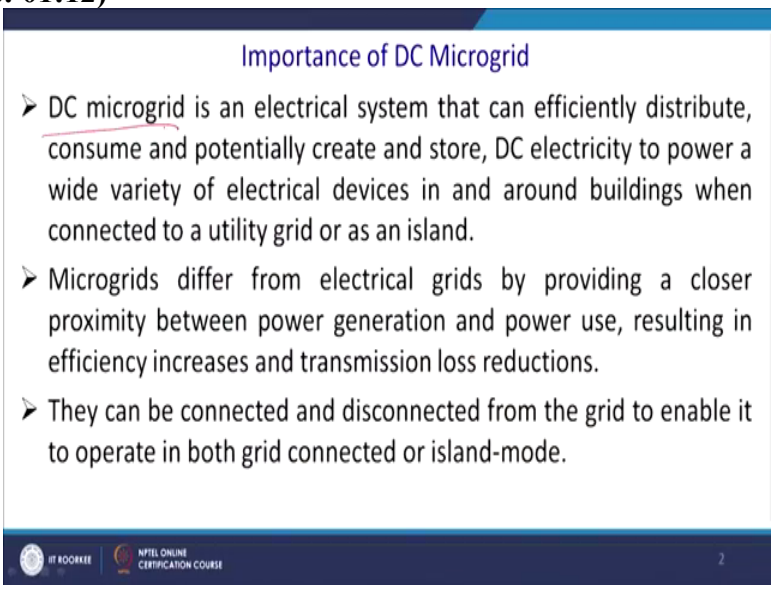

And after finishing this courses you are aware of those entities and that is what we can say that DC microgrid why it is important is that is an electrical system that can efficiently distribute consume and potentially create and store DC electricity to power a variety of the electrical devices in and around the building when connected with a utility grid or in islanding mode. This is the one of the entity and with the penetration of the solar and the storage device being battery.

So we have it is better to have a direct DC to DC conversion instead of have multiple point conversion of multiple point conversion of AC to DC or DC to DC. The microgrids differ from the electrical grid by providing a close proximity to the generator and the power use. Resulting in efficiency increases and transmission loss reduction please go back to the old battle of Nikola Tesla and this those one of the main advantage of the Nikola Tesla with the AC that you can step

up the voltage and thus conduction losses will come down.

And generally load centres and the generator units are being divided by the space. But since this space is no longer existing and thus you have a potential to reintroduce the DC and they can be connected or disconnected from the grid to enable it to operate in both grid connected on the islanding mode.

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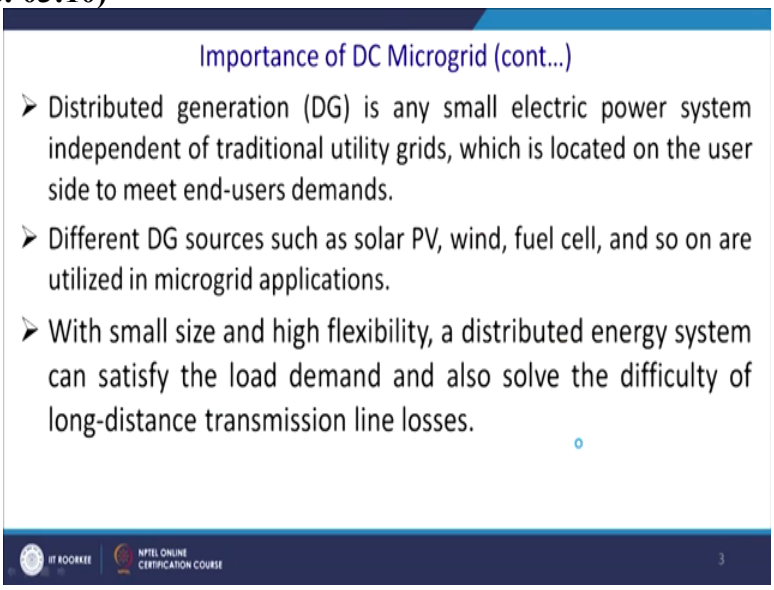

Thus you have you may have a distributed generations most of the cases with these microgrids in small electric power system independent of traditional and utility grid Windmill solar or you may have a biomass which is located on the user side of the; so user side to meet that end users demand. Different DG's such as solar PV, wind, fuel cells and so on are utilized in the microgrid application.

So, you can harvest power so the consumers can also be the hardener of the power. With a small size and high flexibility we have seen different kind of architecture of that DC microgrid and auto microgrid you know our initial lectures are distributed energy system can satisfy the load demand and also solved the difficulty of long distance transmission losses. So, you do not have any time the TND losses.

Because transmission losses will be 0 because you are very close proximity to your load and source another all main aspect was in distribution system was since the consumer is an entity and the supplier is another entity. There in a mode of conflict most of the cases the condition of the theft and all those issues are there. And to you may; as since you are making the consumer also

the stakeholder to this microgrid due to this involvement and participation those activities has been drastically reduced.

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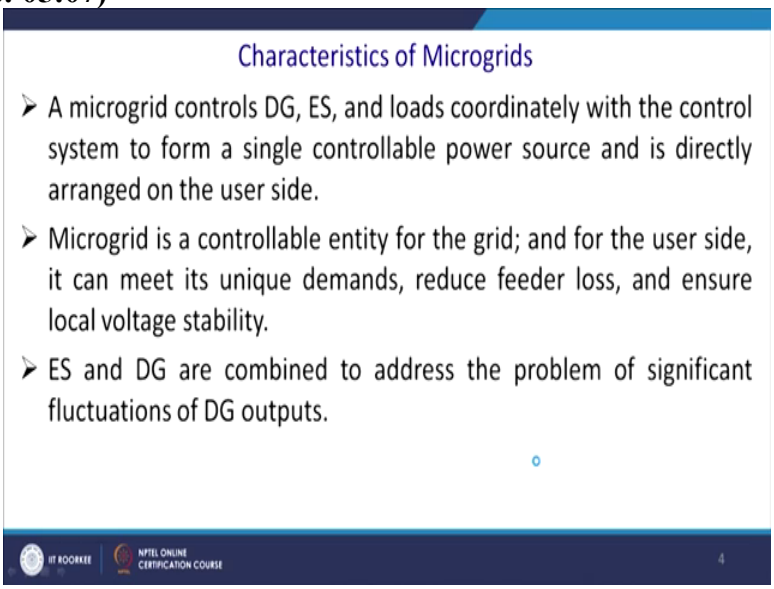

A microgrid control distributed control and the storage elements and the load coordinates themselves with the control system to form a single controllable power source and is directly arranged to the end-users. So, this is something we have to understand this whole itself is an entity. microgrid is controllable entity for the grid and for the user side and it can meet the unique demand. So, you may have a particular function say at the particular microgrid so it can fetch little bit more power from other microgrid.

