DC Microgrid and Control System
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Lecture - 28
DC Microgrid System Architecture and AC Interface

Welcome to our lectures on the DC microgrid and the Control. We shall continue with the DC microgrid architectures and its interface with AC. So, what we were saying that there is a bipolar and the unipolar DC microgrid.

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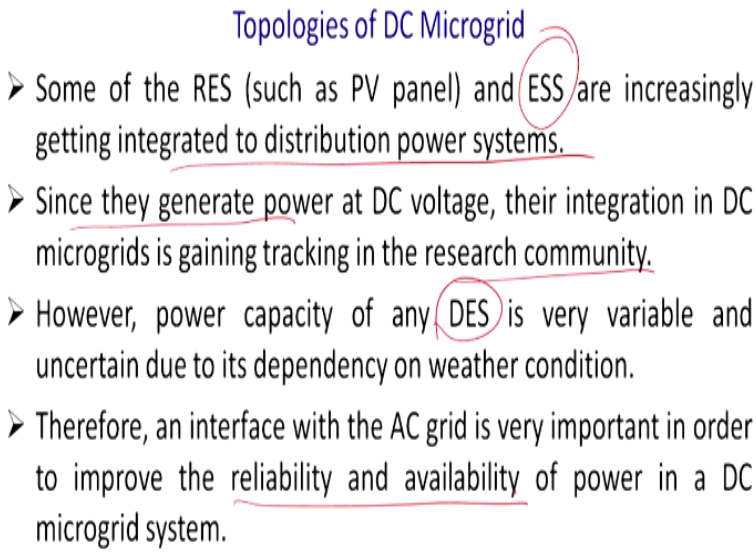

So, some of the energy resources, so there is a PV panel and ESS that is the battery cells energy storage are increasingly getting integrated to the power distribution system and we are now coming into the concept of the zero peal house. So, you have to flatten your load and thus you can have a zero peak community and so same way it can be extended to the zero big city. So, this is the new concept is emerging. Since the zero generated power at the DC voltage, their integration in the in DC microgrid is getting cracking in research community.

However, problem is that the power capacity of this distributed generations are variable. So, solar, one of the problems of solar is huge uncertainty are very variable and uncertain due to depending on the weather conditions. Therefore, the interface with the AC grids is very important in order to improve the reliability and the available of the power to the DC microgrid system if it is not placed in isolated locations, and if there is an existing grid, so you should be using it and thus we should try to interact with the DC grid.

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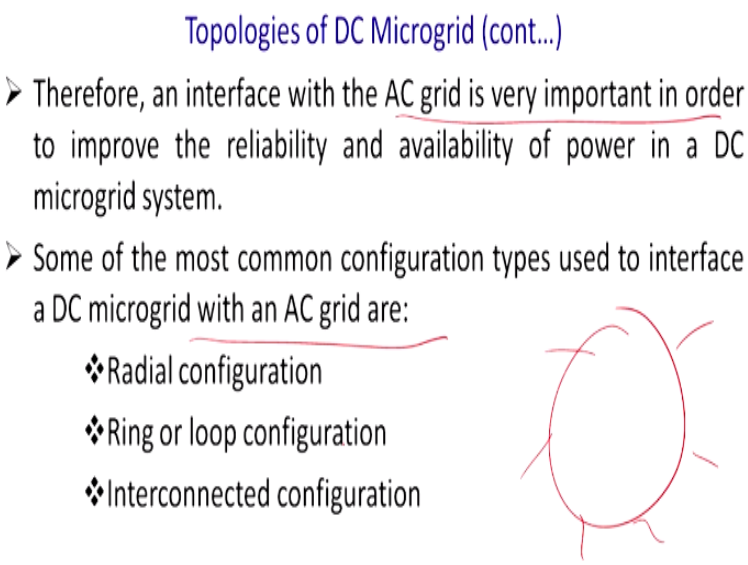

So, for this reason, therefore, the interface of the AC grid is very important in order to improve the reliability, availability of the power in a DC microgrid system. Some of the most common configuration type used to the interface a DC microgrid to the AC grids are we shall show you if you have idea of the AC transmission system, these are you are quite aware of the radial configuration, so you connect all the load radially, thereafter you got a ring loop configuration, and interconnected configurations. These are typical AC configuration, but in we shall see that what is little change here.

