DC Microgrid and Control System
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Lecture - 04
Microgrid vs Conventional Power System

Welcome to our NPTEL lectures on DC microgrid. Today we are going to discuss about DC microgrid versus conventional power systems and similarity and the differences. So our content today will be the central grid which with the traditional grid which we are seeing for long hundred years.

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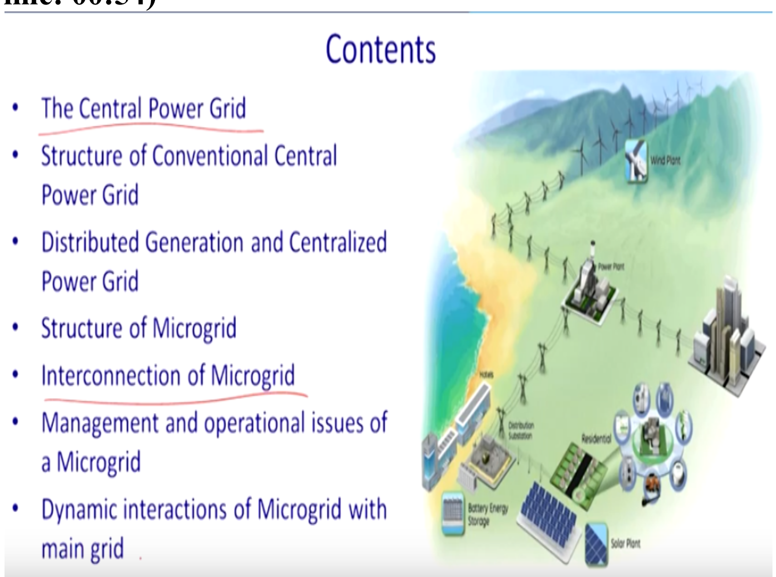

Structures of the conventional central power grid, then distributed generation and centralized power grid, structures of microgrid, interconnections of microgrid, management and operational issues of microgrid. Then dynamic interactions with the main grid. So that these are the topic we are going to cover in our discussions. So central power grid.

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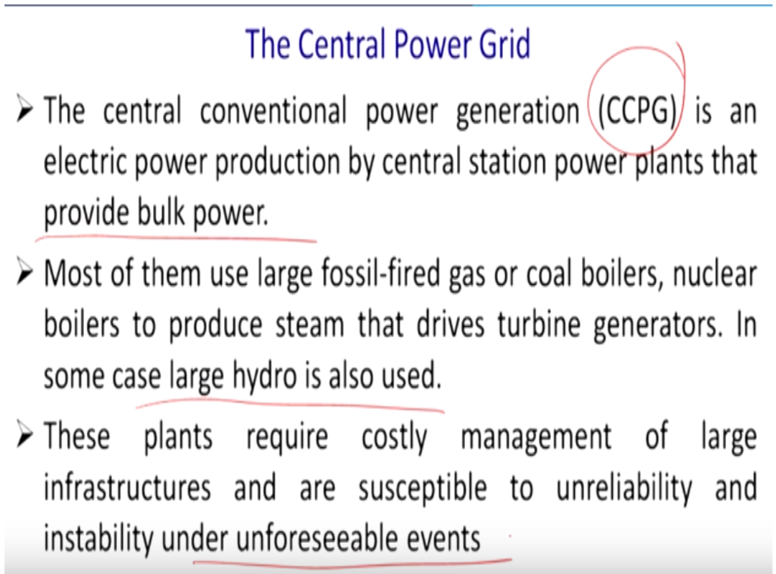

Central power, the central conventional power generation that is we shall take it is as a abbreviation we will use in future. That is CCPG is an electric power production by central station power plant that provide bulk of the power and generally since it is provide bulk of the power it required to be placed away from the load centre because that much of the land is not available in the load centre.

Most of them uses large fossil-fired gas or the coal boiler nuclear boiler to produce steam that drives the turbine generator. In some cases large hydro may be used depending on the availability of that large tank and other facilities. These plants require costly management of large infrastructures because it has a lot of power plant instrumentations and lot of plant you require lot of water and its cooling. So huge infrastructures.

And are susceptible to unreliability and instability under many foreseeable events. For example huge landslide may break the dam or it may be earthquake or the enemy attack, all those things. Or even a cyber attack and you put actually all the turbine out of its synchronism. So for this reason this has got a vulnerability in unforeseeable circumstances.

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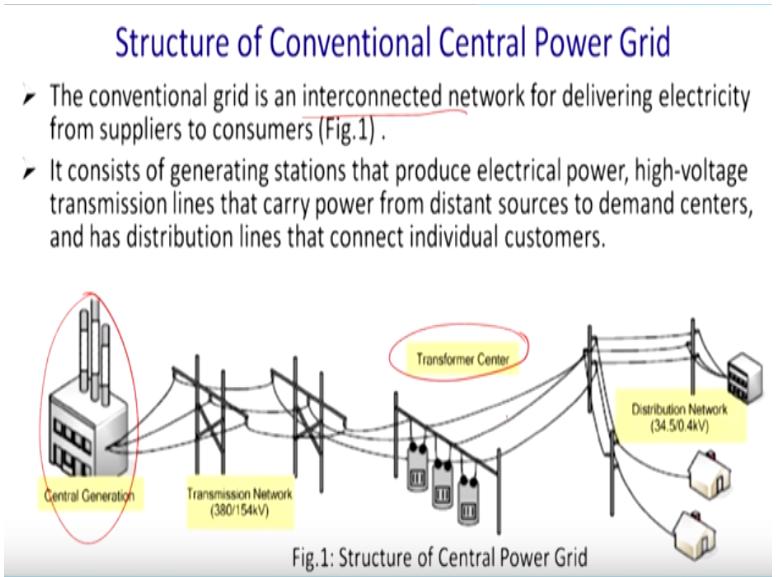

Fig.1: Structure of Central Power Grid

So structure of the conventional central power grid can be described below as the conventional power grid is an interconnected network for delivering electricity from supply to the consumers consisting of generating stations that produce electrical power, high voltage transmission lines that carry power from distant sources to the demand centers and has distribution line that connect individual customers.