And it can share and reduce the feeder losses and ensure the local voltage stability. So, you may have a peer-to-peer networks and all those entities we have discussed and that by that applying we can ensure the local voltage stability. And this energy stream storage element and DG's that is distributed generations are combined to address the problem of significant fluctuations of the DG outputs. So, that is something we required to keep in mind.

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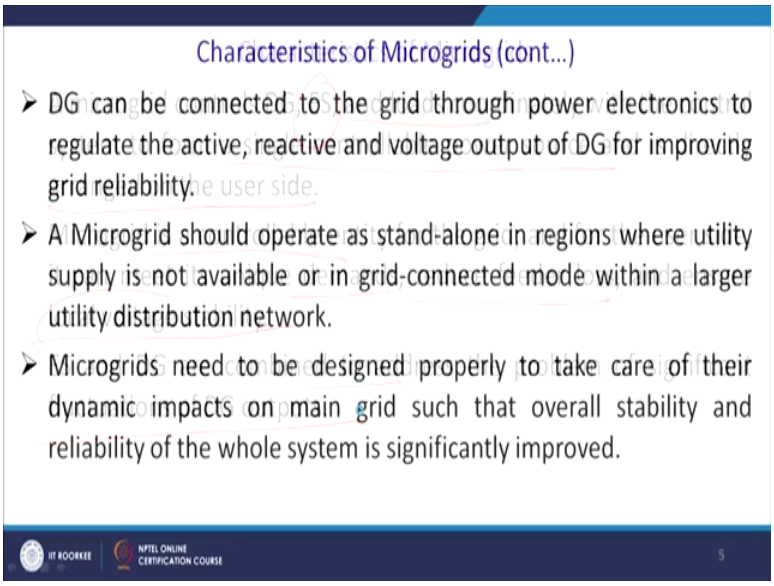

Moreover DG can be connected to the grid through the power electronics to regulate the peak you control that is active reactive control once you are injecting or taking power from the grid we have to maintain the grid code and the voltage output or the DG's further improving the great reliability. Sometimes we may feed the reactive power if required to get stabilisation and all those issues.

A microgrid should operate at stand-alone in region where utility supply is not available or you have a blackout for some days. In grid connected mode within a large utility distribution network, so this is also possible so it is flexibility is more. Microgrids need to be designed properly to take care of their dynamic impacts on the main grid's such that overall stability and reliability of the whole system is significantly improves.

So that is the whole idea of the microgrid so it needs to be designed properly to take care of their dynamics impacts that is a load change or adding our plug-and-play kind of devices or main grid such that the overall stability and the reliability of the whole system is significantly improved.

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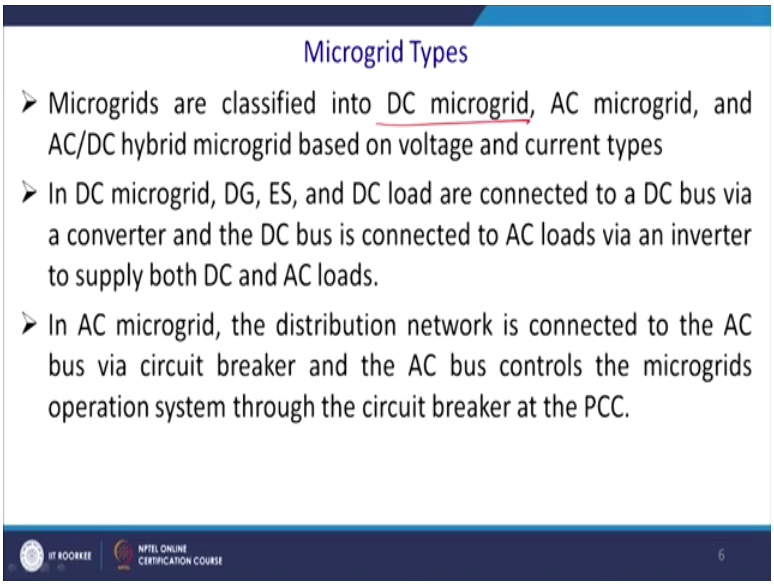

Microgrids are we have already discussed those again we are just recapitulating DC microgrid AC microgrid an AC/DC hybrid microgrid based on their voltage and the current types and our discussions was from the microgrid we gradually talk about more about the DC microgrid. Please understand to understand this well but first we required to understand the microgrid. So, for this reason in first few lectures you will find we had discussing all these three type of microgrid.

Because DC microgrid some time is existing as a hybrid microgrid and so while you are studying and DC microgrid we required to understand its interaction with the other microgrid present to the system. In DC microgrid this DG's distributed generation and EC and this energy storage and the DC loads are connected to our DC bus via converter and this DC bus is connected to the AC load by an inverter to supply this DC and the AC load respectively.

So, we may have a conversion and that is useful also because once you are converting AC to DC there after AC then you are throwing the rest of your AC system. So, once you are converting only DC to AC that entity is missing. In AC microgrid the distribution network is connected to the AC circuits by means of the circuit breaker and AC bus control. The microgrid operation system through the circuit breaker at the point of common coupling.

