Introduction to Smart Grid
Prof. N. P. Padhy
Department of Electrical Engineering
Indian Institute of Technology, Roorkee

Lecture - 24
Modelling of DC Smart Grid Components

Welcome you all for today's lecture on DC Smart Grid Modelling. In the initial introduction we have realized that there are so many components to make or create a smart grid and one of the very basic and fundamental smart grid type could be DC smart grid where all the loads and generations are connected to a DC bus. During today's lecture we try to cover up the following points importance of DC.

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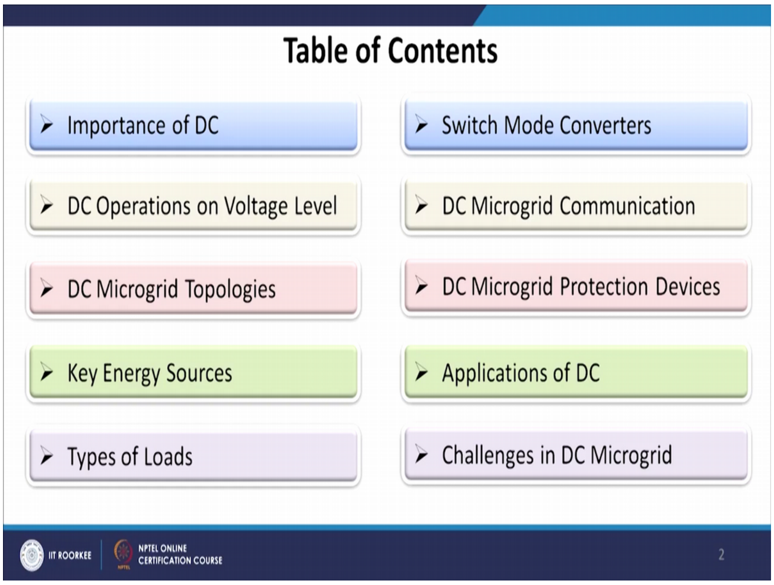

Why we go for DC instead of AC, which was so, old and acceptable to the whole world. Dc operation on voltage level at what voltage actually we have to operate whether it is 48 or something else; DC micro grid topologies, key energy sources, types of loads, switch mode converters DC micro grid communication, DC micro grid protections, applications of DC and challenges in DC micro grid.

Now, what is the importance of DC or disagree technology? Now if you all focus on the type of load today we do use in our residences, commercial places, industrial places the most commonly load is lighting and as we all aware the lighting loads are in DC or they are the DC loads, and lighting loads covers very close to 40 to 50 percent of the total load during evening hours and hence my majority of the load today is DC in nature.

As well as one important source that we are talking about today is the major renewable energy integration through photovoltaic which is once again DC, and hence the very important topic on storage that works on DC. So, keeping these three things in mind, majority of the loads are of DC type, my storage is of DC type as well as my renewable energy sources especially in PV photovoltaic's type is also DC.

So, if you talk about a smart grid consisting of many components, but majority of the components are DC nature and hence DC technology or DC smart grid technology need to be given importance for real time implementations. And now this comes to my mind all the time why already we do have AC system in place. So, why do we go for DC technology?

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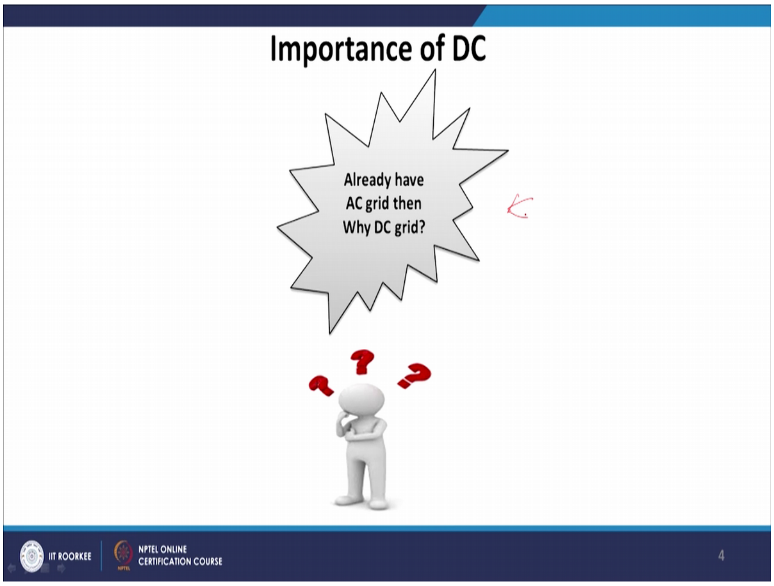

The question to all of you before we proceed further; why do we move to DC grid technology and the very easy answer could be, because of the maximum DC load maximum DC source and the energy storages it is nothing wrong to move to DC grid instead of AC. But to be very practical we cannot replace the AC system at all, but DC grid can play a complementary role there is existing is grid. So, in our future lecture we will also see what is AC smart grid, and end of the lecture series will also talk about AC-DC smart grid, but today let us focus only on DC smart grid modelling.

Now, various conversion stages like AC-DC DC-AC can be avoided by forming a DC grid.

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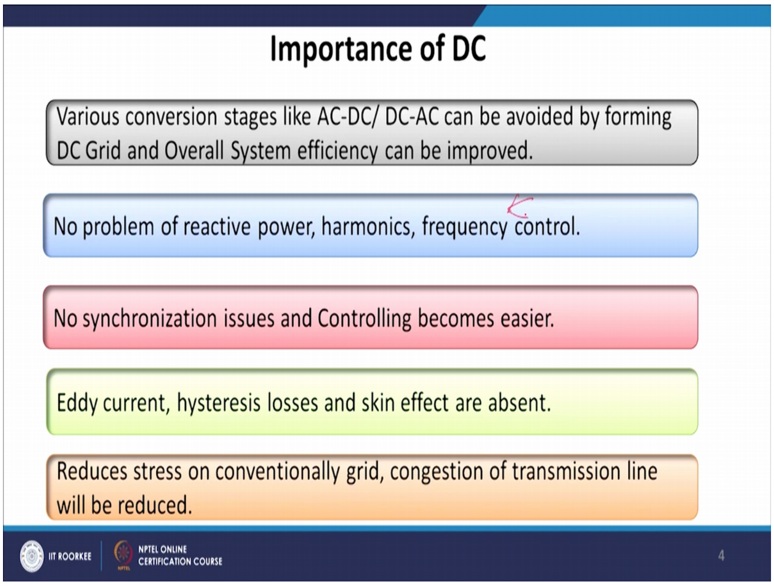

Because if you have a purely AC grid and if your storage system is in DC, then the DC need to be converted to AC for it supply to the grid and also AC need to be converted to DC during its charging.