So you have a central generation. Then we have a transmission network. Generally if you want to send a power 1 kilometre away you are supposed to step up 1 KV. So you are sending a power in 100 kilometre away you are supposed to step it up to 110 KV. Then transformer center. So you have the transformer. Then it will be stepping down. Then generally it will be located in a switchgear, that is outside the city.

So you do not want to bring a very high voltage inside the city. So thereafter it will be taken underground and we have a small distribution transformer and feeders feeding the load or the consumers.

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Distributed Generation and Centralized Power Grid Comparison

Value	Distributed Generation	Centralized Generation
Continuous Power	Operated to allow a facility to generate some or all of its power on a relatively continuous basis. Important DG characteristics for continuous power include: ❖ High efficiency ❖ Low emissions	Though operated to provide continuous power, its characteristics results in: ❖ Low efficiency due to high transmission losses at the transmission system ❖ High emissions
Premium Power	It provides power services at a higher level of reliability and power quality than typically available from the grid	Provision of power at low reliability and power quality cannot be guaranteed due to inherent high power losses.

So distributed generations and centralized generation, let us put it in a perspective. The value is we require continuous power, continuous quality power mind it. So distributed generation operated allow the facility to generate some or all of its power to a relatively continuous basis. Important distribution generation characteristics for continuous power include high efficiency and low emissions.

And while I say centralized operated to provide continuous power, its characteristics results in low efficiency due to high transmission losses at the transmission system and high emission. Now all those effects comes into the picture for the high voltage applications. Premium power, it provides power service at higher level of reliability and power quality than the typically available from the grid that the power electronics required to ensure.

Because you will choose the power solar inverter that actually generate power with THT less than 3% whereas we may accept the THT in a grid maybe 5% because of the industrial pollution. Provisions of a power at low reliability and power quality cannot be regulated due to the inherent high power losses and also it is a feeding a consumers bulk consumer and that is a polluting of course. Nowadays we are demanding high reliability. Ultimately we require to have a power quality devices to correct it.

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Distributed Generation and Centralized Power Grid Comparison

Value	Distributed Generation	Centralized Generation
Cost	Low variable cost Low maintenance costs	High variable cost High maintenance cost
Resiliency	More resilient since it serves low power demands continuously.	Less resilient but serves high power demands continuously
Sustainability	Sources of power makes it more sustainable	Sources of power results in less sustainability

Now cost. In a distributed generation low variable costs because you are generating from the solar wind and its cost is coming down and also it has a low maintenance cost. Centralized generation high variable costs because of the fluctuating nature of different prices. You know since you are using a oil let us a gas fired base service station. So then oil prices or the gas fire's price varies your raw material prices varies and thus you have a high variable costs.

And also high maintenance cost since you require to maintain the power from the generation to the users. So you have a different kind of people and different stakeholder all has to develop to give power. So resiliency. We may have lot of redundancy in case of the distributed generation. So thus this gives to the resiliency. More resiliency since it serves low power demand continuously.

Less resilient because serves the high power demand continuously. Sustainability sources of power makes it more sustainable. Sources of power results less sustainability because these are the issues because it is used as the fossil fuel and most of this operation are not environmental friendly. Now let us come to the structures of the microgrid.

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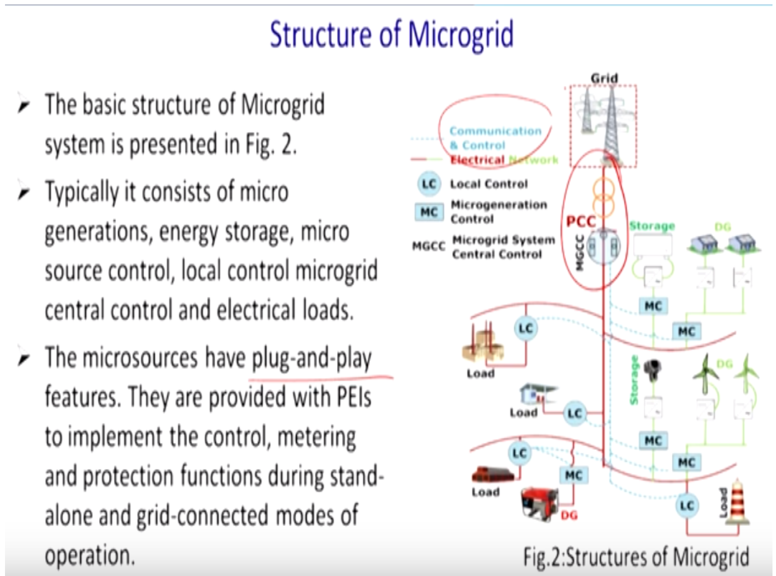

So you have communication control. This is the blue dotted line and red and green line are the electric network. And LC will be a local control and MC will have a microgeneration control and MGCC that is microgrid system central control. So you have a different hierarchical control to smooth operations of this microgrid. So the basis structures of the microgrid system is presented in this figure.