So, this is quite easy to connect so you have a circuit breakers and Isolators that is a way generally how the substation power comes to you. But in cases that you see we require our active rectifier.

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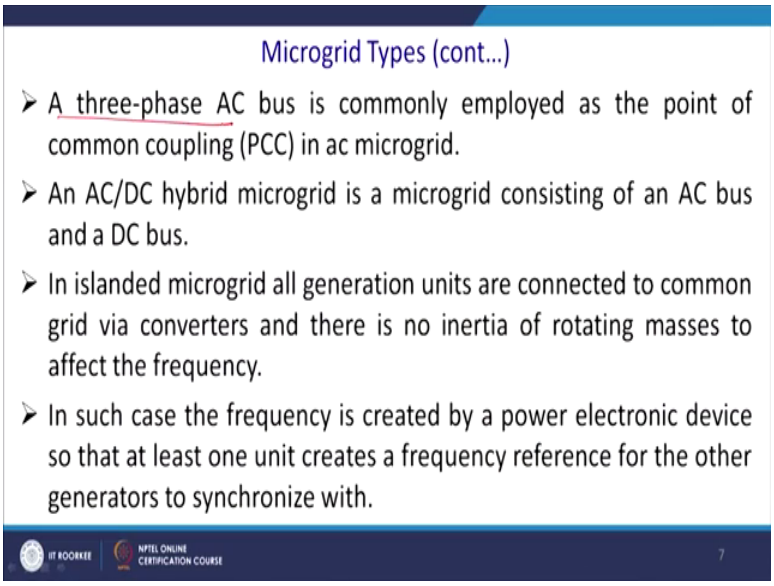

The 3-phase AC bus is commonly employed as a point of the common coupling please understand that if the load is more than 3 kilowatt generally we require to go for the 6 phase, 3 phase. So, AC/DC hybrid microgrid is a microgrid consisting of the AC bus and a DC bus in islanding microgrid all the generation unit are connected to common ground or common grid by a converter. And there is no inertia of the rotating masses to affect the frequency this is one of the very big disadvantage.

So, since you do not have any rotating entity and since you have only the switching devices. So, inertia of the system is much, much less than the conventional convention and your synchronous generator. So, inertia will come down for this reason it require very fast action of the controller. Controller has to act but quite fast compared to your SCADA and conventional grid. In such cases the frequencies is created by the power electronics devices.

Students are requested to see that white papers of the any solar company a say for example there's a German company like SMA, white papers of SMA with their upgrade solution. So, they have that particular entity is called Sonny called Sonny Boy and it forms the grid and all other inverter follows it. In such cases the frequency is created by the power electronics devices so that at least one or one unit creates the frequency difference for the other generator to synchronize it.

Please mind it while in the case of the normal synchronization your biggest generator generally sets the frequency. But here it is not the so you can make any solar unit any unit can be a your setting of the frequency you have discussed this entities in detail in our previous lectures. Generally energy resource like the entities which has a maximum power handling capability

generally made to control the frequency. Like battery and solar may be at the point it is controlling.

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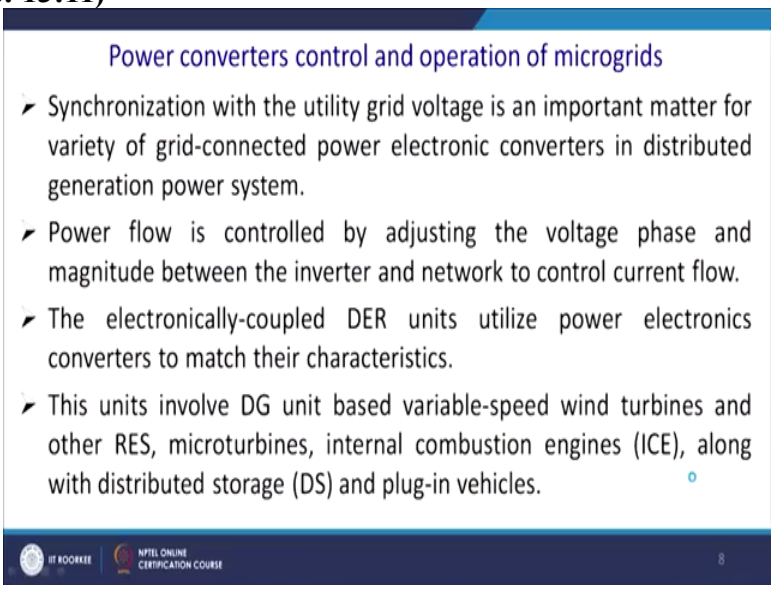

Synchronization with the utility grade voltage is an important matter for the variety of the grid connected power electrics converter in distributed power generation system. So, we have to read required to see that what is the point of entry, so that we can give the redundancy. If the particular converter is non-functional you can manage to send power through the grid or you can take out power to the grid so this kind of architecture we have already discussed and is one of the important criteria while the power converter control and the operations of the microgrids.

So power flow is controlled by adjusting the voltage phases and the magnitude between the inverter and inverter and the network to control the current flow. The economically coupled sorry electronically coupled DER units utilize power electronic converter to match their characteristics. This unit involves distributed generator units based on the variable speed wind turbines and there RE's micro turbines, internal combustion engines sometime it may be there or the generator along with the distributed storage maybe the batteries and the plug-in electric vehicle. All comes into the pictures of this microgrid of it as an entity.