Similarly, the PV technology needs to be converted from DC to AC and the loads that always need to be converted from AC to DC. Just to avoid those conversion from AC to DC as well as from DC to DC, we need to have a DC grid expecting that the overall system efficiency can be improved. No problem of reactive power harmonics and frequency control; no synchronism issues and controlling become easier. Eddy current hysteresis losses and skin effect are absent, reduces stress on conventional grid congestion of the transmission line will be reduced.

Now we do have different voltage level of operations because if you start from HVDC to medium level DC and then low voltage DC networks, we do have a strong 500 kV plus HVDC system in place.

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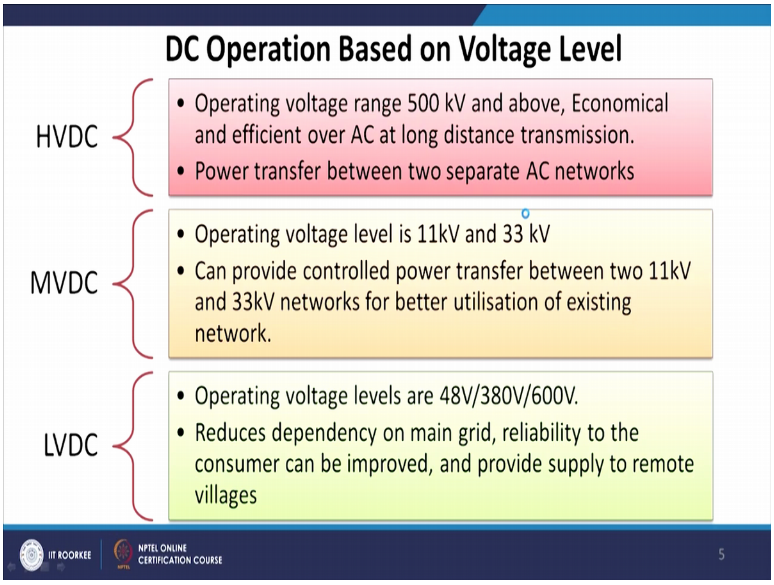

So, the operating voltage in HVDC range beyond 500 kV and economical which is also efficient over AC system. Now power transfer between 2 AC system is also possible through this pdc link we can interconnect two AC systems. Now, the next one which is medium voltage DC system, where operating voltage level is around 11 kV to 33 kV can provide control power transfer between 2 11 kb and 33 kV networks for better utilization of existing systems. Now finally, the LVDC operating voltage level are 48 volts 380 volt and 600 volts, but 48 volts seems to be reasonable for residential applications.

It reduces dependency on main grid, reliability to the consumer can be improved and provides supply to the remote voltages of a remote villages. DC micro grid topology the structure let us concentrate on single bus topology. And then we will move to multi bus topology.

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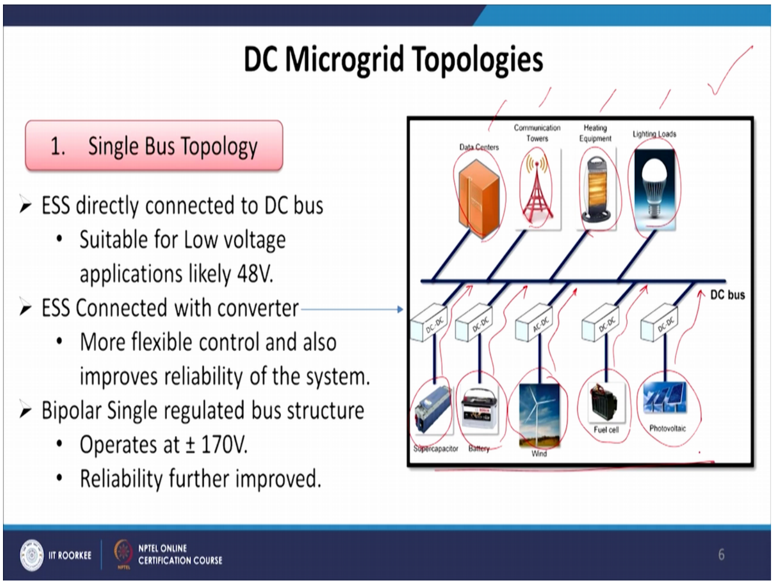

Now, the single bus topology please concentrate, we can just see that the photovoltaic energy source through DC-DC converter, can be connected to my DC grid. Similarly, the foils serve through a DC-DC converter can be connected to my DC bus and then the wind energy sources through a AC-DC converter can be connected to my DC bus, and then we have a battery storage which can be charge through a DC-DC converter as well as the super capacitor which can connect it to my DC bus through AC-DC converter.

Now, concentrating on loads we do have a data center where 80 to 90 percent load devices are of DC communication towers can take direct energy from DC grid, heating equipments as well as the lightning loads they can directly be connected. So, if you look into this architecture of a single bus topology, as a whole I can say the DC grid can catter those specific loads through those generations.