Figure 2 typically is consists of 2 microgenerations or more than that. Energy storage microsource control. Mostly it will control the quality of power it is feeding to the system. Local control microgrid. Local control microgrid, central control, and electrical loads. Microsources have plug-and-play features. So if you wish in a day you are not here and do not want that solar power to be trapped, you may not trap or you are having a maintenance issue you can put your solar inverter off.

So these are plug-and-play kind of devices. They are provided with the PEs that is basically power electronics to implement the control, metering, protection function during the standalone and the grid-connected mode of operation. You may connect this point the grid to exchange of the power once you have a surplus to the microgrid you can sell it to the grid or if you have a more load demand you can take it from the grid.

Or you make operate in islanding mode. So that also comes under that MGCC operation.
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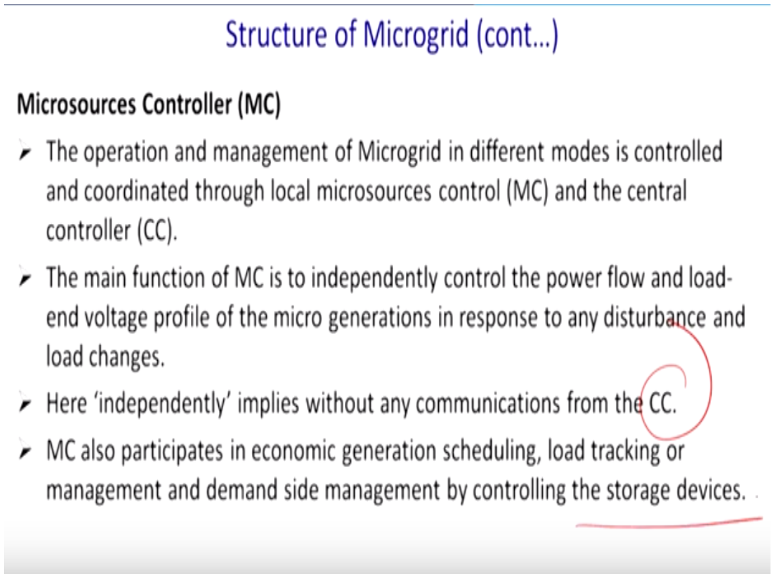

So microsource controller, operation and management of the microgrid in different modes of controllers coordinated through local microsource controller and the central controller. We may have a distributed control and we have a centralized control. The main function of the microsource is independent control of power flow and the load end profile, the micro generations in response to the any disturbance and the load change.

So you know actually you have a source input disturbance. All of a sudden your heat radiation level fall because of the clouding then it has to see that what is the load demand and it may cut down unnecessary load. Or the rivers, you may actually get the greatest sunny day all of a sudden then your solar generation picks up and then which they put into the queue some of the activity that may start.

So these are the task of this MC where independently implies without communications with the centre communication. So this is something can do and it is a distributed control in a local level. MC also participates in economic generation scheduling, load tracking or management and demand side management by controlling the storage devices.

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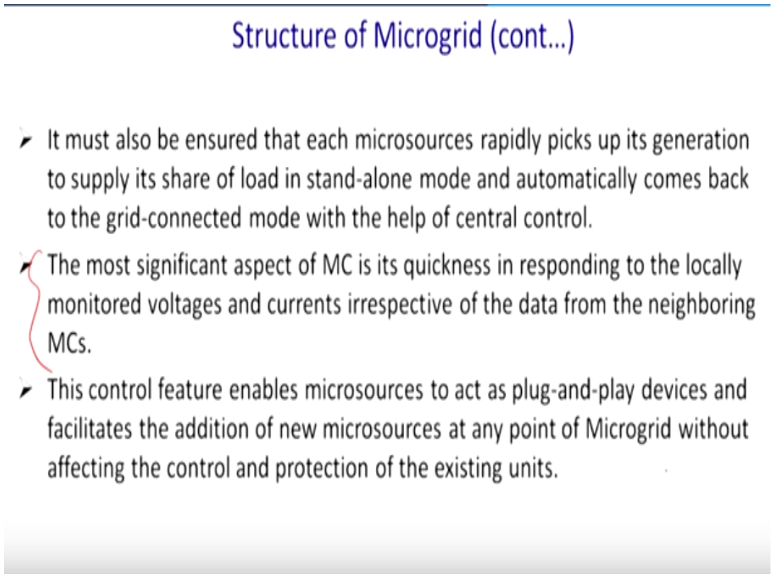

It may also ensure that each microsources rapidly picks up its generation to supply its share load in standalone mode and automatically comes back to the grid connected mode with the help of central control. The most significant aspect of MC is its quickness in responding to the locally monitored voltages and current irrespective of the data from the neighboring MCs. So this is the most important feature. That is point number this point.

The control features enables microsources to act as a plug-and-play devices and facilitate the addition of the new microsources at any point of time to the microgrid without affecting the control and protection of the existing units. So if you want to have your existing solar power plant, you add another solar power plant you are welcome to do that without having any hindrance to the rest of the microgrid.