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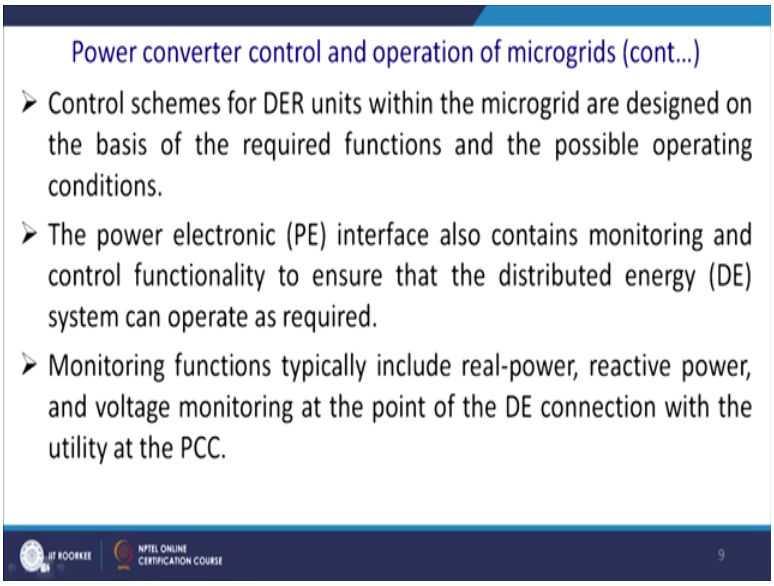

So, the control scheme of DER units within the microgrids are designed on the basis of the required functions and the possible operating conditions. The power electronics P reference also contains the monitoring and that control functionality to ensure that the distributed generating unit that is PE system can operate as required. So, it may require to pick you control it may require the droop control for the DC microgrid.

It when occur the PYF control so all those entity can be factored into this distributed generation by the power electronics interface. Monitoring function is typically included a real time real power and the reactive power and the voltage monitoring at the point of this DE connections with the utility with the precession. So, that is the requirement so you require to have real power reactive power and the voltage monitoring generally at is the entry point of the grid to the microgrid.

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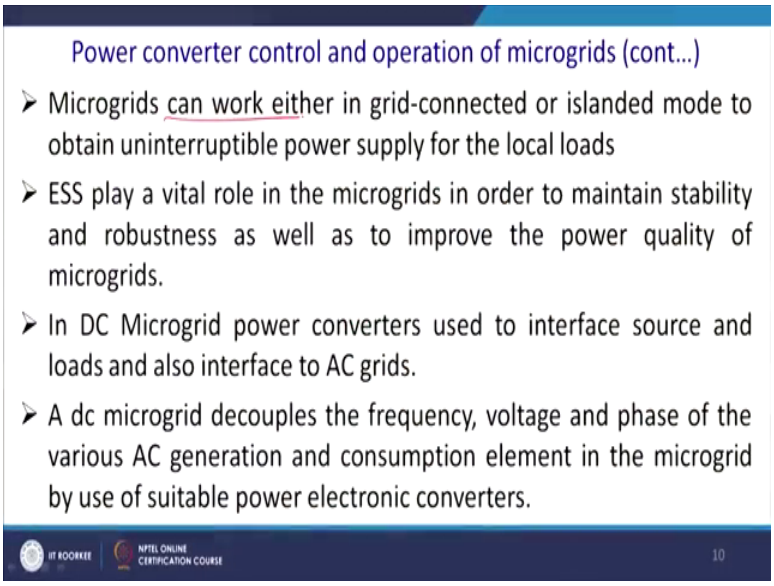

So, microgrid can work either in grid connected or islanding mode to obtained and in interruptible power supplied for the loads. ESS play a vital role in microgrid in order to maintain the stability and the robustness as well as to improve the poor quality of the microgrids. In DC microgrid power converter are used to interface source and the loads and also the interface to the microgrids.

The DC microgrid decouples the frequency voltage and the phase of the various AC generations and consumption element in the microgrid by use of the suitable power electronics converter. So, this is the part of the DC microgrid application in the power electronics.

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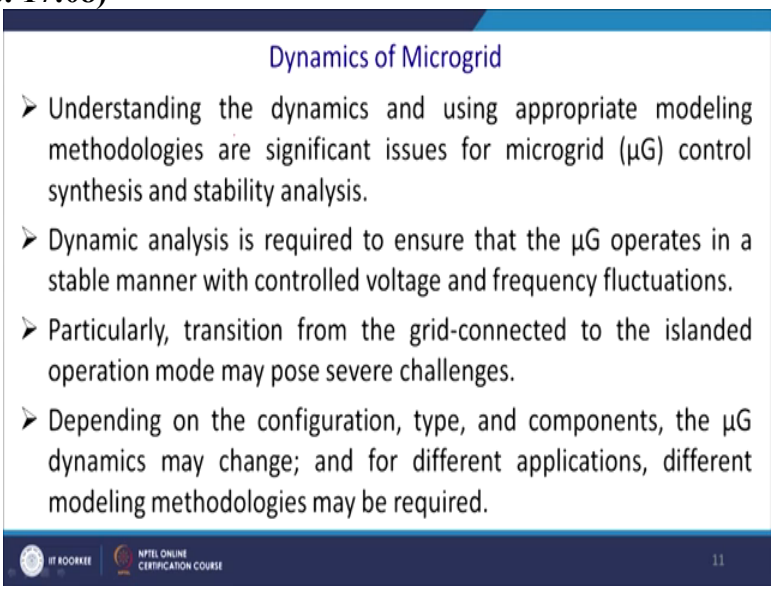

So, understanding the dynamics of the microgrid that is one of the important entity that we required to consider. Understanding the dynamics and the using appropriate modelling of the

microgrids are significant issues for the microgrid control synthesis and the stability analysis dynamic analysis is required to ensure that the microgrid operates in a stable manner with control voltage and the frequency fluctuations for interaction with AC DC microgrid or hybrid microgrid.

Particularly transitions from grid connected to that landing operations may pause in a post several challenges that is something we required to address also. Depending on the configurations type and the components the microgrid dynamics may change and for the different application and the different modelling method may be require. We have seen that we have applied different control strategies different modelling strategies to understand but understand on the dynamic characteristics of the microgrid.