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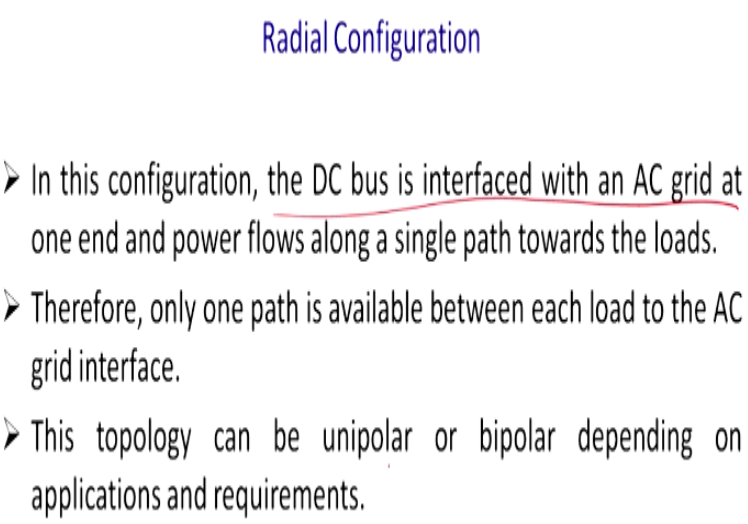

In this configuration, DC bus is interfaced with the AC grid at one end of the power flow in a single path towards the load and loads are in a peripheries of the rings. Therefore, only one

path is available between the load to the AC grid interface and this topology can be unipolar or bipolar depending on the applications you require.

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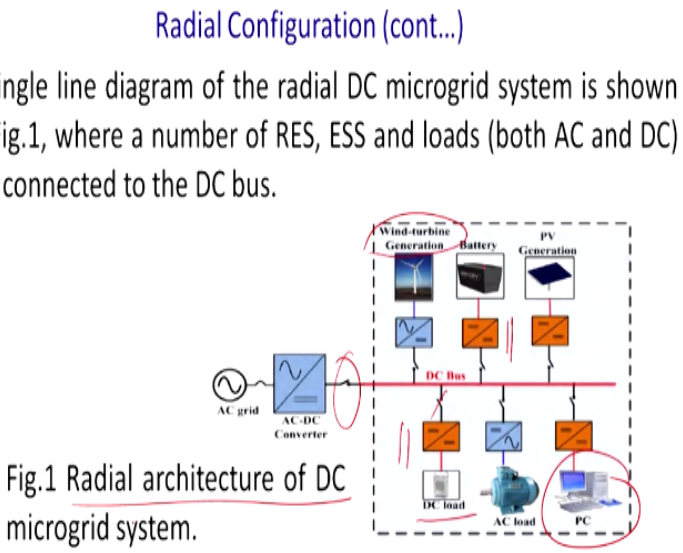

So, this is the configuration, though I have a drawn drawing a straight line, ultimately it can be drawn in a circular type. The single line diagram of the radial DC microgrid system is shown in figure 1. There are a number of RES that is renewable energy resources and the energy storage delivered, so you have a DC to DC, AC to DC conversion and thus you got an islanding or the grid connected mode. You have a wind turbine generation, thus you can convert DC and fit to the DC grid.

You have a bidirectional battery connection, so that power can be fed through or get in from the batter, so PV generations, thereafter you can close it and you can have a DC load generate, you can have a regenerative breaking also and thus it can be a if it is a DC load, if it is resistive kind and it is unidirectional, then you can have adjustable speed drive, then you have a nonlinear or the constant power load or CPLs, these are computer desktop and laptops.

So, these are the architectures of the, radial architectures of the, DC microgrid system.

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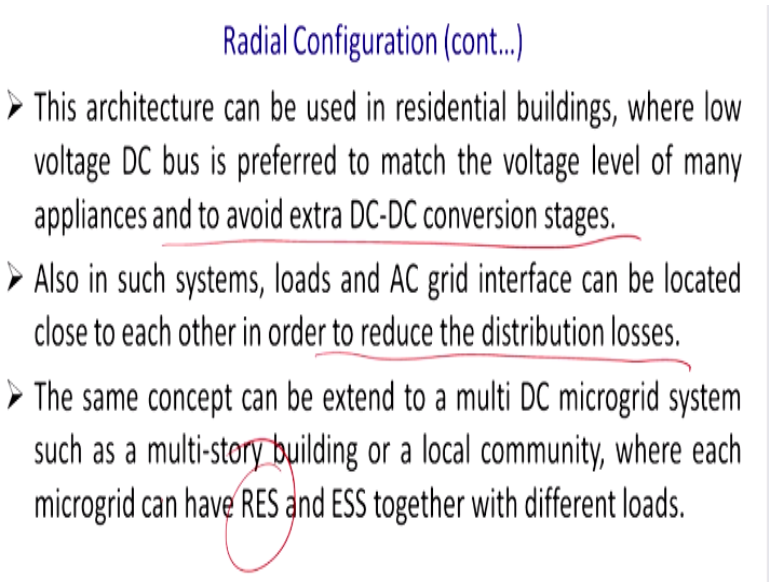

Now, this architecture can be used in residential buildings, where two voltage are being preferred to match the voltage level of the many appliances and avoid extra DC to SC conversion state. So, for example, if you are feeding your Acs, AC generally nowadays, you can have a inverted fed ACs, thus you supply it power DC input and there you may require 2 V voltage and your LED you would require a less voltage and also you may have a different kind of voltage level for the different appliances, and but if you have a single voltage bus, then your number of DC to DC conversion will be more.