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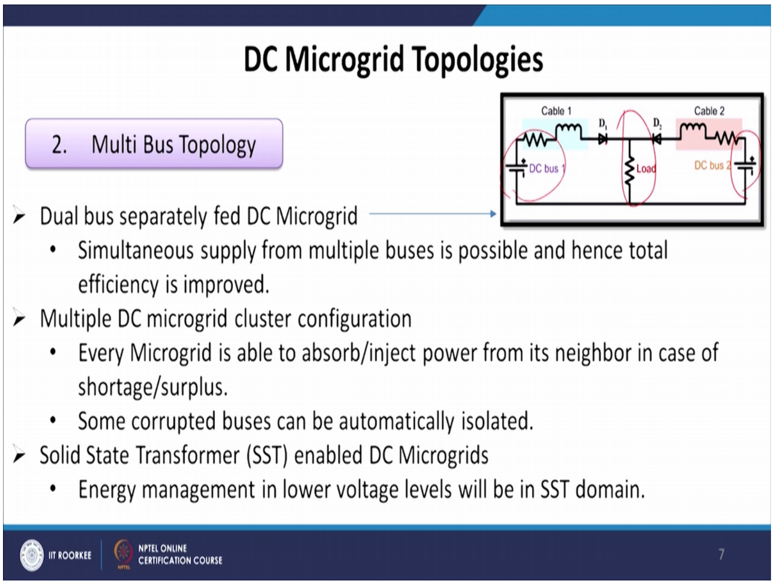

Now when you move to multi bus topology, two different DC buses can together supply loads dual bus separately fed DC micro grid, simultaneous supply from multiple buses is possible and hence total efficiency is improved. Multiple DC micro grid cluster configuration, every micro grid is able to observe or inject power from its neighbor in case of storage sorry shortage or surplus some corrupted buses can be automatically isolated.

Now solid state transformers that is SST enable DC micro grids energy management in lower voltage level will be in SST domain.

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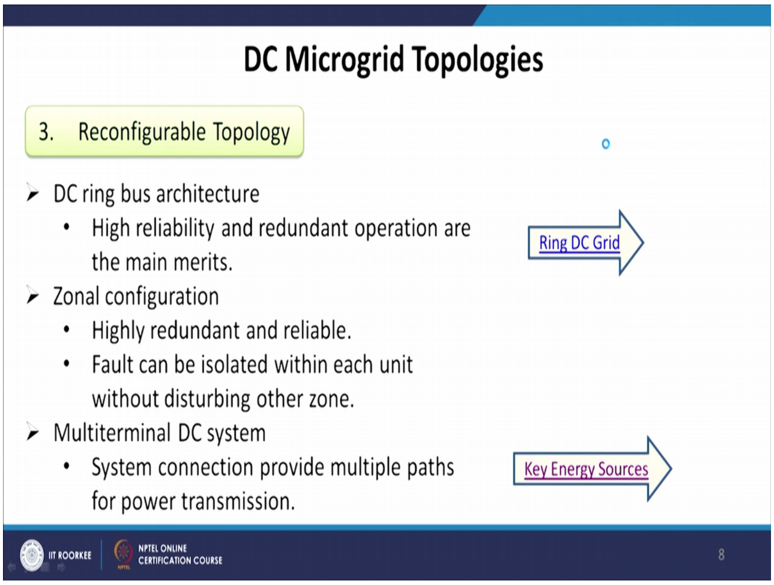

Now the reconfigurable topology where let us focus on a DC ring bus architecture.

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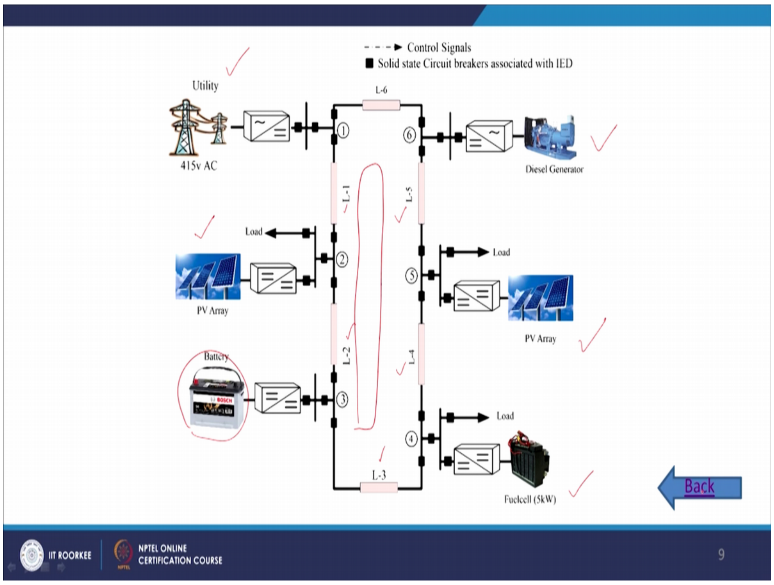

The DC ring bus architecture you can see that the ring structure is of this type, we do have cables or the lines L 1 L 2 L 3 L 4 L 5 and the sources that is a battery PV grid digital generator PV array and fuel cell can be connected to this ring structure.

Now, next we have to understand the ring structure which is highly reliable and it has many merits compared to other architecture of DC grid. But as a whole reliability is the main feature of a ring architecture. Zonal configuration it is highly redundant and reliable fault can be isolated within each unit without disturbing other zones.

Multi terminal DC system where system connection provides multiple paths for power transmission, and hence in general though those three different type of architecture can be adapted for DC micro grid operation and now let us move to key energy sources.

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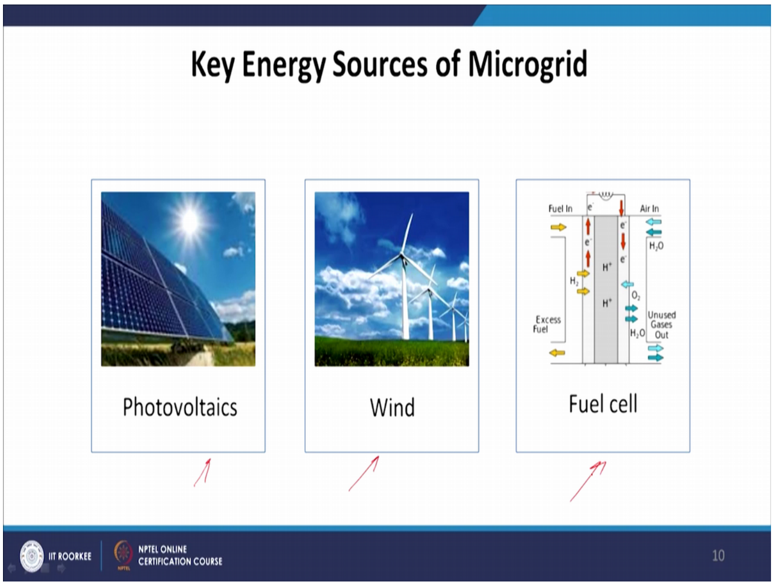

The first one could be photovoltaics, the second one could be wind, and third one could be our fuel cell.

