DC Microgrid and Control System
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Lecture - 27
DC Microgrid System Architecture and AC Interface

Welcome to our lectures on the DC Microgrid and the Control. Today we are going to discuss, previous few discussions was based on your in general microgrid and we tried to cover some portion of the AC microgrid so that you can understand with the comparisons what are the different microgrid architecture it would be and today we are going to discuss in detail the DC microgrid architectures and its interface with the AC systems.

So, it is a continuation of the previous lectures, students are requested to go through the other previous lectures, then only he can or she can understand the correlation better.

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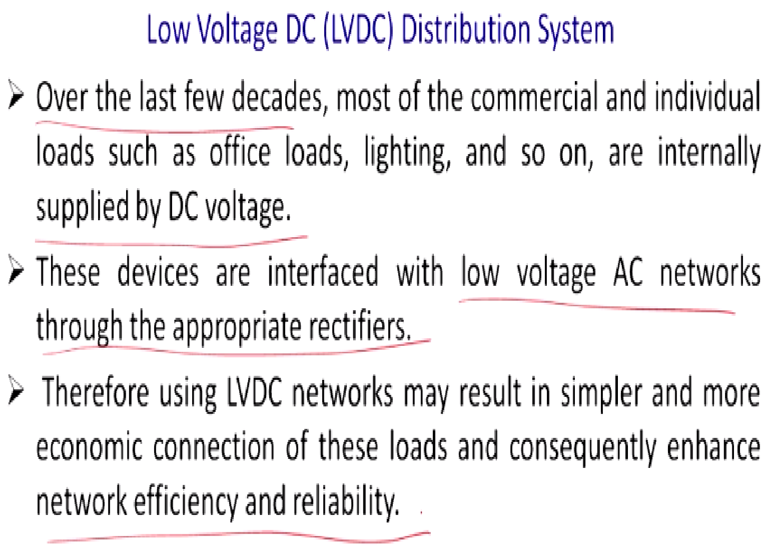

So, issue is that over the last few decades, most of the commercial, individual such as office loads that mean these are desktops, laptops, lighting, these are LEDs and so on are internally supplied by the DC voltages. You may have a big LED TV that internally supplied by the DC supply and thus what happened these devices are interfaced with the low voltage AC networks through the appropriate rectifiers generally, otherwise, you may just convert into the AC to DC by rectifier and you will inject see that with a six pulse converter convert and thus you will inject sufficient amount of the harmonics into the system.

For this reason, nowadays we are putting a restriction once you are converting AC to DC, you have a limited amount of the restrictions on the THD also and thus not simple diode based rectifier cannot serve the purpose. Therefore, using low voltage DC network, normally result in simpler and more economic connections of these loads and consequently enhances the network efficiency rapidly. Please understand that there were many disadvantage of the harmonics, once you converting the DC to, AC to DC.

Then you are throwing a lot of harmonic into the system and those harmonic will direct every component, your cable rating, power handling capability of the cable required to be directed, your transformer required to be to be directed. So, for this reason and it may cause also, it may cause the interference with the communication network as well as it may cause the oscillation sink to the power system.

Because you may have a natural frequency of oscillation that is close to the seventh harmonic, most of the cases because you have mostly you have a capacitor bank and thus you have a and you have a leakage reactants of the big transformer and that gives you the natural frequency of oscillations. If somehow when you are converting AC to DC, so that and if you know that if it is a six-pulse converter, predominantly you have six N plus minus one as harmonic, and then what will happen.

Those harmonic those harmonics if the component of the seventh harmonic is quite high and that is close to the natural frequency of the oscillation of the network, then it may cause a resonance into the system and ultimately power in the main circuit will be due to the seventh harmonic and you will have a lot of problems due to that. There will be a ripple, there will be a torque ripple, ultimately your synchronous machine will not be running and ultimately you don't feel able to feed power to it because you know sine v sine m omega t integration over 0 to 2 pi x I sine m omega T d omega t is 0 over the period.