Also in such systems, the loads and the AC grid interface can be located close to the each other in order to disti reduce the distribution losses, so that is one of the major advantage here because you know you have a predominantly resistance in the circuit unlike in a in case of the transmission losses you have considered that x/r ratio has got 0.7 or something like that value, but here you got predominantly resistance losses.

Some concept can be extended to the multi DC microgrid systems such as multi-story building or a local community where each microgrid has all own distributed own energy reserves that is called resource energies and the storage energy for catering the different kind of load. What we have seen in the peer-to-peer configuration in different kind of configuration in AC, same thing can be done in DC. So, let us talk about the multi DC microgrid configuration.

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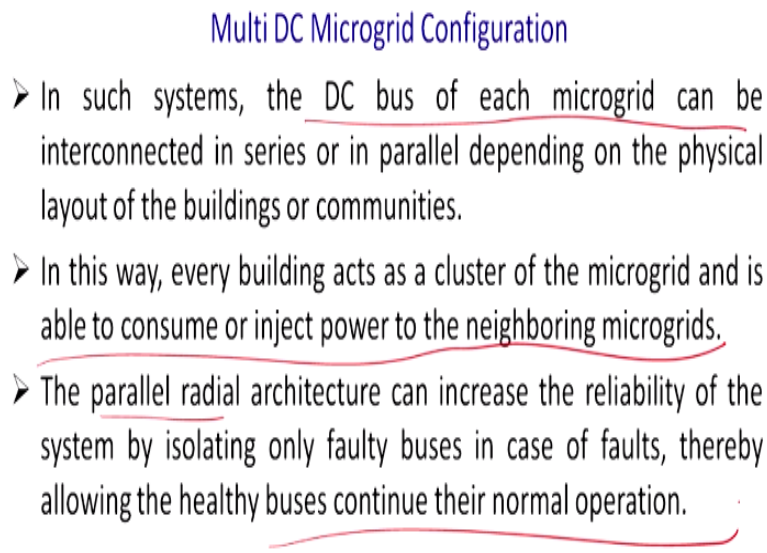

Such system in this case what happen, the DC bus of each microgrid can be connected in series or parallel depending on the physical layout of the buildings and the communities. So, you can check it out where it fits what, whether two you require more voltage, then you can connect to the two, you can put them in series and thus voltage level get higher and you may have also provide the parallel path, positive or negative DC bus, and thus you got it gives you the redundancy.

In this way, the every building acts as clusters of the microgrid, so another microgrid, it is when we call it a nanogrid and is able to consume or inject power to the neighboring microgrid. If you have our surplus, for examples, 2 buildings in a community, both have solar installations. So, if someway power is surplus in one of the building, it can be transferred to the other building.

I shall come in next slide that is the parallel radial architecture can increase the reliability of the system by isolating only the fault buses, in case of the fault, you know please understand, DC microgrid has a huge challenge on faults, so far fault locating, fault detections, fault isolation is a very big challenge in case of the DC microgrid, and this parallel radial architectures has a capability of faster isolations and faster detections and faster eliminating the fault and thereby allowing healthy buses to continue in a normal operation mode.

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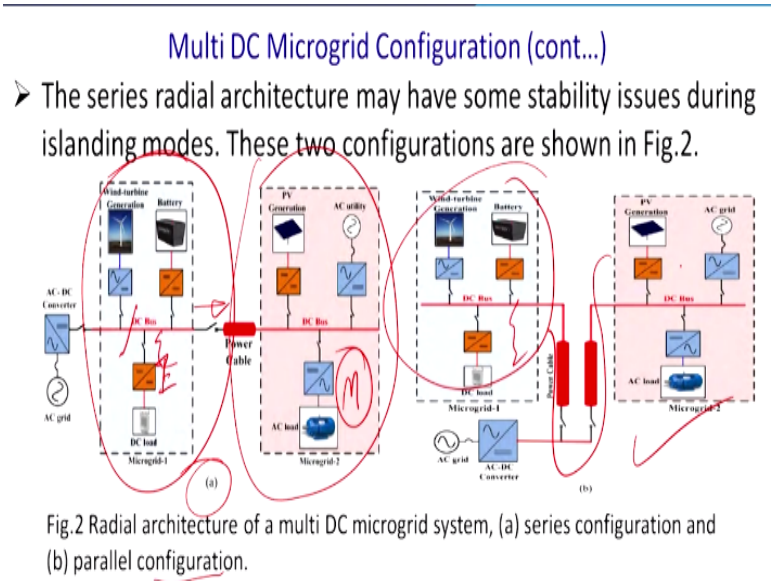

Fig.2 Radial architecture of a multi DC microgrid system, (a) series configuration and (b) parallel configuration.