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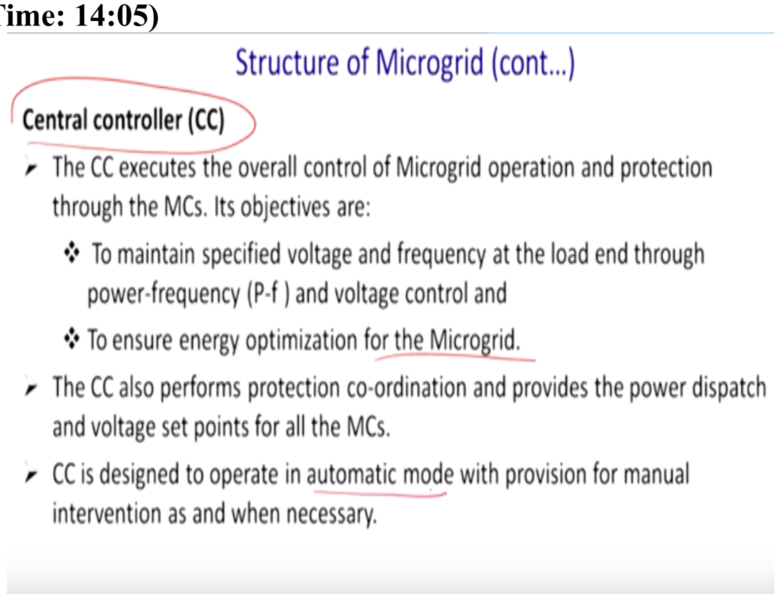

Then what is the task of the centralized control? Centralized control execute overall control of the microgrid operation and protection through MCs. So it get datas from the MCs and ultimately it takes a supervisor role. What does it do? It maintain specific voltage and frequency in case of the AC microgrid and in case of the DC microgrid only the voltage at the load end through the power frequency and the voltage control and to ensure energy optimization for the microgrid.

The CC, the centralized control also perform protection, co-ordinations and provide the power dispatch and voltage set points for all the MCs. CC is designated to operate automatic mode with provision for the manual intervention whenever necessary. So these are all intelligent control but human being are given a right of option.

So some time we have to set the priority of first for some condition relating so the authenticated person or administer or someone have a right, super user has a right to write off. Interconnection of the microgrids.

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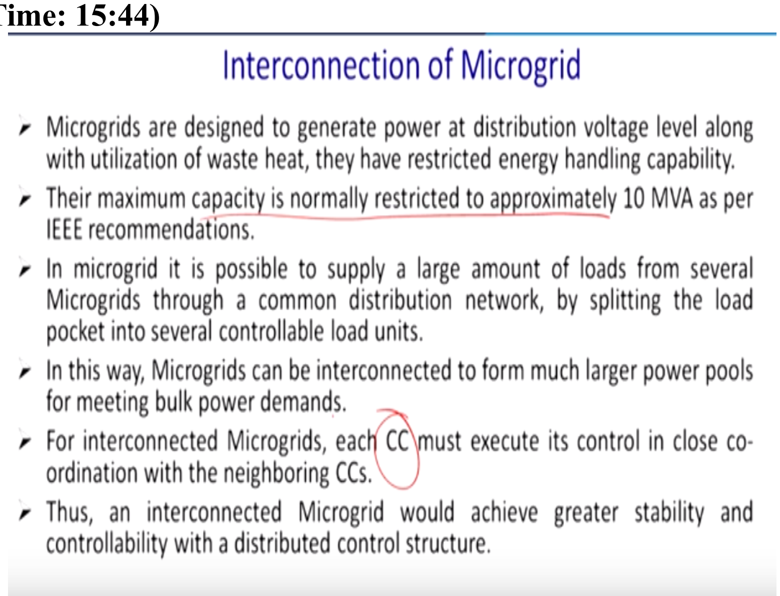

Microgrids are designed to generate power at distribution voltage level along with utilizations of waste heat, they have restricted energy handling capability. For this reason the maximum capacity normally restricted approximately is 10 MVA as per the IEEE recommendation. So that is also quite big power from the Indian perspectives.

In microgrid it is possible to supply large amount of load from several microgrid through a common distribution network like splitting the load pocket into the several controllable local loads. That is also localize, this is called localization of the load. In this way microgrid can be connected form much larger power pools for emitting bulk power demand.

For interconnected microgrid, each centralized control must execute its control in close coordination with the neighboring microgrids. Thus an interconnected microgrid would achieve greater stability and controllability with the distributed control structure. Now interconnection of the microgrid to the main grid have the following importance.

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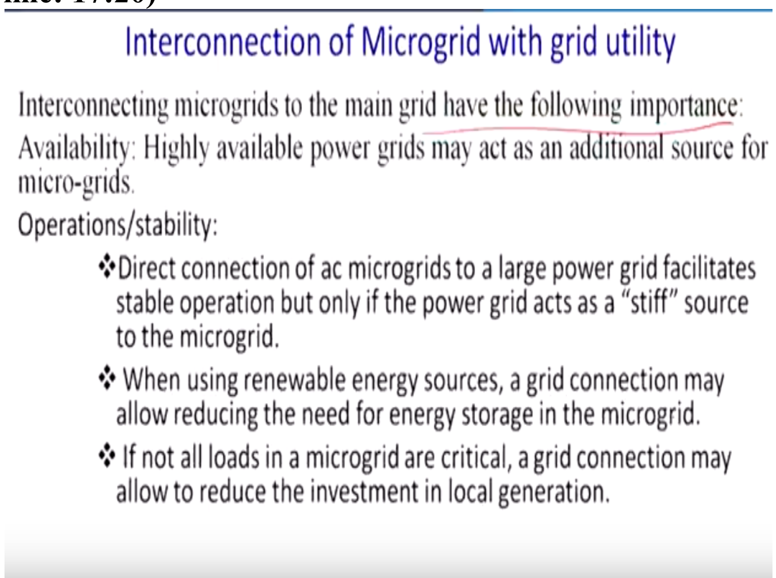

That is what we have seen that there is a point of injection that is called point of common coupling. That is availability of the grid definitely. You may put a microgrid in isolated places there is no grid then there is no question of grid connectivity arises. So availability, highly available power grid may acts as a additional source for the microgrid.