So thus you may not have any real power transmission because you have a seventh harmonic. Here, it is a fundamental and you have seventh harmonic. So, those are the, and thus you just get an oscillatory power. So, those are the very big challenges, and for this season, we are putting a lot of restrictions on AC to DC conversion and it has to be done through the proper rectification process, where you will be injecting a low THD, but that is not always feasible also, that I will cover it later.

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Low Voltage DC (LVDC) Distribution System

- Networks that are supplied by voltage below 1 kV are called low voltage (LV) networks.
- Moreover, to convert an existing AC network to a DC grid, the maximum value of the AC grid can be selected as the nominal voltage of a LVDC system.

The network that are supplied by voltage below 1 kV is called the low voltage network, mostly we have to 202 volt RMS as DC as AC and we will have a same DC voltage we can take it as in most of the cases or we also have a 48 volt battery system can be considered as a reference. Moreover, to convert the existing AC network to a DC grid, the maximum value of the AC grid can be selected as the nominal voltage of the LVDC system, that has got a huge advantage.

So, if you take a maximum current handling capability of this DC where it will be root two times higher So, current handling capability for it will be more.

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LVDC Distribution System Topologies

- An LVDC distribution system constructs of power electronic converters and DC link between the converters.
- The topology of LVDC distribution system can have different kind of variations.
- Common to these different topologies are that AC/DC conversion is always located near medium voltage (MV) line.
- The DC/AC conversion can instead be located at different locations.

An LVDC distribution system construct of constructs of power electronic converters and DC link between these converters. The topology of LVDC distribution system can be different kind of variation, we shall discuss in detail what are the different kinds of variations of the of this LVDC distribution system. Common to these different topologies are that AC to DC conversion is always located near to the located near medium voltage or the MV line and the DC/AC conversion can be instead to be located at the different locations.

So, these are few issues, and so, you have to take that power from this point of conversion to the point of load and thus we have a different kind of topologies.

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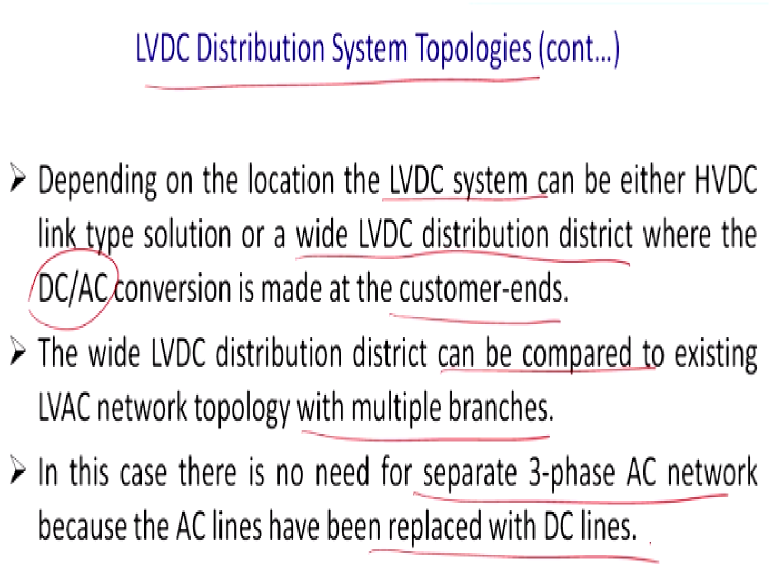

So LVDC distribution system topologies depending on the location of the LVDC system can be either HVDC link kind of solutions or wide LVDC distribution district where the DC/AC conversion is made at a at the consumer end. So, that is something we required to understand it. The wide LVDC distribution district can be compared to the existing LVAC network topology with multiple branches, that is something we required to keep in mind.

So, we can have a different kind of load, we can have a different kind of voltage level, and thus we can have a branch where you may have a same voltage level, but for example, you know in our household application also we have a different line 6 ampere line and the 15 ampere line. So, in a 15 ampere line, you can connect generally the power load and the 5 ampere line, you connect generally fans, lights, this kind of light loads, and for example, this kind of aspects would be there in case of the LVDC system and thus we can have a different kind of topology, that will I am coming to the next slide.

In this case, there is no need for the separate 3-phase 3-wires. So you don't need to have to have, you ha you required to only the written path, you need not to have to have the 3-wire system because AC line have been replaced by DC line and no neutral can be used the same way.