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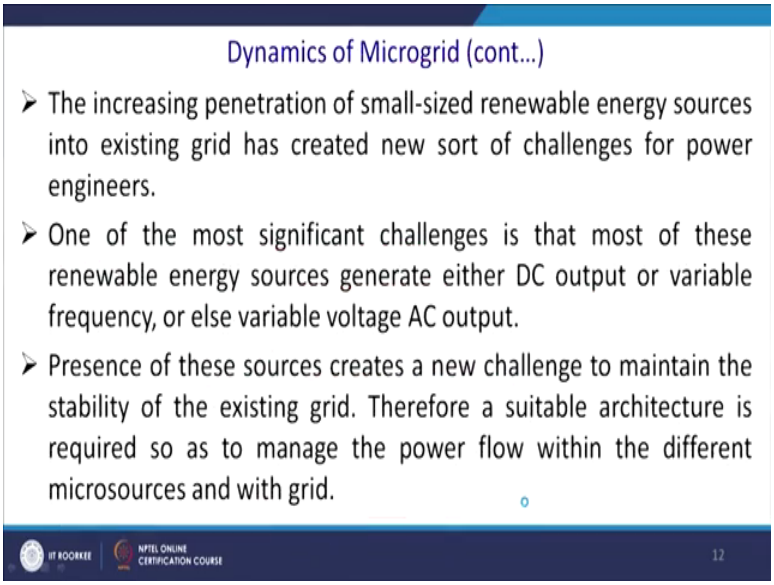

The increasing penetrations of small size renewable energy sources into existing microgrid has created a new short of challenges in a power electrical engineers that is something we require to address it being a future researcher. One of the most significant challenges is that the most of this renewable energy sources generate either DC output or variable frequency or else the variable voltage AC output that is something is that we require to, address it.

Presence of the source because solar and we based on the irradiation will change if you have a CPLD, current value will change if you change the voltage. So, ultimately there are lot of must watch into the system and we required to address this challenge. Presence of the sources creates new challenges to maintain the stability of the existing grid because you know that in case of the

synchronous generator it will inject the power to the grid at a constant voltage.

But it is unlikely in case of the microgrid so solar would give you the voltage depending on irradiation. Therefore a suitable architecture is required so that to manage the power flow within that different micro sources within the microgrid. Now microgrid integration that is also one of the important characteristics to coordination of the resource of the load can be based on either centralization on the decentralization approach.

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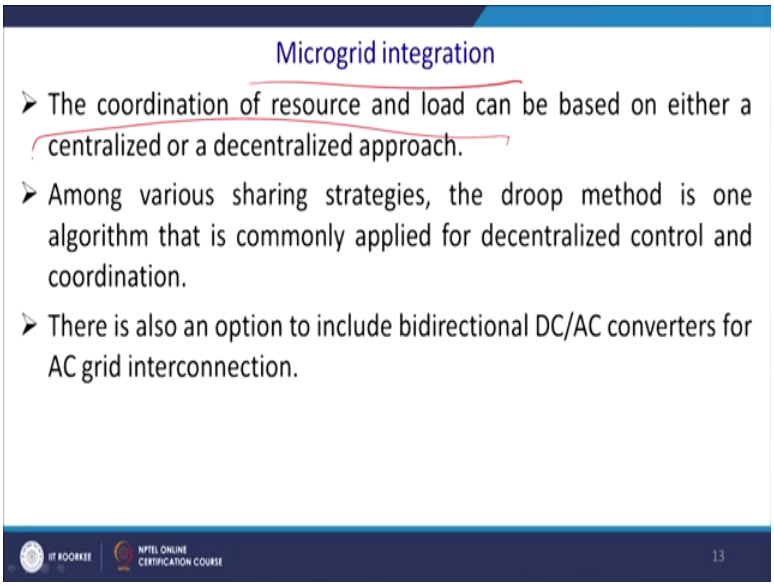

This has been discussed among the various sharing strategies our droop method is one of algorithm and that is commonly applied for the decentralized strategies. And we prefer also the decentralized strategy to reduce the loading of the centralized system. There is also an option to include the bi-direction and digital DC converter for the AC grid interconnections so that power can flow from grid side to the microgrid and vice versa.

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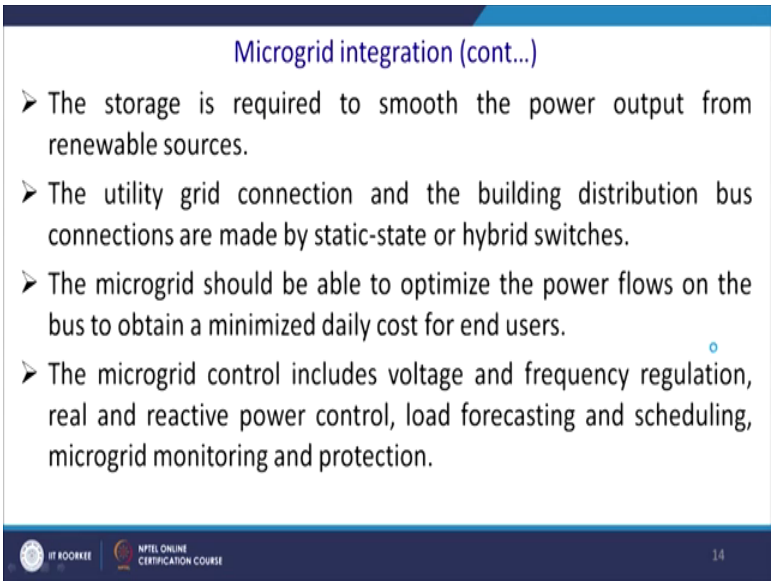

And thereafter since such a generation peak of this renewable energies and the demand peak because of the behavioural pattern of the human being are not same and for this reason we require power storage. And storage is required to smooth the power output from the renewable energy sources. And you can make a 0 peak big building like that. The utility grid connections and the building distributions bus connections are made by static state or the hybrid switches.

The microgrid should be able to optimize the power flow on the bus to obtain minimized daily cost for the end-users that is something we want to ensure. The microgrid control includes voltage and the frequency regulations real and the reactive power control, load forecasting. So, that is something from the pattern of the history you focused it, scheduling because you want to change that particular pattern or the behaviour gradually with the consumers so that you can try to match the peaks of this input peak of the generation picks and the load peak close to each other.