Direct connections of AC microgrid to a large power grid facilitate stable operation but only if the power grid acts as a steep source to the microgrid. When using a renewable energy sources a grid connection may allow reducing the need for the energy storage in the microgrid. For this is actually it is quite helpful because there is a concept of autonomy.

That is why we have a mostly solar microgrid and ultimately you may consider that there is a rainy day and thus generation of the power will be low and for this reason we require to design the battery size. So if you have that grid connectivity then you may consider that you know okay battery size can be lower so you may not because power may go or power may go off not throughout the day.

So for this reason 1 day power backup may be sufficient but if it is islanding mode then what will happen the cost of the battery will increase. If not all the loads in a microgrid are critical, so that is very important thing so and that is also true. Most of the cases they have around 20% or 10% of the loads are the critical load. So grid connection may allow to reduce the investment in the local generation.

So once your let us say you are using a high bulk power consumption. When actually power available to the microgrid is plenty you can schedule your work at that time.

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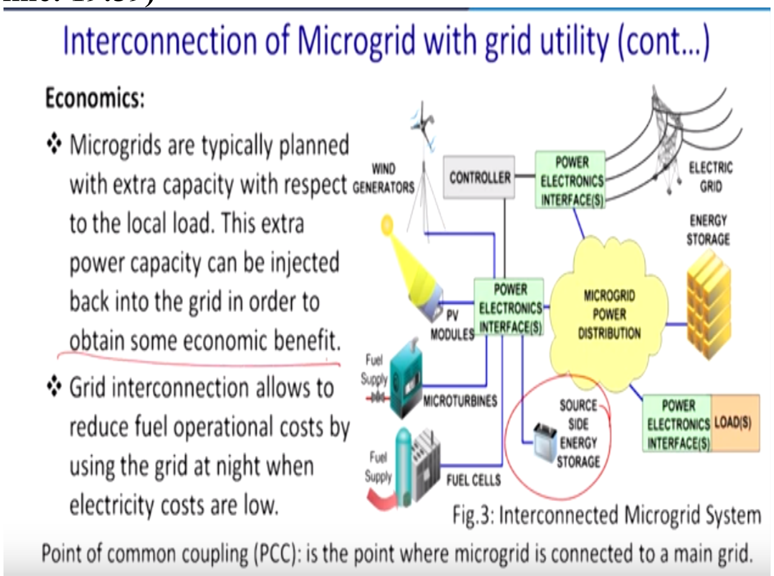

So interconnection of the microgrid with utility grid. One reason is the economics. Microgrids are typically planned. So for this you can see that you know these are wind generations. This is a PV module. This is the microturbine and you may have a fuel cell and ultimately power electronics comes into the pictures and this is the battery and this is a microgrid distributions.

Or you may have a and this is a controller through that it is active power rectifier generally or filter depending on the bidirectional power flow happens on the grid to the microgrid and vice versa. And you may have a bulk of the energy storage to exchange the power. And power electronics load interface can be done by it. So this is the interconnected microgrid system.

Microgrids are typically planned with the extra capacity with respect to the local load. This extra power capacity can be injected back to the grid in order to obtain some kind of economic benefit. Generally we have a tariff benefit once you sell the power to the grid instead of taking. That is the way of using device to setup the microgrid. Grid connection allow to reduce fuel operation cost by using a grid at night when electricity costs are low.

Point of common coupling is the point where microgrid connected at the main grid. So this is the overall operation we are going to explain into the next slide.

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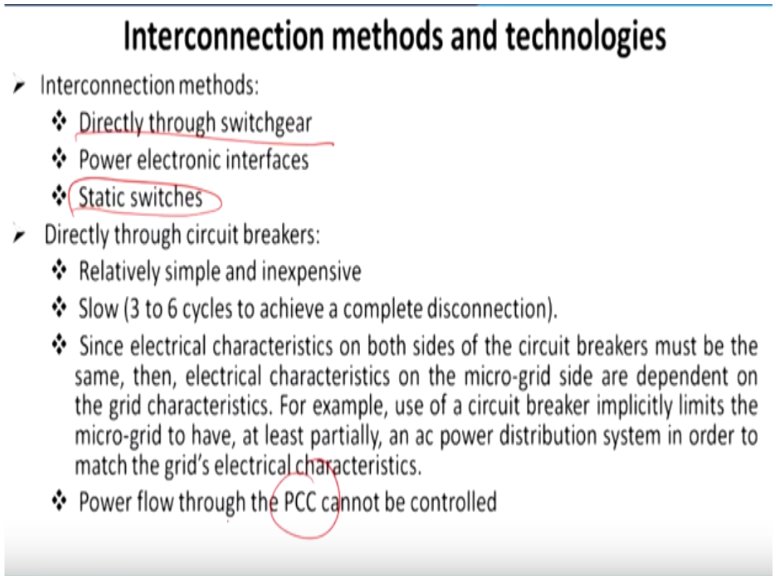

Interconnection method. Definitely it can be directly to the switchgear. This is a traditional method. Power electronic interfaces, so now we have a solar inverter and islanding techniques all those been placed and they have a static switches mostly for the maintenance purposes. And directly through the circuit breakers also you can do that relatively simple and inexpensive but it require cycles of operation, slow 2 to 3 cycle to achieve the complete disconnections.