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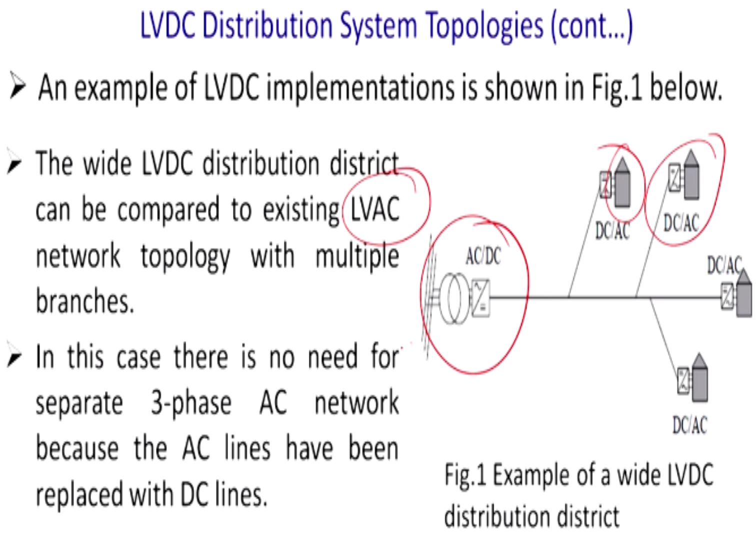

So, for this reason, this is the one of the architectures. You got conversion AC to DC from the main grid and there you will ensure that your THD is quite low. Thereafter, you are transmitting with the DC and you may have a household AC because of the historical vision and thus you are reconvening to DC to AC and that is better because you know what happened you can you might be knowing that you were running this inverter fed ACs, as ultimately its input has been rectified and then fed into the DC.

Then it has been reconverted into the AC as required by the source. So, for this reason, AC to the conversion seems most of the modern law incorporates by itself, and same way here also. So these are the few examples of the wide LVDC distribution system. One of the aspect is that it has a predominantly inductive loss and even in a multiple point, you don't have a problem in the grid that is the power quality that has been addressed here. So no power quality problem because the entry point of AC to DC here what do you do, you ensure that the THD and the power factor is good.

So, the wide LVDC distribution district can be compared with the existing low voltage AC network branch topology with multiple branches. In this case, there is no need for the separate 3-phase network because the AC lines have been replaced by the DC lines. One of the advantage is that power bulk handling capability of the DC is more because due scheme affect one, generally once you got a scheme effect, you have a harmonic, that is what I was saying that our harmonic.

If you have a sufficient amount of harmonic, you required to direct your converter, you required to direct your cables, you required to direct your transformer. So far this reason, this aspect doesn't arise when you have your DC direct DC transmissions.

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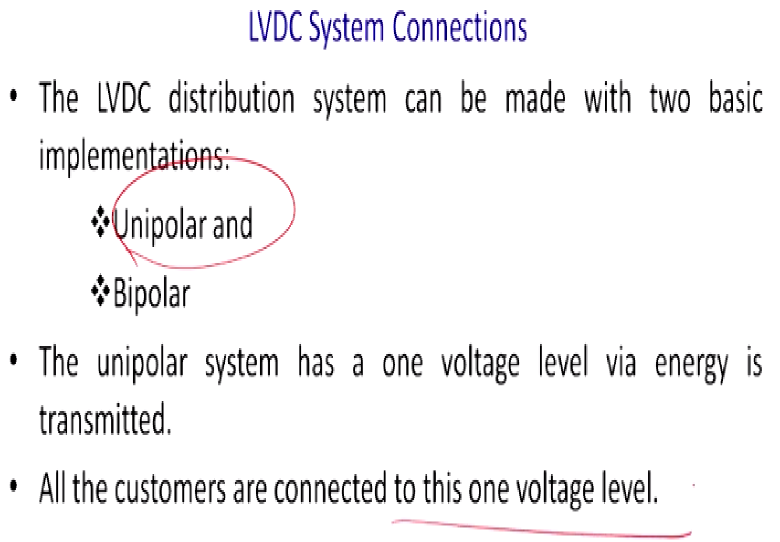

The LVDC distribution system can be made with a two basic implementation, that is unipolar ut is 0 to 200 volt or 0 to 48 volt or bipolar, then it is actually 3-wire connections; plus, zero, negative. The unipolar system has one voltage level by energy is transmitted. All the customers are connected to the one voltage level. In case of the, in case of the bipolar, you can do little bit of power balance, you can connect the consumer to the negative and positive loading, negative and the positive voltage wires.