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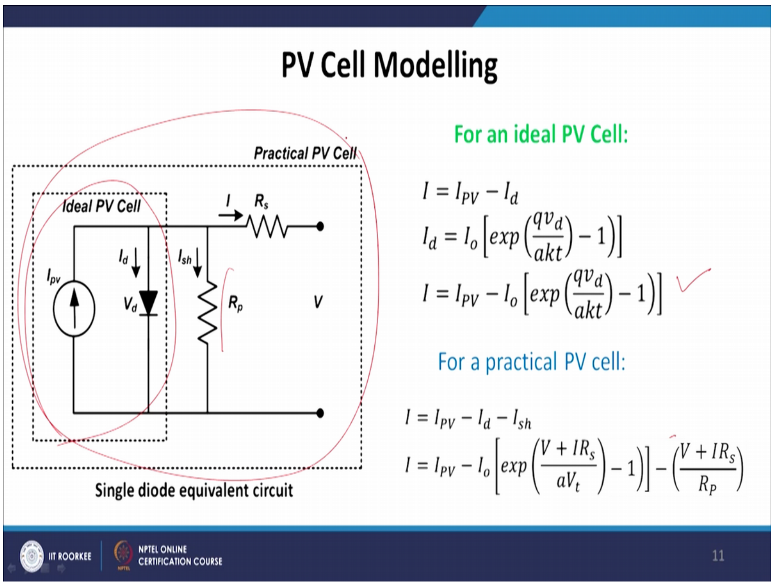

Now, the PV cell modelling which is important let us concentrate to different type of modelling first one is the ideal one single diode equivalent circuit, but the practical one where we have to represent your PV cell with both suntanned series resistances and for an ideal PV cell, the current equation is given by this and for practical PV cell the current extra expression can be obtained by this.

So, please do remember we have to consider the practical modelling of our PV cell for any further analysis.

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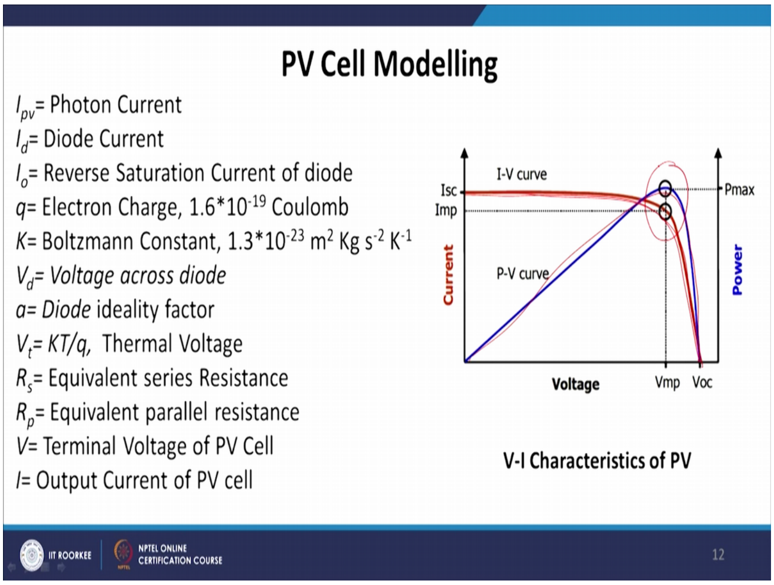

Now, one more important aspect of PV cell modelling is, our PV and iv characteristics. Now if you look into the iv characteristic of the PV cell or which in the red line. And similarly if you plot the PV characteristic which is the blue line, and you can see the iv characteristic drops drastically when my power is at maximum point.

So, this cs of our interest will discuss further why the maximum power point is important in PV cell analysis.

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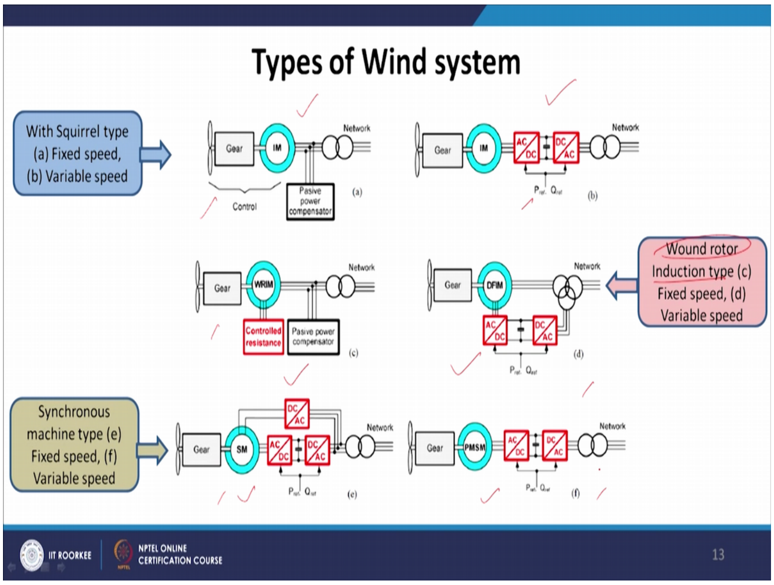

Now, let us move quickly to the different type of wind systems, with squirrel type we do have two different fixed speed as well as variable speed and this is my fixed speed type representation, and this is variable speed type representations.

Now, we will move to the second type of wind system which is bound rotor induction type again this is fixed type and variable speed type representation, and the third one we have synchronous machine type, where we have fixed speed and variable speed. So, those six architecture any one of them can be used as a wind power plant architecture for us, depending upon variable as well as fixed speed type.

Now, for modelling of a wind turbine the following variables you need to be considered.