Since electrical characteristics on both the side of the circuit breaker must be the same then electrical characteristics on the microgrid side are dependent on the grid characteristics. Let us put an example. Then only we understand better. For example, use circuit breaker implicitly, limit the microgrid to have at least partially as an power distribution system in order to match that grid characteristics.

Otherwise you know that impedance matching is a very big issue. So those aspect has to be put into the aspects. And power flow through the PC cannot be controlled if you have this option that is with the static switches or the direct through the switchgear. So power flow will be totally depending on the load. So interconnections also we can place some kind of checks and balance by the technologies.

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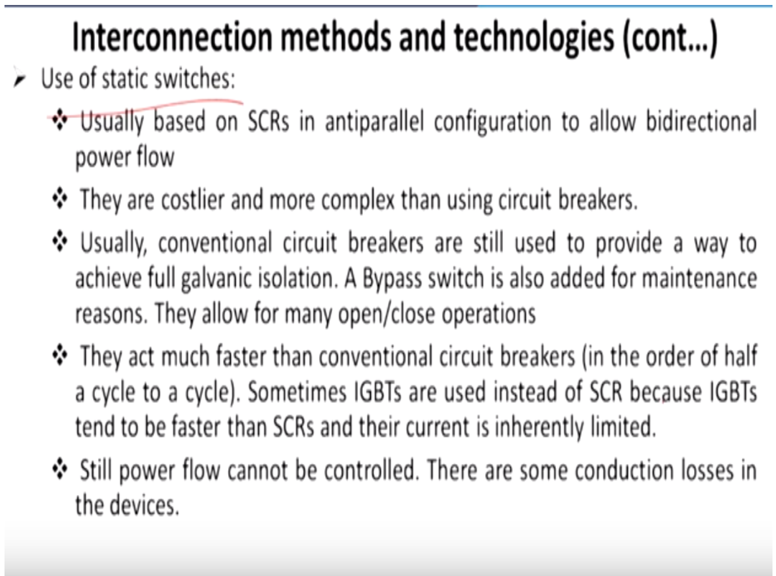

So of course if you use the static switches then you see that what happened. It is usually based on the SCRs and in antiparallel configuration to allow the bidirectional power flow. Depending on the rating, if you are rating, nowadays actually, nowadays we are coming with the (()) (23:43) devices SIC so this SCRs can be soon replaced by IGBTs. They are costlier and they are more complex than the circuit breaker where advantage is that power flow can be controlled.

Usually conventional circuit breaker are still used to provide the way to achieve full galvanic isolation. A bypass switch also added to maintain, for the maintenance reason I was saying that for maintenance purpose we require to have a isolators. They allow many close or open operation. They act much faster than the conventional circuit breaker in order to the half of the cycle. Sometime IGBTs are used instead of SCRs.

That is what I am saying and IGBT will find its more space with while this actual this high (()) (24:37) devices are put into the practices. IGBTs tend to be faster than SCRs and their current is inherently limited. Still power flow cannot be controlled. There are some conduction losses in the devices. For this reason we are also researching in that area and we are talking about SiC devices to take care of the low power flow losses.

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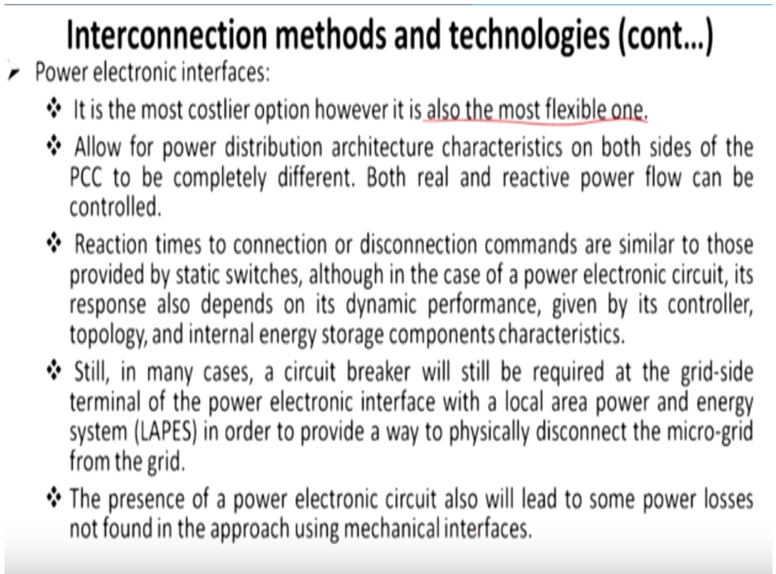

Now comes into the third entity that is power electronics interfaces, interconnection by the power electronics devices. It is the costlier option till now. Of course we expect that cost will come down gradually. It is the most costlier option, however, it is most flexible one. It allow power distribution architecture characteristics to both side of this PCC to be completely different.

You can have a different frequency here, you can have a different frequency, you can have a different voltage level everything can be different. Both real and the reactive power flow can be controlled. That is the PQ control and generally the power entry is through the active power filter or rectifier. Reaction times of the connection and disconnection command are similar to those of the provided by the static switch because it also uses IGBTs only.

Although this case of the power electronics its response depends on the dynamic performance given its controller topology and the internal energy storage component and characteristics. Still in many cases the circuit breaker will still be required at the grid side because to have a at quenching and all those leakage current those issues has to be tackled.