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LVDC System Connections (cont...)

- In AC grid systems, the power from utility side can be transmitted using two wires (single-phase) and four wires (three-phase).
- The power in DC grids can also be transmitted using similar configuration: two-wire (unipolar) and three wire (bipolar) systems.
- The difference between these two DC grid configurations is the number of available voltage levels.

So, the AC grid systems that the power from the utility side can be transmitted using two wires for the single phase and 3-phase 4-wire system for the three phase with del with a neutral and the power in the DC grid can be transmitted using similar configuration 2-wire unipolar and the 3-wire bipolar, and in this case also you can see that considerable amount of the copper seeping because you don't require the fourth wire.

The difference between these two DC grid configuration is that number of the available voltage level and sometime in modern day, it prefer the bipolar system because you can balance your loads.

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Unipolar DC Microgrid System

- In a unipolar DC system, sources and loads are connected between the positive and the negative pole of the DC bus as illustrated in Fig.2.

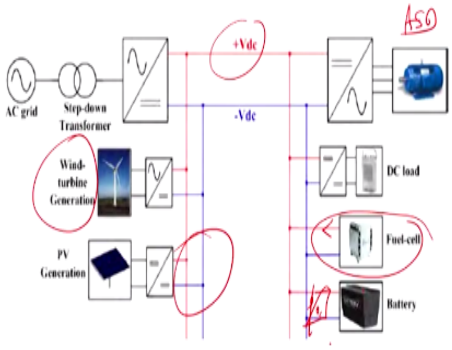

Fig.2 Unipolar DC microgrid configuration.

In unipolar DC system, source and loads are connected between the positive and the negative pole of the DC bus voltage as illustrated in this figure. This is a unipolar DC configuration.

You have step-down transformer, and thereafter you have a low you have an interface of DC to AC and thus uh you AC to DC conversion and thus you got a DC voltage and this is your, the blue line is the 0 potential line, it has been considered.

Again, you may have a wind turbine that will be converted into the DC and will be fed the same power into the DC bus and solar with the MPPT tracking and same scaling and power boosting. So, you will get the same voltage and these are your AC to DC application. It may be the adjustable speed drive. So, you can apply V/f or vector control for the better efficiency and then better utilization of the torque and you may have a DC load. These can be the LED, you can bypass your different kind of entities and this is your fuel cell.

Fuel cell generally transmit power, so power it will go to this bus, and also you got a battery that will be the bidirectional, you can and of course generally battery will be interfaced via DC to DC conversion with the bipolar in nature. And if you strictly maintain the battery voltage, if you strictly maintain the battery voltage at 48 volt, then maybe a mechanical switch can operate one but you can see that simple diode can operate because charge can flow from this way.

Once it is on, you can turn on the mechanical switch to charging and for the discharging you can also take it a different path generally, but in general to control actively, we required to put a DC to DC converter in front of the, bi-directional DC to DC converter in front of the battery also.

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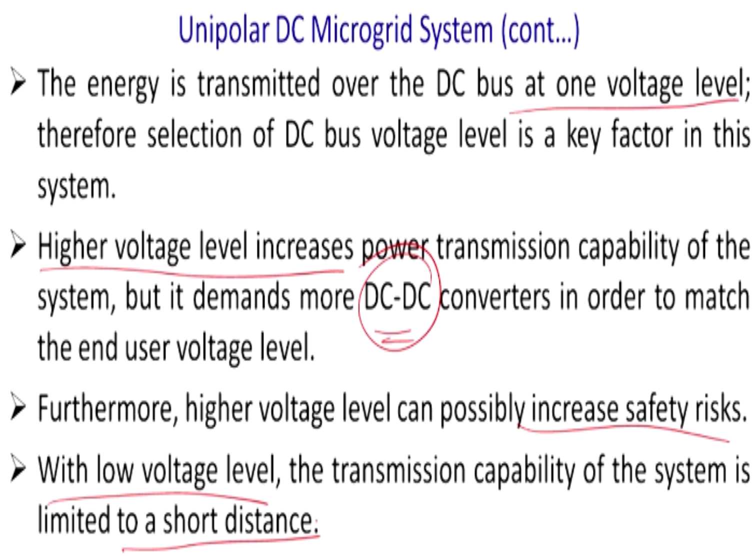