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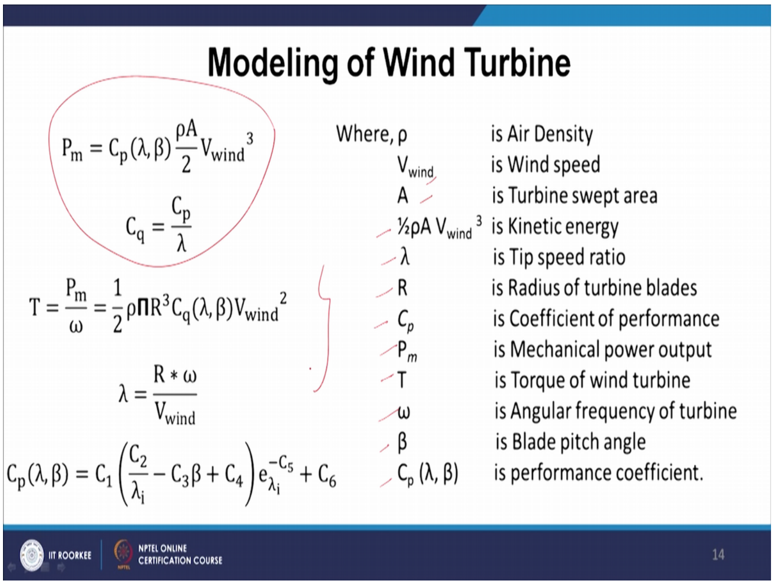

So, air density which is row, wind speed, turbine speed turbine swept area, kinetic energy, tip speed ratio, radius of turbine blades, coefficient of performance, mechanical power output, torque of wind turbine, angular frequency blade pitch angle and performance coefficient.

So, using this we can determine the power of a wind turbine as well as the talk equations.

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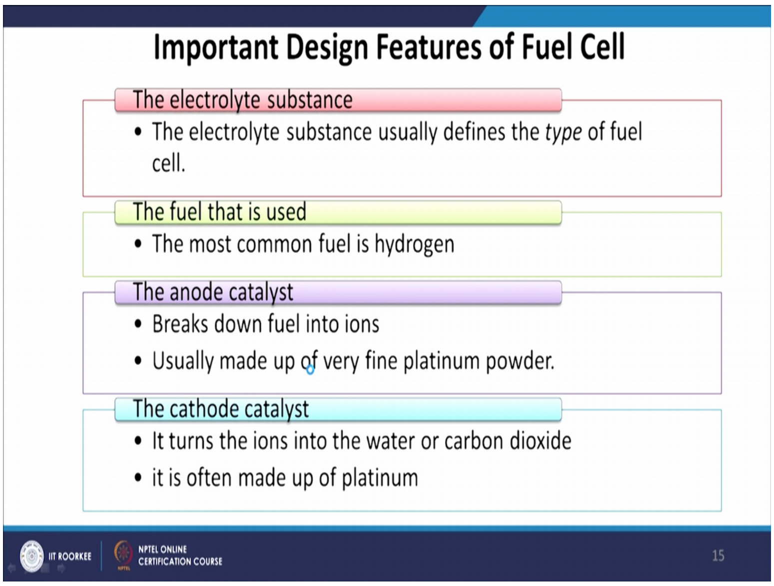

Now, important design features of the third type of sources that we have considered in our lecture today the fuel cell, it has the electro type substance the electro type. The electrolyte substance usually defines the type of fuel cell the most common fuel used is hydrogen, breaks down the fuel into ions usually made up of very fine platinum powder. It turns the ions into the water or carbon dioxide. It is often made up of platinum.

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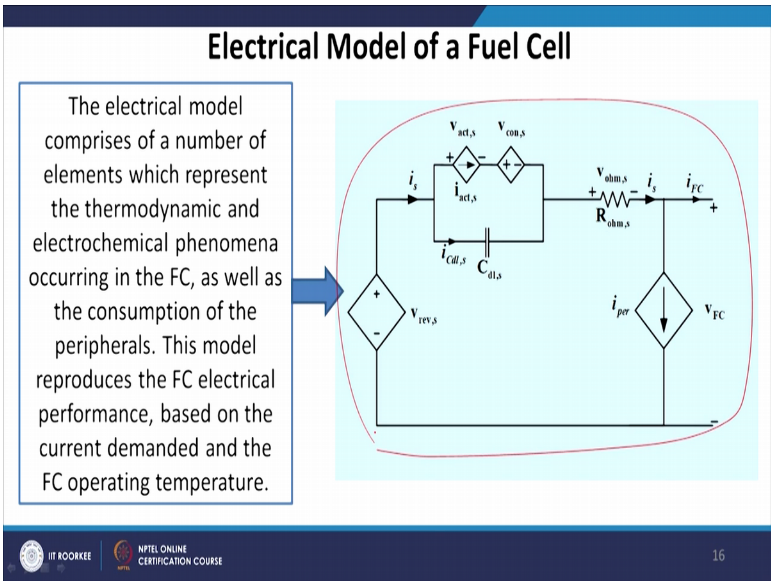

Now if you see the modelling of a fuel cell, the electrical model comprises of a number of element which represent the thermodynamic and electrochemical phenomena occurring in the fuel cell as well as the consumption of the peripherals. This model reproduces the fuel cell electrical performance based on the current demanded and the fuel cell operating temperature.

So, this is what the basic model we need to consider for our fuel cell design.

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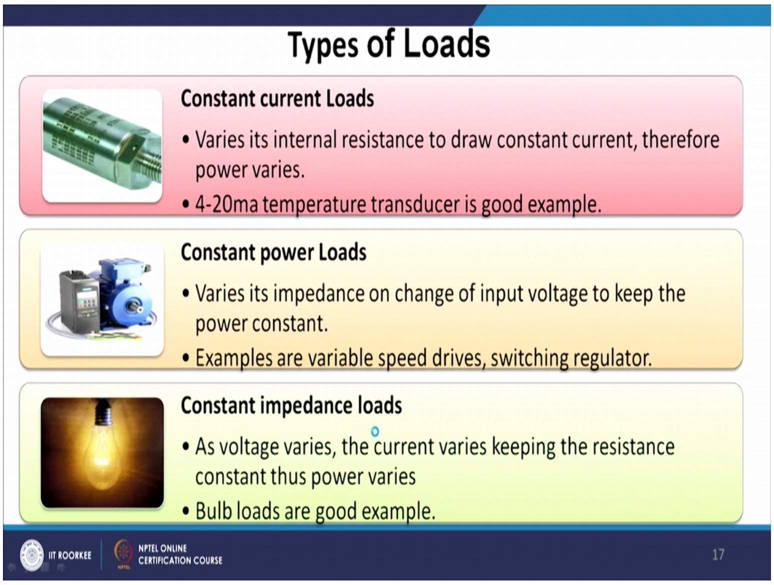

Now, the commonly seen loads in any system are either of constant current type, constant power type or constant impedance type very quickly because we cannot ignore the different type of loads because my smart grid is of DC type. I have to respect and accommodate all the type of loads that are commonly used in day to day period.