Terminal electronics interface with the local area and energy system in order to provide the way of the physical deduction of the microgrid from the grid and also leakage current was a very big issue. Presence of the power electronic circuit also will lead to some power loses not found in the approach of the mechanical interference because till now we do not find a seamless transition of power electronics turn on to turn off.

Because there is a turn on losses as well as the conduction losses in case of the power electronics devices. So next, the last important thing is the management and the operation of the microgrid.

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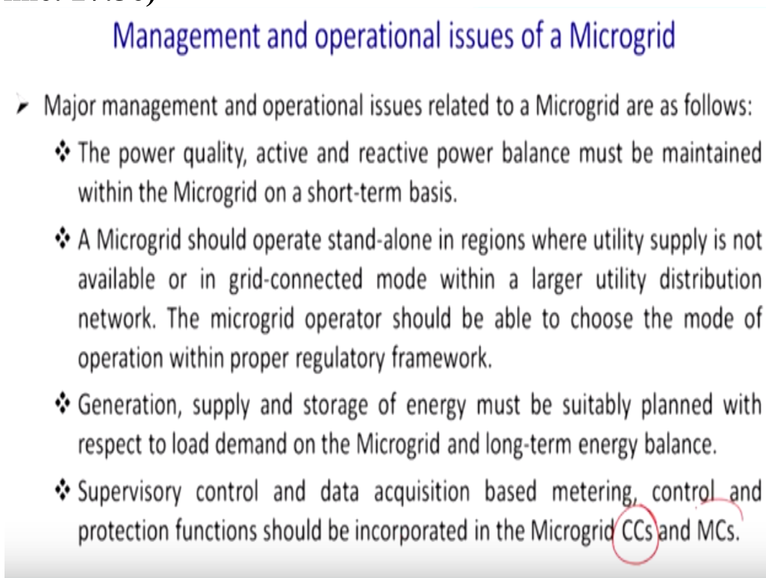

Major management and then operational issues related to the microgrid are this power quality active or the reactive power balance must be maintained within a microgrid on the short-term basis. So it has to be balanced in a particular timeframe. Microgrid should operate standalone in a region where utility supply is not available or the grid connected mode within a large utility distribution network.

The microgrid operation should be able to choose the mode of operation within proper regulatory framework. Generation, supply, and the storage of the energy must be suitably planned with respect to the load demand and the microgrid long-term energy balance. Supervisory control and the data acquisition based metering control and the protection function should be incorporated in the microgrid controls and the MCs.

Then microgrid operation should be ensured through generations scheduling economic load dispatch and optimal power flow operation. These are the different consideration we have to keep in mind. System security must be maintained through the contingency analysis and emergency operation like demand side management, load shedding, islanding, and the shutdown this can be practiced whenever it is required seamlessly.

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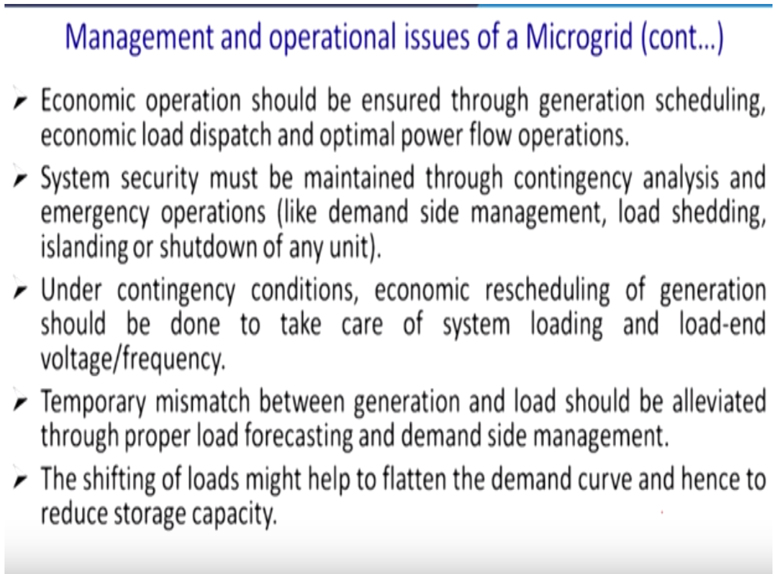

Under contingency condition economic scheduling of generation should be done to take care of the system loading and the load end voltage frequency regulations. Temporary mismatch between generation and the load maybe elevated to the proper load forecasting and demand side management. The shifting of the load might help to flatten the demand curve and hence reduce the storage capacity, so for this reason.

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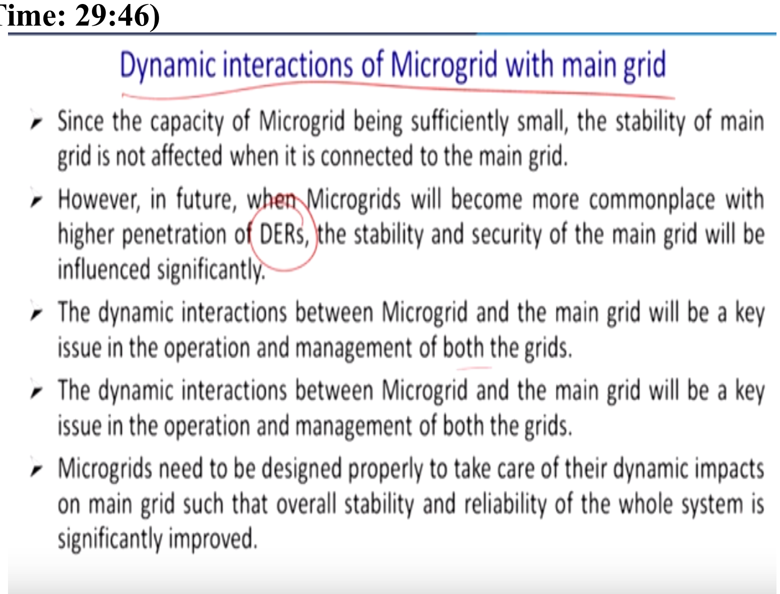

And the dynamic interaction of the microgrid with the main grid. This is one of the important aspect of it, please put in addition to it. Since capacity of the microgrid being sufficiently small, since we are saying the word micro, the sustainability of the main grid is not affected when connected to the main grid, please understand. It is always actually the smaller entity will be affected.