The energy is transmitted over the DC bus at one voltage level. Therefore, selection of the DC bus voltage in this case is the key for the total designing, whether you will have to 220 volt RMS voltage, whether it will check same thing, whether you will get a 48 volt since battery will be around that voltage level, so that we have to carefully calibrate and see. Now, there are two things ha we once you try to send power, high power always you will find associated with the high voltage.

We generally require to send high voltage once you are operating with high power because if you have more current, then what happen to send more current, then thickness of the copper required to increase and other issues will be there, magnetic effect, and for this reason, we generally also try to send and thus losses will be more and for this reason you know when you are sending big amount of power, voltage also required to be high. And for this reason, we are saying that higher voltage level increases the power transmission capability of the system.

It is v square by R, simple. So if you increase the voltage, it will be squared off, that will be the power rating. but it demands more DC to DC converter. The link can be used for more transmitting more power, but you may require a different level because ultimately the utility cannot take that particular voltage level and thus you required to put a DC to DC converter to step it down, and operation of the DC to DC converter is unlike the transformer, it is a little complicated because the switching is involved and it is not a dump device like a transformer, that it works on the windings.

So, it has losses, it has also its operations and it is it is required to be actively controlled and thus it is associated with the costs. And for this reason, we required to optimize the voltage level and the requirement of the DC to DC converters in order to match the inducer voltage level. Furthermore, the higher voltage level can possibly increase the safety risk, so you can, one can get a shock and insulation has to be proper, those issues also there.

For example in USA, they handle with the more current even though they anticipate better loss, they say that you design this motor better, but we are going to send power at 110 volt instead of the 220 volts so that you don't get a shock or that shock will be less severe. With a low voltage level, the transmission capability of the system, transmission capability of the system is limited to the short distance.

So, you required to have a small distance to cover, otherwise even if you will are sending a big power, then power losses occur, a big power and voltage is less, automatically current is more and thus you will cause a huge copper loss in the DC system.

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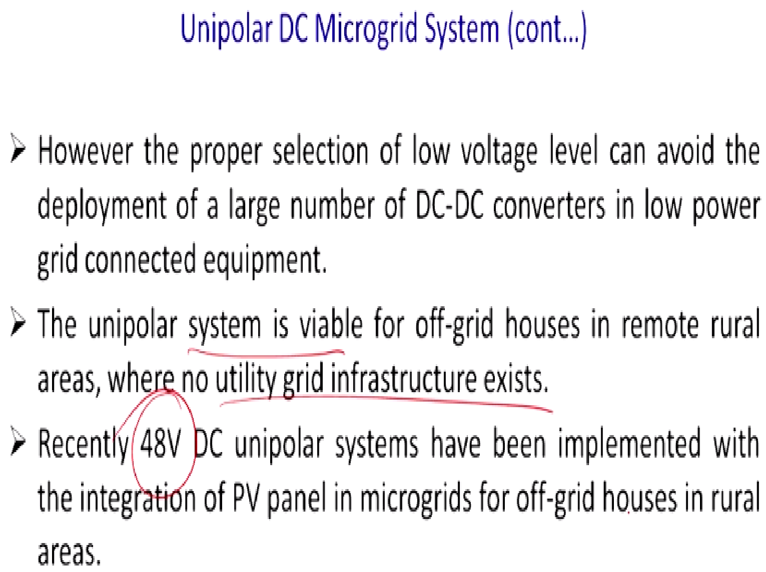

So, for this reason, the proper, however the proper selection of the low voltage level can avoid, so you have to match these two conflicting conditions. The voltage level can avoid the deployment of the large number of DC to DC converter in low power grid equipment, but also you incur more copper loss. The unipolar system is viable of the off-grid houses in remote rural areas, where no utility grid or infrastructure exists. For example, you make a resort, when we say resorts were running with the DGs.