So, we have a different kind of systems, please check that system A that is the series configuration and system B the parallel configuration. In this architectures, architecture may have some stability issues during the islanding mode that I will come little later, but let us understand the configuration. This is a series, it is a one microgrid, may be our electrical department. Another we have in our campus, our neighborhoods and the mechanical department.

So they are connected by the series connection, but problem is they are connected by a single line and the grid is single point gets its entry. So, this is the point and you can have you can, if there is a power surplus let us say electrical department, you can send back to the part of the mechanical department and vice versa, but in this configuration your you got one for all our, but problem lies you know if something happens here, ultimately, you know, due to this fault here, this mechanical department has to force to operate in islanding mode.

So, that is some restriction you are imposing because it is it is being a farfetched from the AC to DC converter, but in this case you know, those issues not there, they have both these entities are given proper importance. If some fault has been occurred here, so you can bypass this part of the network and you continue to feed in a healthy mode in a without affecting anything, but problem lies you have to send power through this. So, you have to talk with this way.

So, this is something while exchange of the power in the parallel condition is little complicated and what it is quite simple in case of the series contribution. So, this is all about the radial, please understand there are many microgrid mesh also.

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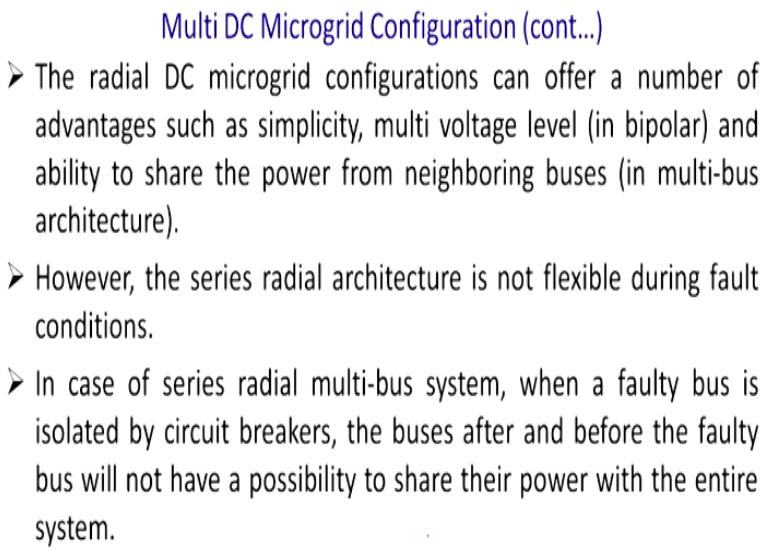

The radial DC microgrid configuration can offer a number of advantage such as simplicity because it is a very simple as you can see, multi voltage level in case of the bipolar and ability to share power from the neighboring buses in case of the multi-bus architectures. However, in series radial, architecture is not flexible during the fault condition, for this reason, we generally nowadays avoid series radial connections. There is only one single backbone, if something happens to it, finished.

In case of the series radial multi-bus system, when a faulty bus is isolated by a circuit breaker, the buses after and before the fault bus will not have a possibility to share the power with the entire system, and thus it is very much vulnerable to the single fault. For this reason, we are going for the parallel loop.

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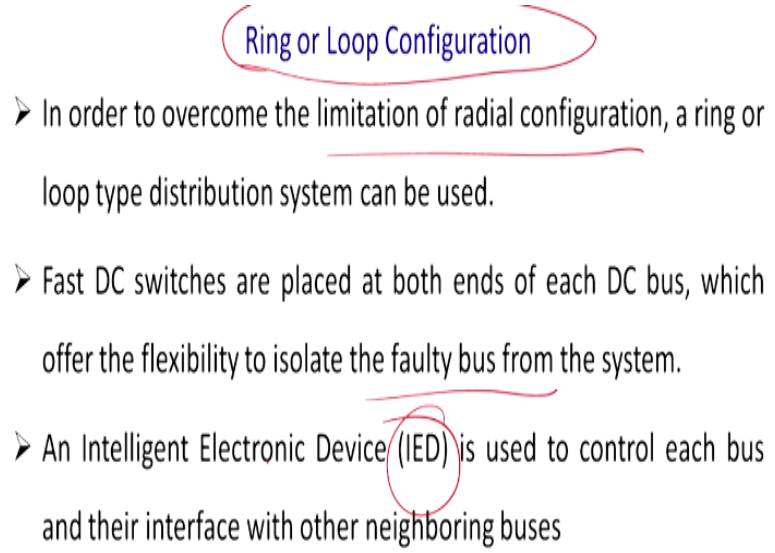

Now we are going for the ring or the loop configuration, that is also it is inspired by the AC distribution systems. In order to overcome the limitations of the radial configuration, ring or the loop configuration system can be used. So, the next slide you will see that that fast DC switch are replaced at both end of the each DC bus which offer flexibility to isolate the fault bus of the system and intelligent electronic device that is we abbreviate as IED is used to control each bus and their interface with the neighborhood buses.