So, that size of this storage element reduces and the microgrid monitoring and the protection. Protection is very important issue especially in the DC microgrid because it does not have a normal 0 as explained in case of the AC system.

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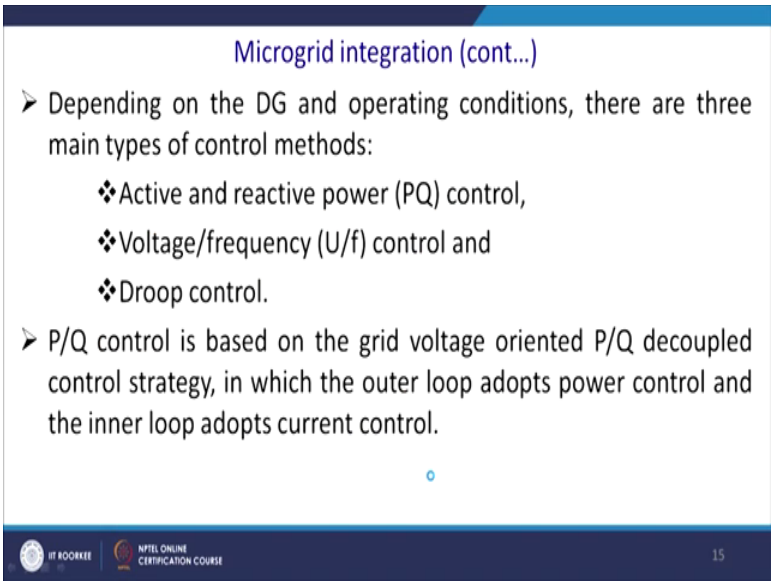

And generally we have discussed in detail all these three control that is integration. Depending on the distributed generator and operating conditions there are three main types of the control. One is active reactive power control voltage frequency control and the droop control, PQ control is based on the grid voltage oriented PQ decoupled control strategy in which the outer loop adopts the power control and the inner loop adopts the current control.

So that is the something we require to follow we have discussed in detail in our lectures please refer to those lectures.

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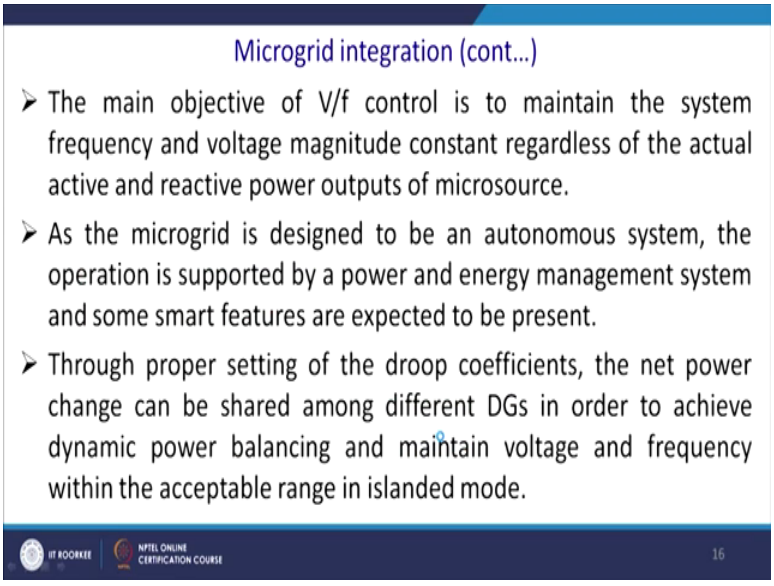

And thereafter the main objective of the V by F control is to maintain the system because if you control the system frequency very of control if you do it there is flux become constant. And so

the AC system which can have in case of the AC microgrid can run very well. So, of course it is for the AC microgrid or the hybrid microgrid not for the DC microgrid. But you may have such that one microgrid is running close to you and is V by F control. And another you want to integrate it to the DC microgrid.

So then you may go for the PQ control and we record to switch over. As the microgrid is designed to be an autonomous system the operations is supported by the power in the energy when is resistive and some smart features are expected to present. What happen if you do the V by F control then what will happen if you just reduce since may assume that your power is low and thus you have made V by F control.

So, what will happen your torque will remain constant but speed will come down may be little bit and thus you know your fan may run 5% less speed but you know it would not feel that it is running at a 5% less speed. So, this is a beauty of the V by F controlled. The whole idea of the microgrid is to give proper energy management with least discomfort to the consumers. So, through the proper settings of the group efficiencies the net power change can be shared among the different DG's in order to achieve the micro dynamic power balance and maintain the voltage and frequency within the acceptable range of the islanding mode.

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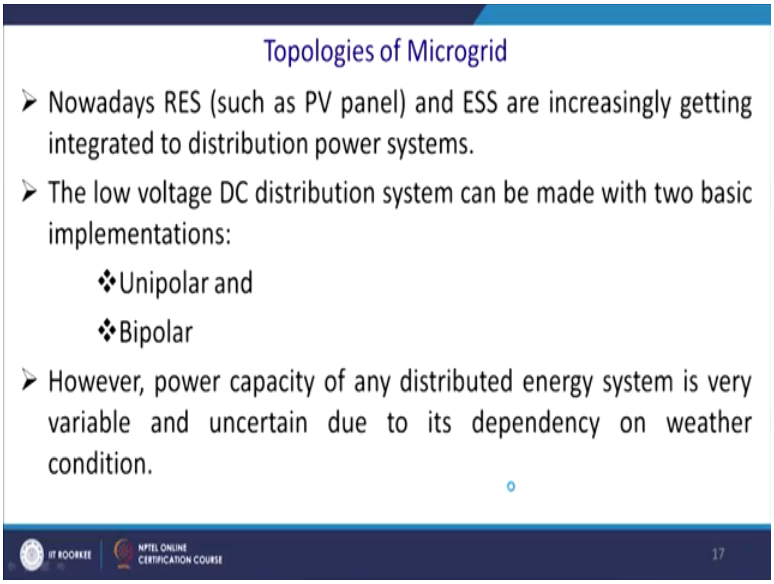

And another we have discussed topologies of the microgrid we just recapitulating it again here these are unipolar and the bipolar microgrid. Nowadays we have seen that bipolar microgrid gives you more redundancy. So, nowadays I this IS set an energy resources such as PV panel and

the in NND storage element are increasingly getting integrated in the distributed power systems and thus you may have a unipolar topology you supply plus.