Now, you can you can reduce the usage of the DGs by the solar and wind, you may have a resort, so plenty of winds may be there. So ultimately, you can with the battery, DGs, and those systems if you are running it that kind of resort, I think ecofriendly resort, so in that case, you will have a unipolar system that is better if you don't have any grid connection. Recently, 48 volt unipolar DC system has been implemented with the integration of the PV panel in the microgrid of the off-grid houses in a rural area.

If you, just I have said in a uh in our initial lectures that fast microgrid was mostly DC and that was implemented in the southern island is West Bengal, that was, that is where actually Ganga Sagar pilgrimage takes place. So that to taking because there was a no load most of the season, but only there is load in the Makar Sankranti. So, to address those case, first installation, but that was itself is a big case study, it was a case of failure though, but from that installation, we learned a lot of experiences and that has been taken care of in our previous installations.

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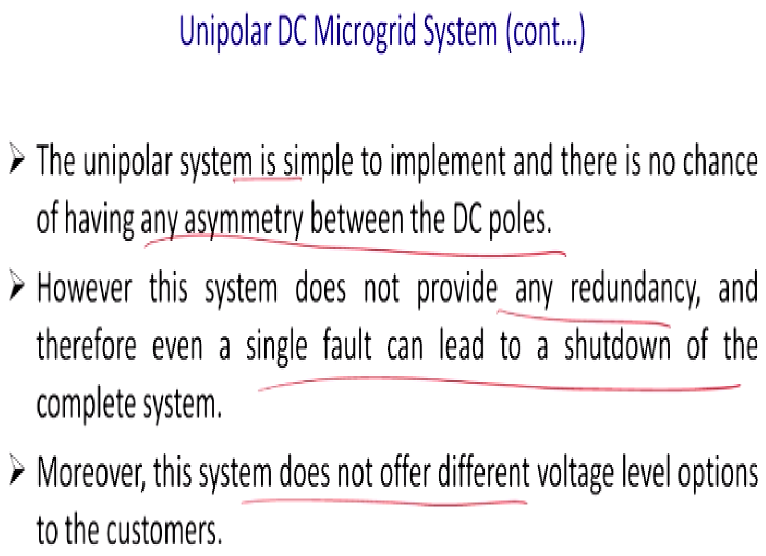

The unipolar system is simple to implement and there is no chance of having any asymmetry between the DC poles, that is something you have to keep in mind. So, that is a very big advantage of using that, and if you have a more positive load and the negative load, the neutral point that is the zero potential point what you were saying, it will shift something like the neutral point of your transformer one and you got a high current will flow, so same will happen here. However, system does not provide any redundancy.

If the power goes off, one line is goes out. So, its power is going into by the single line, in some way that has been disturbed. So, ultimately you have to live without power, and therefore, a single fault can lead the shutdown of that total complex system, that is the vulnerability and you require to have a protection, we shall discuss protection in detail in later side. Protection also of DC microgrid is a very big challenge because you don't have a natural zero here.

Moreover, this system does not offer different voltage level options to the customers, so that is also one of the disadvantages and thus we require to use many DC to DC converter, either step-up or step-down the voltage to meet the requirement of the particular load or the energy resources.