However in future the microgrid will become more common place with higher penetration of the DERs distributed generations and storage element. The stability and the security of the main grid will be influenced significantly with the presence of the microgrid. The dynamic interaction between the microgrid and the main grid will be a key issue in operation and the management of both the grid. That is the challenge we are going to face in future.

The dynamic interaction between microgrid and the main grid will be a key issue of operation and the management of the both the grids. Microgrids need to be designed properly to take care of their dynamic impacts on the main grid such that local stability, reliability of the whole system is significantly improved. So these are few issues of the dynamic operations and dynamic interactions of the microgrid with the main grid.

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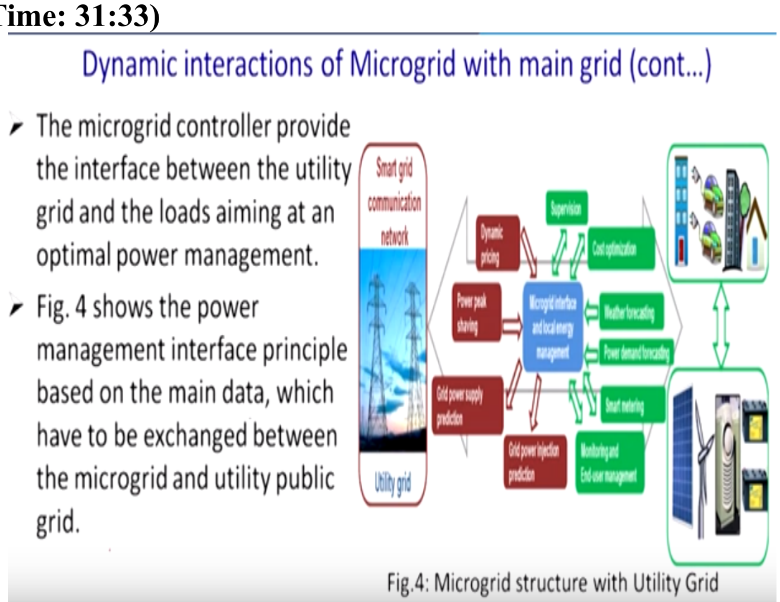

Fig.4: Microgrid structure with Utility Grid

And then this is the microgrid and you have a supervision, you have a dynamic pricing. You have a peak load shaving. Thereafter grid power supply prediction. All those and ultimately microgrid interface and local energy management, cost optimization, weather forecasting, power demand forecasting, smart metering, monitored and end-users. These all come into the one package one which is the interactions with the main grid matters.

So the microgrid controller provide the interface between the utility grid and the load aiming at an optimal power flow management. So this is the figure that displayed that. So figure shows that power management interface, interface principle based on the main data which have exchanged between the microgrid and the utility grid. And what else?

The microgrid controller can take into the account, account of information about the public grid availability and the dynamic pricing. Inform the smart grid on injection of intentions of the power demand with the demand of the end users with respect to all physical and the technical constraint.

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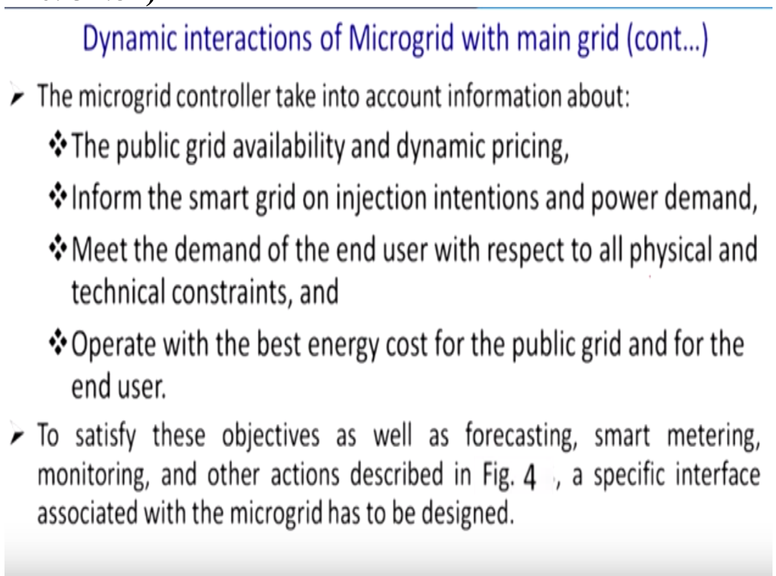

Operate with the best energy cost for the public grid for the end user and thereafter to satisfy its objective as well as the forecasting. Smart metering, monitoring and the actions prescribed in the figure a specific interface associated with the microgrid are to be designed and to be implemented. Thank you. Thank you for your attention. These are the few things while we will connect that microgrid with your main grid.