So, the constant current constant power and constant impedance loads need to be interconnected to my DC micro smart grid as and when required. So, the constant current load which is very common type varies its internal resistance to draw constant current therefore, the power varies. In case of constant power where is its impedance on change of input voltage to keep the power constant and the very important one is the constant impedance as voltage varies the current varies keeping the resistance constant, thus power varies.

Now, other components in case of my DC smart grid is switched mode converters.

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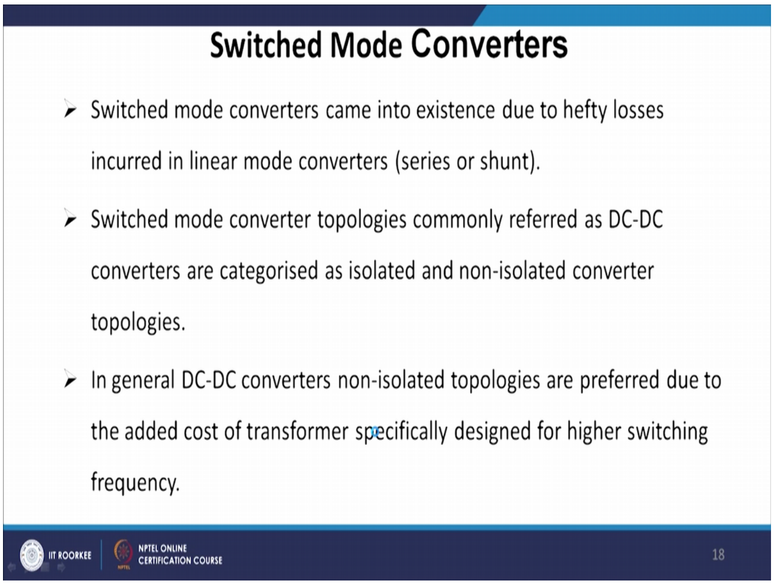

Switched mode converters came into existence due to hefty losses incurred in linear mode converters either there are series or sun type. Switched mode converter topologies commonly referred as DC-DC converter are categorized as isolated and non-isolated converter topologies. In general DC-DC converter non isolated topologies are preferred due to the added cost of transformer specifically designed for higher switching frequencies.

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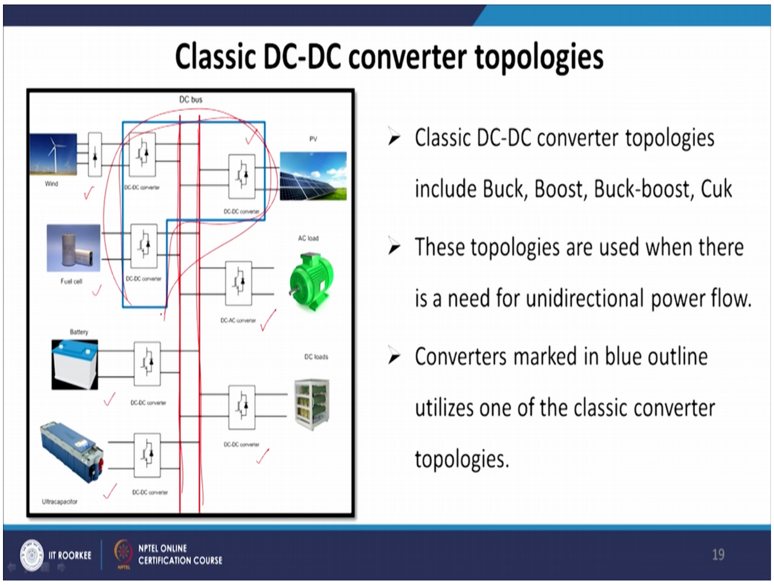

Now, let us focus on DC-DC converter topology if this is my DC bus the red lines represent my DC bus.

So, I can have many for the PV this is my DC-DC converter for AC load, for DC loads, for ultra-capacitor for battery for fuel cell and wind. So, we have different topology for different devices, but the blue jeans especially for the DC-DC converter for wind fuel cell and for PV are of slightly importance and we will discuss recently.

Classic DC-DC converter topologies include buck boost buck boost type, these topologies are used when there is a need for unidirectional power flow. Converter marked in blue outline utilizes one of the classic converter topologies. So, this is what we talked about they all represent the classic topology of converters.

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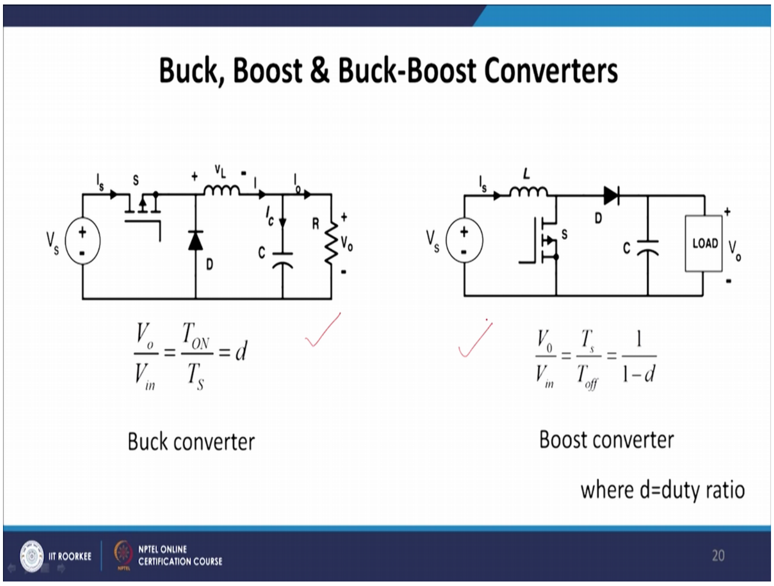

Buck boost buck boost converter and the mathematical modelling is given by this is for buck representation and this is my boost converter modelling.