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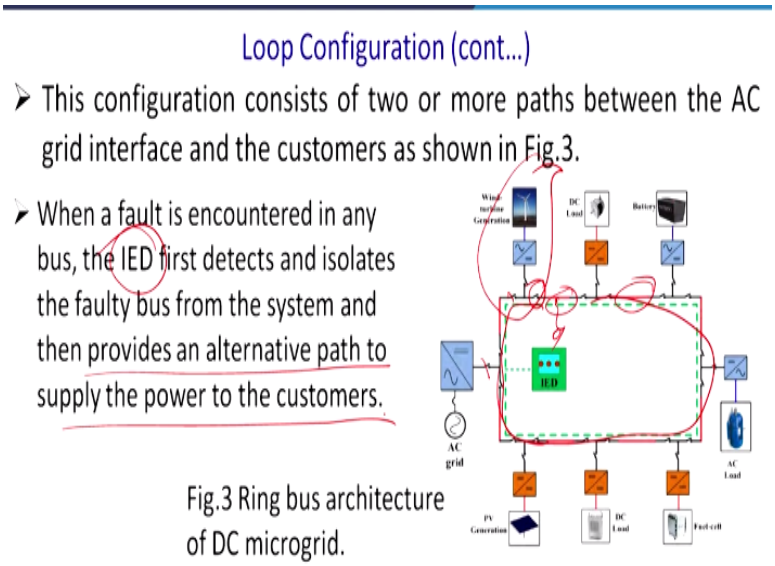

Fig.3 Ring bus architecture of DC microgrid.

So, that is your radial bus. You can see that every point you can make and break contacts. So, you can close this allowing to be islanding mode. You can close this, the power will go there. You can off this part of the switch, this is the part of the your, red portion is your cable. So, again you can close this switch and power will go there, or let us say fault has occurred here,

then what happen, you can, you will be forced to isolate this portion of the load, but you can feed through this.

So, only wind has to overcome, none has to be you can isolate very well and every one can compute because this circuit maker will operate, this will be closed and since fault has occurred here, you will find power has been flowing and all the other all the entities are working fine. This is quite a fault tolerant system and you may design in such a way that multiple fault also it can take, but it can operate in a healthy fashion:

In this configuration consists of the two and more path the AC grid interface and the consumers shown in figure 3, this is the figure 3, and when a fault is encountered in any of the buses, the intelligent controller IED first detects and isolates the fault bus from the system and then provides an alternate path to supply power to the customer, and that is always possible here and thus it has got huge redundancy and fault tolerant capability, this network.

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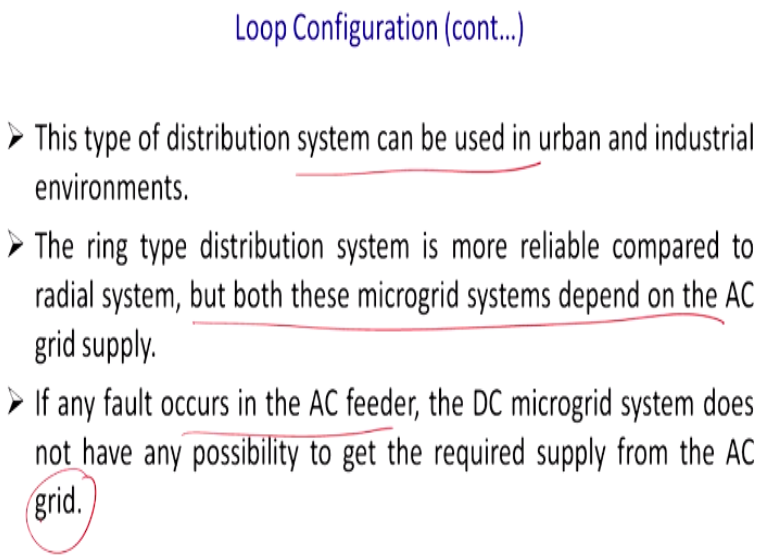

Now, let us come to the loop configuration. This type of distribution system can be used in urban and the industrial environment and also commercial environment. The ring type distribution system is more reliable compared to the red raider radial system, we have seen right now, but both of this microgrid depends on the AC grid supply, that is one of the problem, and for this reason, we are looking for the DC grid of isolating mode, where for the islan for where you are feeding power mostly in an island in condition.

For example, any fault occurs in the AC feeder, you cannot have any tolerance. Ultimately, you will be forced to operate in islanding mode. So, here also loop configuration has some kind of fault tolerance capability. So, let's go here and see that. Any fault occurs in the AC feeders, the microgrid system does not have any possibility to get the required supply from the AC grid and you may require to cut down your load to go to go into the islanding mode, and for this reason, we may have our interconnected configuration.