And ground or zero and you plot; you supply plus minus and ground and thus you have a redundancy if one line goes up you can sub; still keep on supply on the other line. However capacity of any distributed energy system is it is very is very variable and uncertain due to that dependency on the weather condition. Is extremely variable and is uncertain due to the weather condition.

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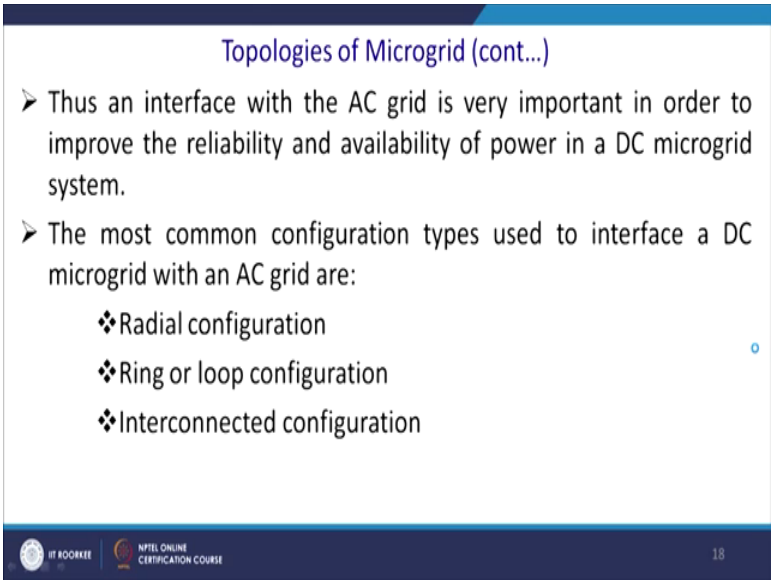

So, now what you have based on that we have to ensure the redundancy we have a different kind of configuration. These are the radial configurations ring configuration income interconnected configuration we have seen in detail all those configurations and we have to choose accordingly if you wish to give a more redundancy. W will choose maybe the ring or loop configuration thereafter we may go for the interconnected configuration to give proper adjustment of your redundancies.

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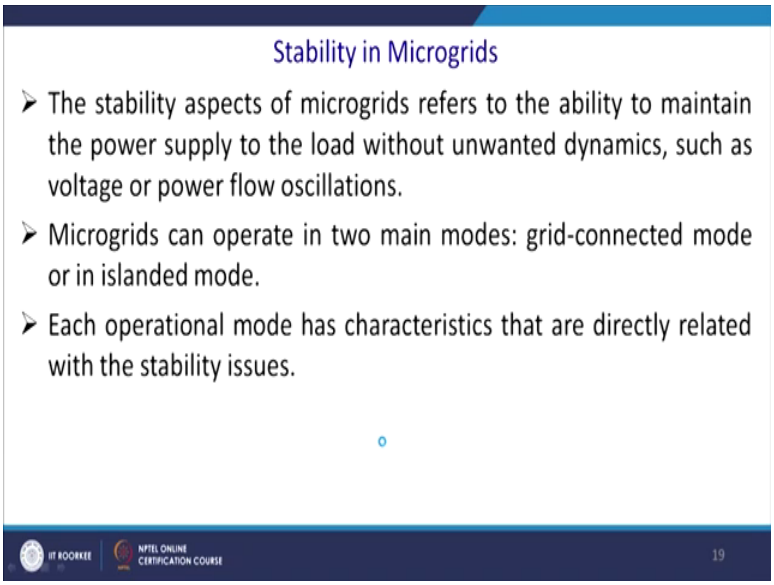

Now stability this is the thing we are discussing for past few lectures. Stability of the microgrid is a very big challenge because of the non-linear issues. And you have a CPLD of a penetration of the CPLD you want that the system to be a plug in plug type you say you wish to switch on a fan you do not bother to put a switch. But in case of the microgrid small load change can we design and properly taken care of by your small signal analysis of the control system.

But if there is a huge load change so then generally it is it cannot be taken care of by the small signal analysis tells us what happened the stability aspect of the microgrid refers to the ability to maintain the power supply and the load without unwanted dynamics such as voltage and the power flow oscillations. And that is what happened microgrid has to operate in a niche container in the islanding mode.

And generally we see that which mode is preferable than each operation mode has have a different characteristics different stability analysis.

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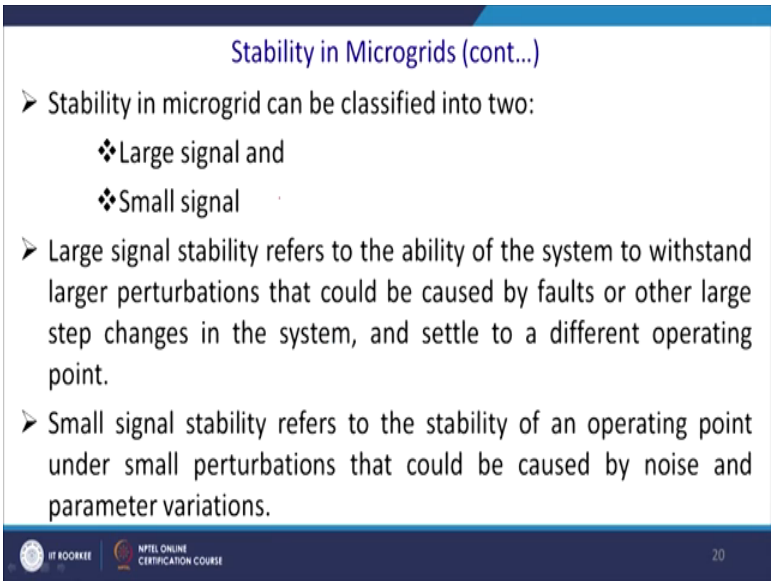

Now for this is what I was discussing we have a large signals as in a small signals. Large signal stability refers to the stability of the system or twist and a large variation of the perturbations and for this reason we find that non-linear control frequently inhalation or the sliding mode controller better. And in case of the small signal analysis we can apply to that our normal control system.