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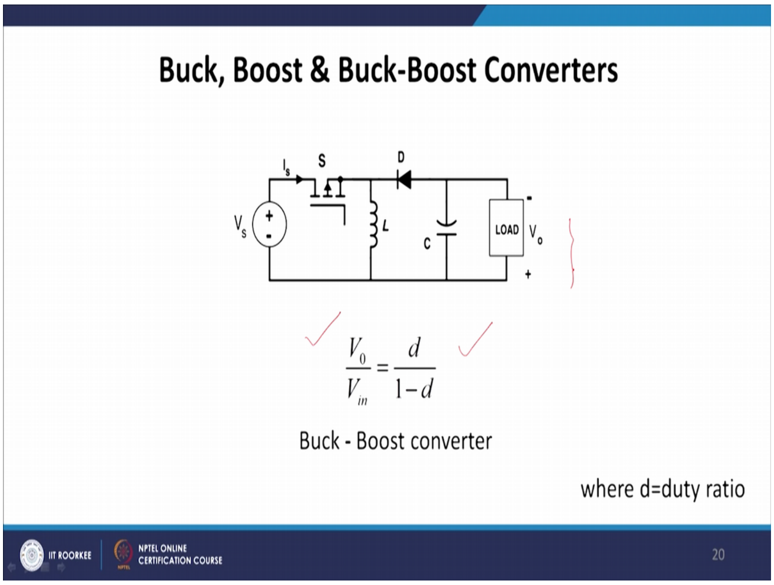

Now, this is buck boost converter representation

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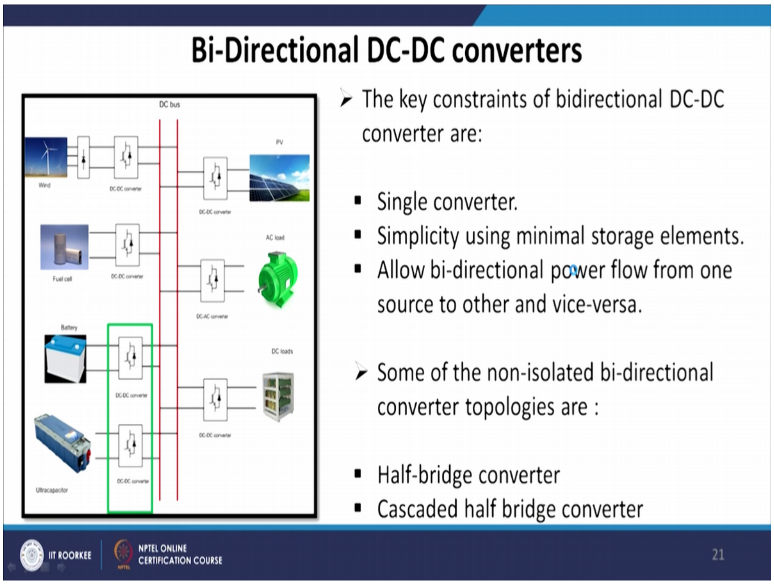

Now we will move to bi directional DC-DC converter, especially for batteries and ultra-capacitor we need to have bi directional DC-DC converter. And the key constraints of bi directional DC-DC converter are single converter simplicity using minimal storage elements, allow bi directional power flow from one source to other and vice versa.

Some of the non-isolated bi directional converter topologies are half bridge converter cascaded half bridge converter a destra.

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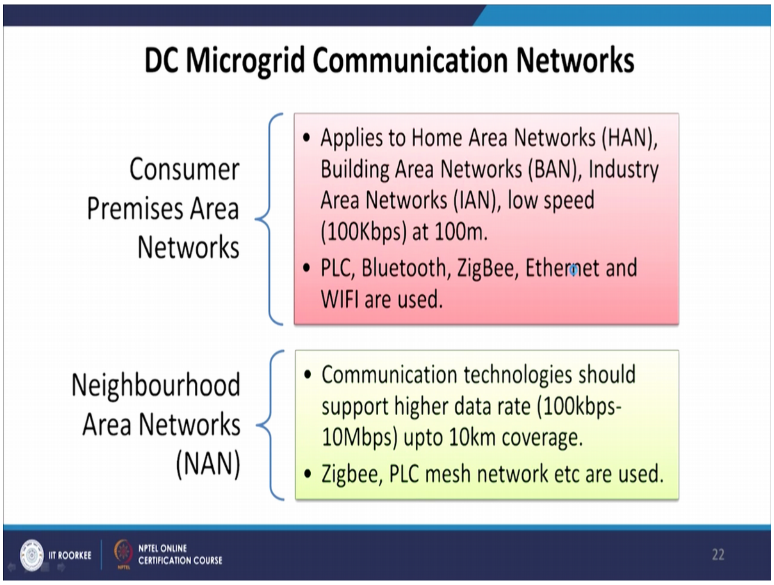

Now, very commonly the communication network we have already discussed in detail, but still this is part of your DC micro grid modelling. So, we use the consumer premises area networks as well as neighborhood area network communication in DC micro grid applications and we also do use wide area networks for DC micro grid applications.