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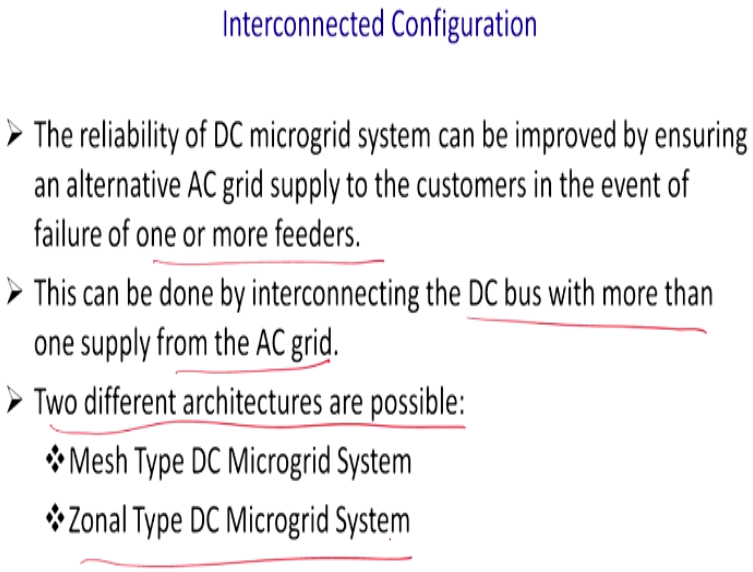

The reliability of the DC microgrid can be improved by ensuring alternate AC grid supply to the customer in the event of the failure of the one or the more feeders. So, that is something we can have a multiple entry point for the AC to DC converter and thus you can feed power if one feeder of the AC to DC converter is nonfunctional. So, this can be done by interconnecting DC bus with the more than one supply from the AC microgrid, that is what generally happens in the loop connections in the AC micro grid ACS distribution system.

So the same thing can be done. Then the 2 different architectures are possible, one is mesh type, DC micro grid system, another is zonal time DC microgrid system.

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Mesh Type DC Microgrid

- In a mesh type DC microgrid, also known as a multi-terminal grid, more than one AC grid interfaces are connected to the DC grids, each through an AC-DC converter.
- Different DC microgrid architectures are possible based on this configuration where several DC and AC power supplies are connected to the DC feeders.

So, mesh-type microgrid system is known as the multi-terminal grid. So, grid is not connected at single point of the microgrid, is connected in various points in the microgrid. More than one AC grid interface are connected in the DC grid, each through the AC to DC converter. Different DC microgrid architectures are possible based on its configuration where several DC-AC power supplies are connected to the DC feeders, that is also quite important.

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Mesh Type DC Microgrid (cont...)

- The MTDC is more reliable compared to the radial or the ring DC grids due to the availability of other feeders to supply power to various parts of the system.
- Similar architectures are utilized in High Voltage Direct Current (HVDC) system such as off-shore wind farms and underground urban sub transmission and distribution system

So, for this is a and you can see that this is a mesh-type DC microgrid architectures and figure shows multiple terminals. So, here you got a grid, here you got a grid, here you got a grid, here you got a grid, here you got a grid. So, you got multi-terminal entry point for the grid. So for this reason, in this configuration, if one of the system is not working, then we can manage to feed from the other AC to DC converter and thus it is called a MTDC architecture. So, most of them we prefer MTDC architectures.

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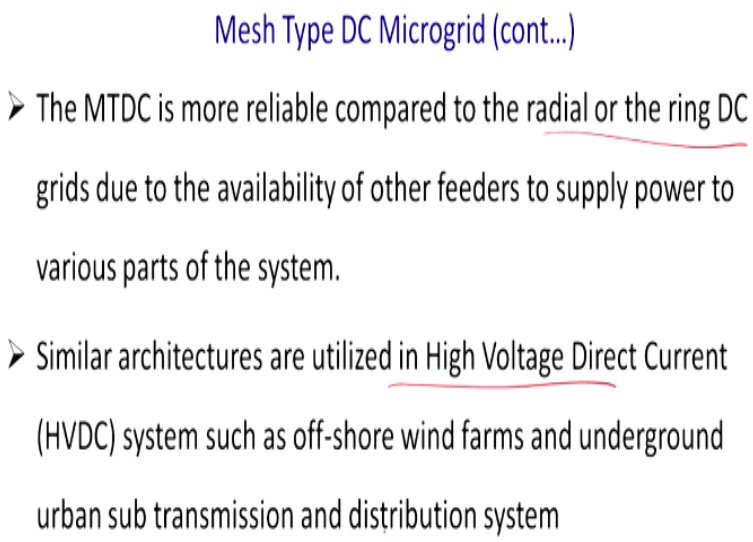

So, as we can conclude that this MTDC architecture is more reliable compared to the radial or the ring DC grid due to the availability of the other feeders to supply power to the various parts of the system. So, we can feed power from a different point from the main grid and similar architectures are utilized in HVDC or the high voltage direct current systems as off-shore or the wind farm or underground urban substations and the distribution systems.