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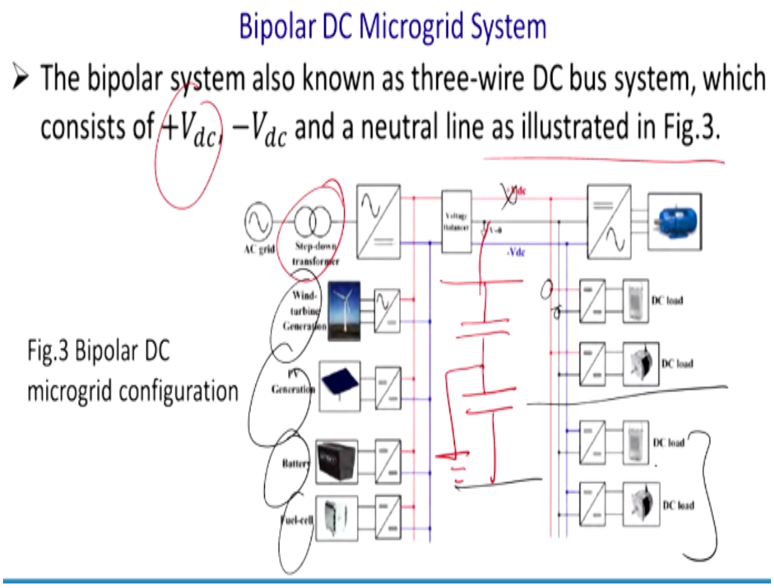

Whereas, you have a bipolar DC to DC convert uh bipolar DC system known as a three-wire DC system, which consisting of the plus dc and the minus dc and the neutral line. So, you have an AC grid, you have step-down transformer, you have the AC to DC conversion system and this is the bus, and here you can see that this is red line is a positive bus and the blue line will be the negative bus, you have a bipolar all those things, and in between you know what you do, you generally make it, so you will ground this, this is something like this.

So, your Vdc, this this will be your plus Vdc. So, this will be your high voltage and this will be your low voltage and this potential will be zero and you will have a bipolar line, other lines are same, but while in this configuration you know, it doesn't require the zero potential, but here it is a wind turbine, here people use a battery, but you may have a DC load and you can see that you will configure accordingly, you have an adjustable speed time, you have AC, DC, DC.

So generally you will give plus minus and that will be converted into the AC, and if you have a DC load, generally you will peak up positive and the negative and you have a redundancy once in some way this line is cut off. So, you can manage to operate and use the switchover this point to negative terminal. So, same way, for the DC load, it you will be connected here and to balance the load, some load will be connected negative to positive, negative to positive.

So, these are the case. So, in that way, you try to balance and also you provide the redundancy of your loading that is called bipolar system.

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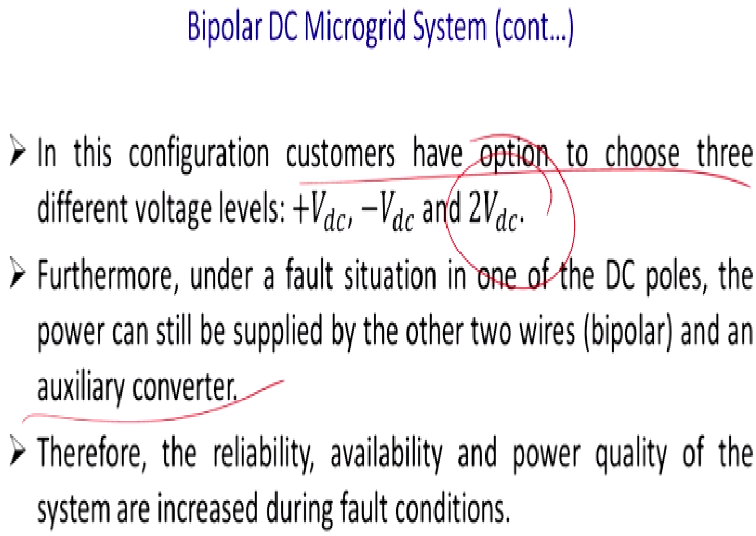

In this configuration, configuration customer have the option to choose that three different voltages, that is also one of the important aspect, you can choose +Vdc, -Vdc as well as the 2Vdc. So, for the high power rating, you can feed from the 2Vdc, just was we are feeding from the adjustable speed for the higher DC link voltage. Furthermore, under fault situation, one of the pole of the DC may go out and ultimately you continue to feed with another pole.

The power can be still supply with the other two wires and an auxiliary converter. So, we required to change one way with something. Therefore, reliability, availability, and the power quality of the systems are increased during the fault condition, also better for the handling the if the power of the few converter is more.