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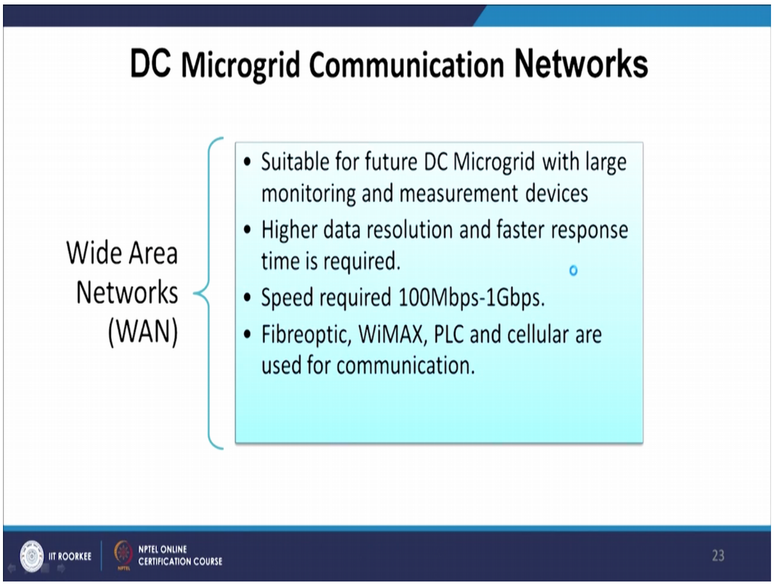

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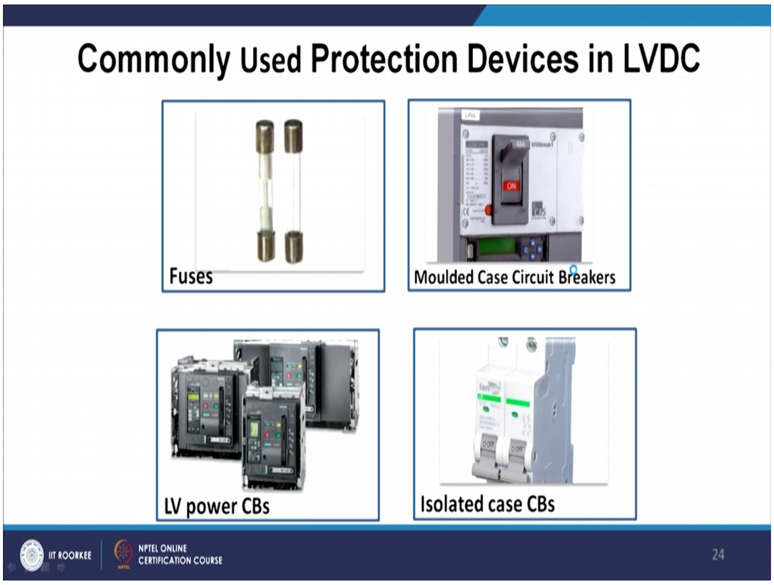

Now that commonly used protections for DC technology, are fuses circuit breakers, LV power circuit breakers and isolated case circuit breakers.

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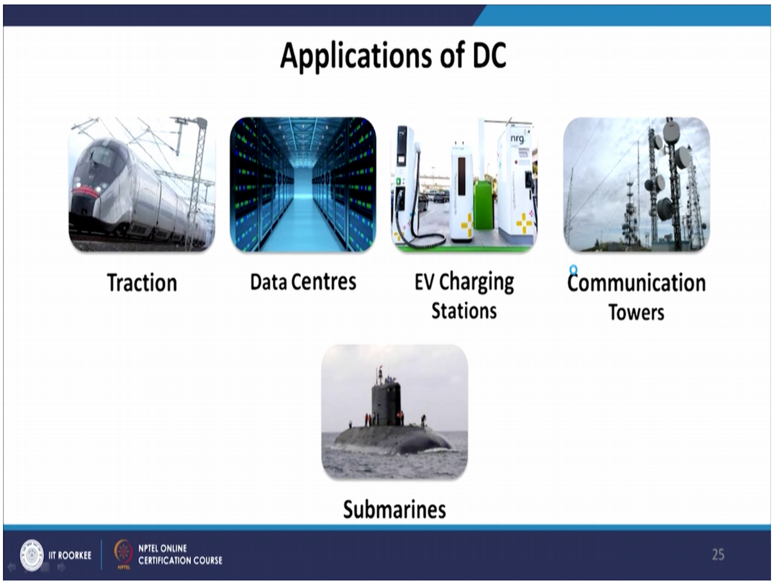

And the application of DC micro grid is mainly could be into traction, data center, EB charging substations, communication towers and submarines all five are very very important of applications. But what are those challenges that one has to take care before moving into DC microgrids modeling and implementation. It has lack of standards it has not been very perfectly evolved over a period of time. It may take a couple of years from now protection issues No DC circuit breakers available.

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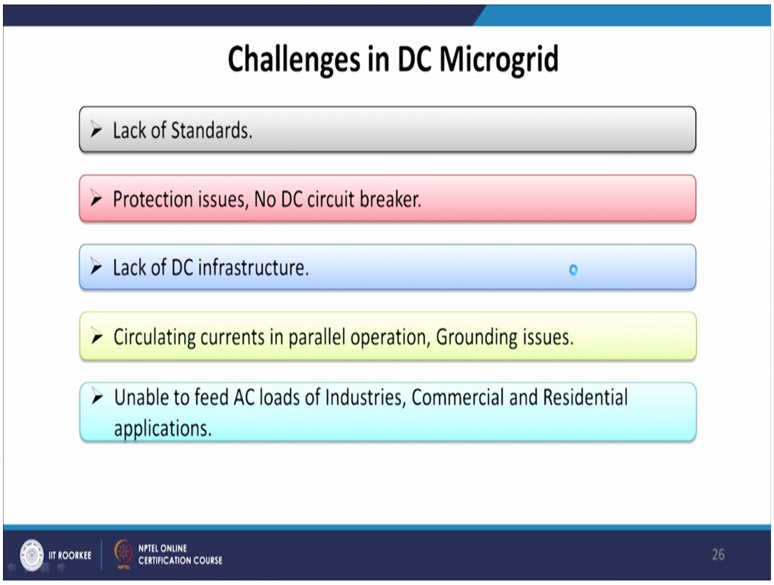

Lack of DC infrastructure circulating current in parallel operation grounding issues unable to feed AC loads of industries commercial and residential applications; higher power loss in LV DC distribution networks and these are the challenges need to be addressed.

So, when we meet next time hopefully we will move to the AC-DC smart grid, where some of the challenges of DC micro grid or smart grid can be taken care by AC-DC smart grid.

Thank you for now.