Once you require to take the bulk power from shes from Sea Island, where you have plenty of wind through the under underwater cable or you go you are required to go the high voltage transmissions and that has to be through the in a highly populated area, it has to be underground, and in that way, you will continue to do so and that is will also have a similar kind of architectures, you should have a multiple AC entry point that gives you the redundancy.

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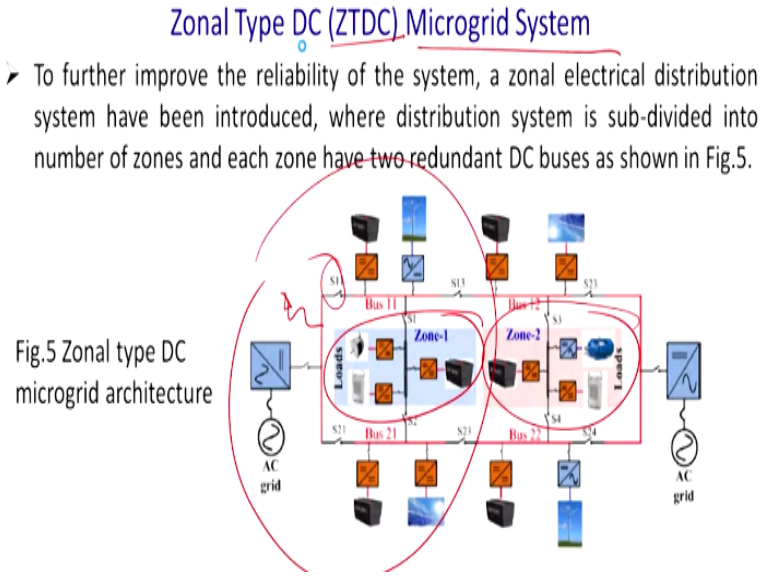

Fig.5 Zonal type DC microgrid architecture

So, this is a we say zonal- type DC or in abbreviation ZTDC microgrid system. To further improve the reliability of the system, zonal electrical distribution system has been introduced. So, you got you will identify this as zone 1, this has zone 2, and you got loads and you identify whose responsibility what, you just specify the responsibility, whatever happens to zone 1, it is the responsibility of the AC grid.

If there is a power surplus or power balance, ultimately this will be taken care of by this grid only, and this will be the entry point and you will have responsibility for the zone 2 and we say that it is bus 11. So, what we can say is that to further improve the reliability of the system, the zonal electrical distribution system has been introduced, where distribution system is subdivided into the number of zones, each zone have 2 redundant DC bus as shown in the figure.

So, this bus and this bus, so if fault has occurred somewhere, of course, you can supply through it by this redundancy and and you can have also that 2 entry point of your AC system. So, this is called zonal-type DC microgrid system.

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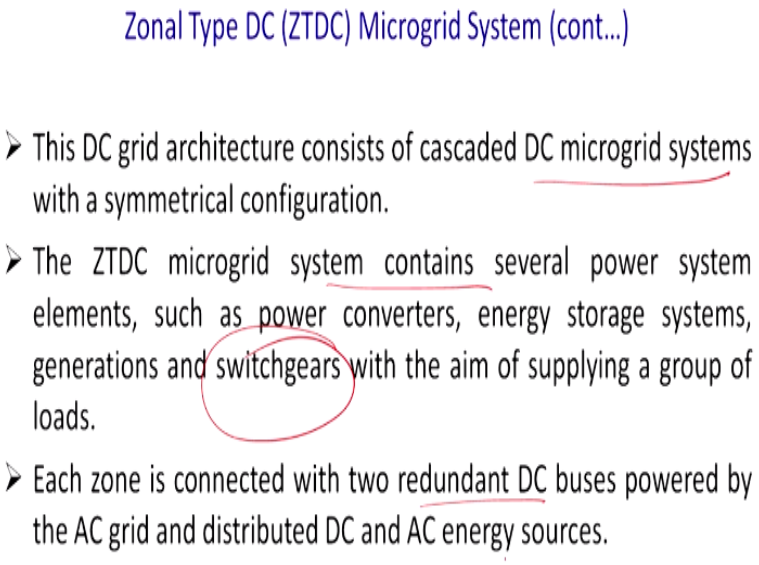

So, what are the features of it? The DC microgrid consists of the of cascade DC microgrid systems with a symmetric configuration, mostly loads has to be symmetrical or mostly the entities that is present in zone 1 and zone 2 mostly symmetrical. The ZTDC microgrid system contains several power system elements such as power converters, energy storage system, generations, and also if it is a very large system you it may incorporate the switchgears with aim to supply a group of loads.