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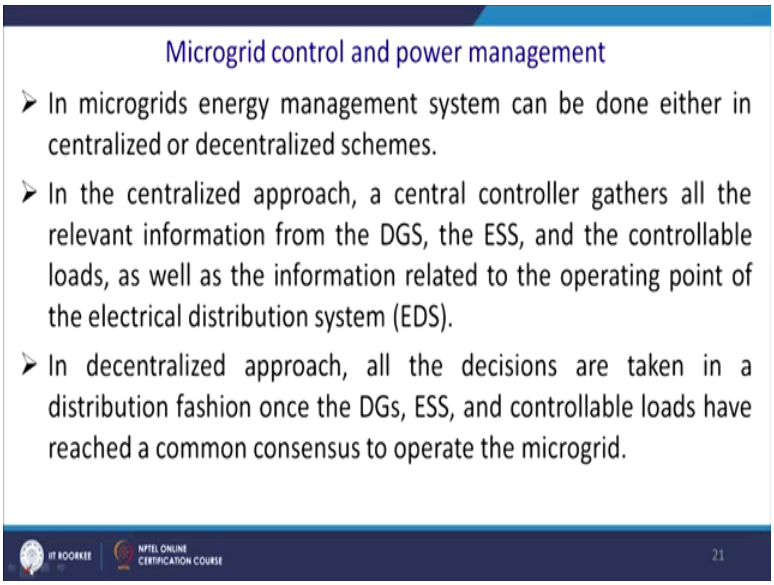

Now micro-grid and the control bar management that is also an issue we have to have an integrated system proper power management required to be placed. And we may have a different kind of approach another one approach is a centralized approach. A centralized approach takes all the information from the online energy resource center DG's and then it gives the instruction otherwise you may have a decentralized approach decision taken in a distribution fashion's.

Once DG's and he ESS are controllable to the local load so generally for this redundancy and all we prefer that this decentralize method.

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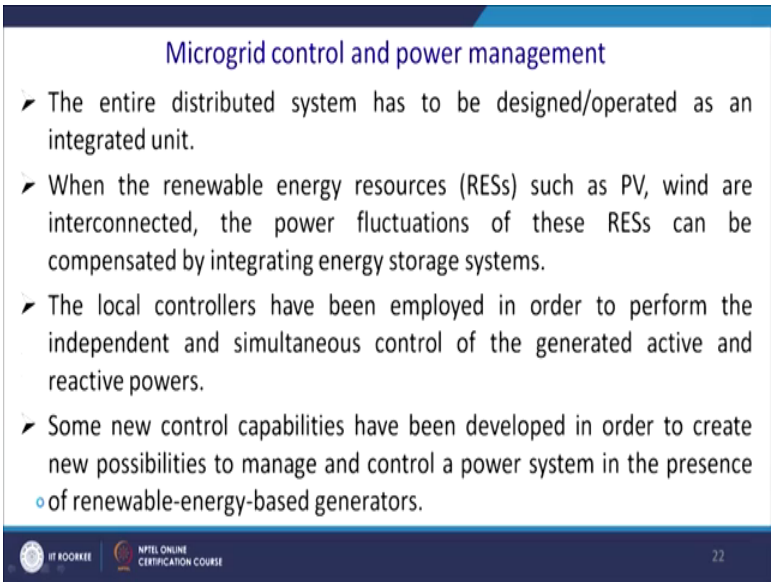

And apart from that so this is that when the renewable energy resources such as PV wind are interconnected. The power fractionation of this distributed energy sources can we comprehend sitting or can be compensated by integrating the storage element. So, sometimes even agreed from commitment so we can ensure that this commitment by the storage element. The local controllers have been employed in order to perform the independent and the simultaneous control and we generated the active and reactive power.

And some new control capabilities has been developed in order to create a new possibility to manage the control and the power system in presence of the renewable energy system. So, there is also some challenges for this proper control and the power management in case of the DC microgrid. So, thank you for your attention we thus conclude our course on DC microgrid. And these are all the entities that is, broadly whichever cover in our last classes.

These are the potential research topic for the all the researcher that is the microgrid and the power management they are after we have talked about the stability of the microgrid also student can student from this power system background generally prefers to work or will work in the power management. And definitely control will be control and stability aspect should be taken care of by the power system people and optimizations people.

They are after they have a topological aspect of the microgrid that can be well addressed found

up from the students or the researcher or the practicing engineer from the power electronics background. And there the integration also this comes under power electronics some extent. And thereafter we have a dynamics of the microgrids then again it is a control entity. Thus and again we are I am silent because I am from the electrical background.

So, there is a huge challenge also to incorporate communications especially in the centralized control scheme. So, thus DC microgrid is a multidisciplinary subject it takes the input from power electronics, it takes the input from the control, it takes the input from this power systems as well as the communications. And instrumentations in other takes input from the all the entities and thus come out as a concept.

Thank you for your attention so we you have studied a power system of instrumentation. Now we should have microgrid system instrumentations as new course. So, application we have seen the power electronics application in the large distribution system like fax. Now we have microgrid applications and we may also have a load flow studies for the microgrid and harmonic studies. So, all those; what we have seen in a large scale it has been boiled down to the single point the DC microgrid.

And it has a huge potential and advantage considering that we are going for the more renewable we are talking about non zero peak building. We are talking about the zero emission building but all those entities has a huge potential. Thank you so much for your attention and looking forward hope that your course this course will be beneficial for your future learning or as a research practitioner or the research scholars in the field of the microgrid, thank you so much indeed.