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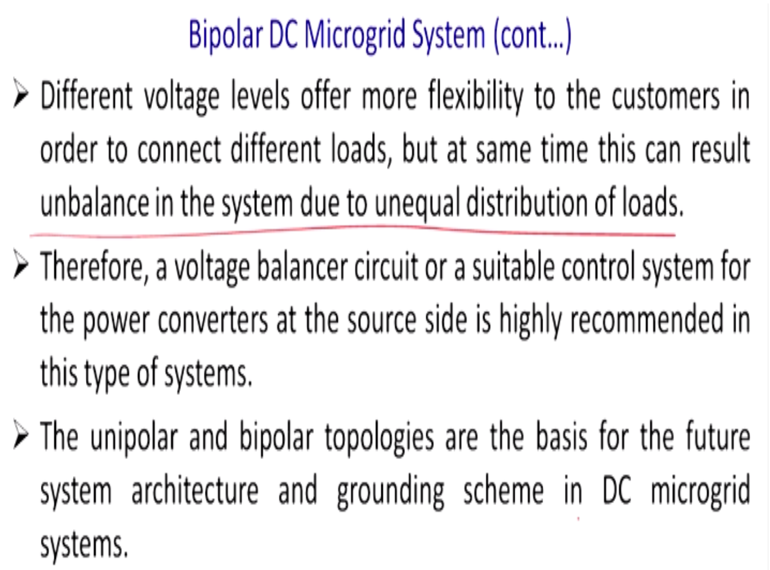

Now, the different voltage levels offers more flexibility to the customer in order to connect different loads, but at the same time, this can result unbalance in the system, that is what I was saying that you know this is a DC unbalance, you might be not aware of it. So, we have talked about the AC unbalance, in one phase you have a more load, another phase you have a less load, but here, you have this problem.

Let us see how we can address, but at the same time, unbalancing the system due to the unequal distribution of the loads, some because you are connecting the positive DC bus to the negative DC bus voltage, maybe the load, less load and the reverts may have the more load. Then, you will find that the which the point which is taking the more load will shift below zero voltage level, that is the one of the disadvantage of it.

Therefore, the voltage balancer circuit or a suitable control system of the power converter at the source side is highly recommended for this type of system. So, you require to be provide that equalization, otherwise you will have floating problem we generally say. The unipolar and the bipolar topologies are the basis of the future architectures of and the grounding scheme of the DC microgrid and grounding scheme also we required to change where as we can see that we have AC grounding here.

Due to this positive-negative, your ground and maybe your loading scheme is different, so you require to have a, you require to balance it, and for this reason, we can also work with the, you have a different kind of balancing scheme, please remember in a neutral point with a solid grounding, thereafter with a resistance grounding, we got a capacitance grounding, we got an inductive grounding, those option is not there.

Because if you put a capacitor, it simply block the voltage, and if you put an inductor, it simply short circuit it, it will not allow unless there is a change in it, sometime here also, we introduce the inductive grounding that is total scope of the protection system of the DC microgrid that itself is a very big challenge while addressing the microgrid, DC microgrid. Thank you.

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Unipolar DC Microgrid System (cont...)

- The unipolar system is simple to implement and there is no chance of having any asymmetry between the DC poles.
- However this system does not provide any redundancy, and therefore even a single fault can lead to a shutdown of the complete system.
- Moreover, this system does not offer different voltage level options to the customers.

I just revisit few aspect for your reference, that is unipolar PWM are simple and are being preferred for the low power level system, but where you require the more redundancy, more reliability, and where do you require to have a more power to be fed, so, 2V level up the voltage is quite suitable, and for this reason, for this reason consider the DC microgrid in case of a mall or maybe a ship or whatever maybe a small isolated island, in that case, we prefer a bipolar kind of power supply, but bipolar kind of power supply will have a problem.

The load connected to the positive DC bus and the negative DC bus will be different, and for this reason, what will happen, what you were saying zero potentially may not be a zero potential and you have to actively make it zero, which maybe shifting some amount by load adjustment or what or by the control technique. So, these are the extra effort you required to put in the case of the bipolar DC microgrid. Thank you. Thank you for your attention. I shall continue with the DC microgrid in our next class also.