Each one is connected to two redundant DC buses powered by the AC grid and the distributed DC/AC energy sources. So, please go back and check. So you got a DC/AC energy sources that is solar and wind and this bus and this bus and this 11 and 21 are the redundant buses. You can feed to either of it. If fault has occurred somewhere, you can simply isolate the part of the buses, but continue to feed to the rest of the buses.

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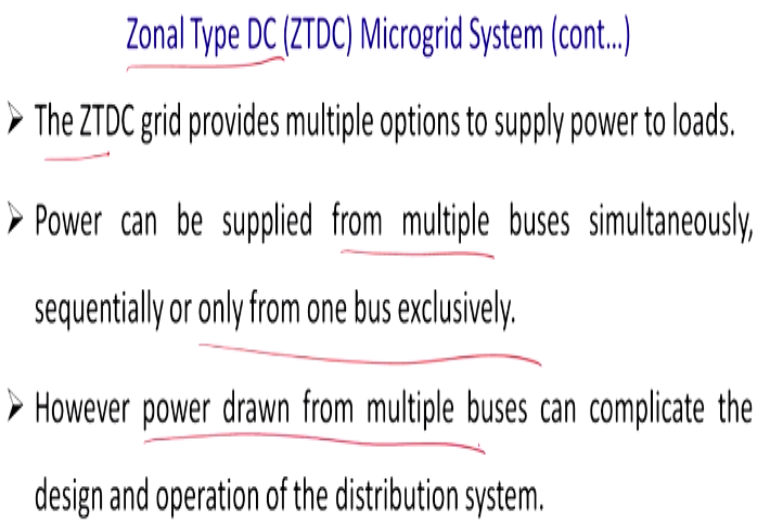

Now, this zonal-type DC microgrid system generally have this the provides multiple options to the power supply of the load and power can come in a different path and thus got a lot of redundancy into the system. Power can be supplied from multiple buses simultaneously and sequentially only from a single bus exclusively. So there is many way to configure and that flexibility designer gives for the optimal loading of the different part of your microgrid.

However, power drawn from the multiple buses can complicate the design, that is what I was saying, and operations of the distribution network. Generally, it is one-to-one correspondence you make, so you are allowed to take power in normal circumstances from that particular bus, but if faults happen, then you can de-route, that is a contingency. So, while considering your different mesh-type, radial type or different kind of DC microgrid, so first one what we have discussed, it is the wind radial type.

This is the simplest configuration and it doesn't have any fault or incapability. So, that is your simple radial system and radial system can be classified into the two elements, that is, series and parallel. So, that is something I have shown here. Then after we shall go to the another mode of configuration, that is the multi DC microgrid configuration and we shall then come to the loop configuration where you got a more redundancy.

This is a loop configuration and thus you can eliminate the part of the circuit depending on the fault condition, its fault or incapability is maximum, and this is all this is less complicated. So, first simplified one is the of course series radial, thereafter comes to the

parallel radial, there it comes to the this loop config, this ring bus and then you got an interconnected configurations or the mesh-type configuration

This is your mesh-type configuration and in mesh-type configuration, in between you have 2 kind of configuration, that is your, this is a zonal-type DC microgrid architectures and these are gaining a lot of popularity here because of this multiple agent involved into the system and you can feed power in a different way for the different load. For example, you identify the point where a fault has occurred, you can bypass the whole part of the circ, bypass that particular load.

For example, let us take you have fault here. So, you just off this switch and rest of this you will find work perfectly fine. So you may have even multiple fault, not only single fault, you may have multiple fault, then also you can see that the system exactly works fine, but in this case is you have a multiple option to transmit power, and for this reason, you will ensure that mostly which bus will be configured for the whole boss because if it is a different kind of configuration, if power is wheeled-through, sometime control system has a challenge.

What happened, you know actually when this power will wheel-through, this potential difference might be a difference. Once you were closing, there will be a transient. So, those controls are quite complex in this case and it require a coordination also. With coordination and control, this zonal-type DC gives you the best solution of among these proposed systems. So, so that is what we are saying that this is the zonal-type microgrid and that is what we are saying.

One main phenomenal features of the this kind of DC microgrid is that zonal type the power drawn from the multiple buses because you have option to take power from the multiple buses, will be a hodgepodge and that will be a complicated sore, complicated problem, the design and distribution system and for this generally, we provide some kind of peer-to-peer architectures.

Please revisit my previous lectures and this kind of architectures is more suited for the peer-to-peer or the hierarchical architecture to sort out this problem of feeding power of the multi sources. Thank you. Thank you for your attention. I shall continue with the different topologies of the microgrid also in next class.