DC Microgrid and Control System
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Lecture-33
Applications of DC Microgrids

Welcome to our DC microgrid and a control system today we shall discuss mostly the theory part as well today. There is application of the DC microgrids so while we will find potential and its applications. So, our presentation layout today will be based on its introduction they are after a different kind of hydro power, tidal power and all those amusement park. So, where we can fit a DC microgrid in is a right suitable option.

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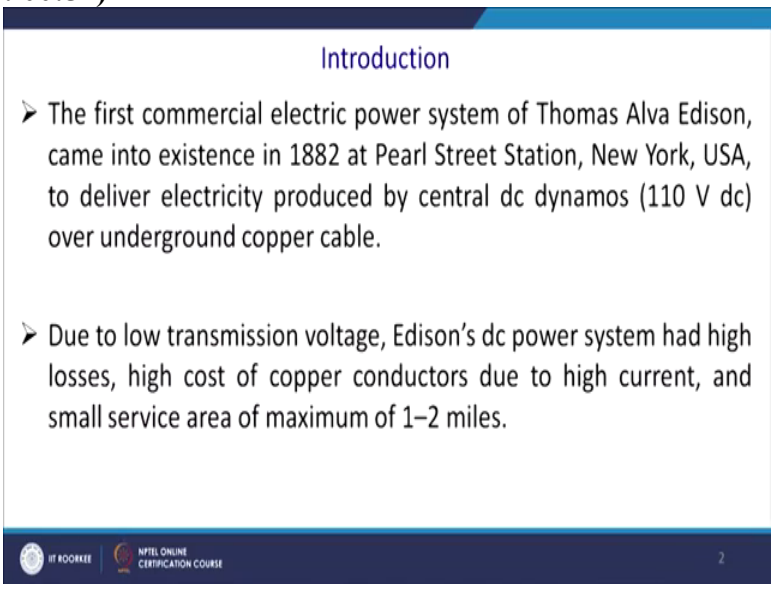

So, let us go back to the little history that was a famous battle between Nikola Tesla and Thomas Alva Edison. So, first commercial electric power system was developed by Thomas Alva Edison in 1882 as long as that time and the Pearl Street stations in a New York to deliver electricity produced by central DC dynamos. So, that at that time there was a DC generator so you had a DC dynamos and the supply voltage was 110 volts.

Still US, continue with this voltage even though it is now AC over the underground copper cable. So, thereafter you know those who know a little bit of history of the electrical sciences they know that our electrical engineering they know that transmission this modern transmission and distribution system ultimately follows the philosophy and application of the Nikola Tesla and

Nikola Tesla shows that AC has definitely merits over DC and but that time power electronics was absent.

So, Thomas Alva Edison required to be supported by the power electronics since that was absent that time ultimately Thomas Alva Edison lose, the battle like anything. But with the help of the power electronics again the concept of the DC has rejuvenated and thus you know there was a problem in that and that time. So, due to the due to the load transmission voltage Edison's copper system, Edison's power system had a high losses because it has it cannot transmit bulk power.

Because if you want to transmit more power and low voltage current required to be high and thus your losses will be more. High cost of the copper conduction due to the high current and small service area maximum of 1 and 2 miles so in between you require to; you can supply. So, you require to put your generator all you want 2 kilometre away from the load Center.

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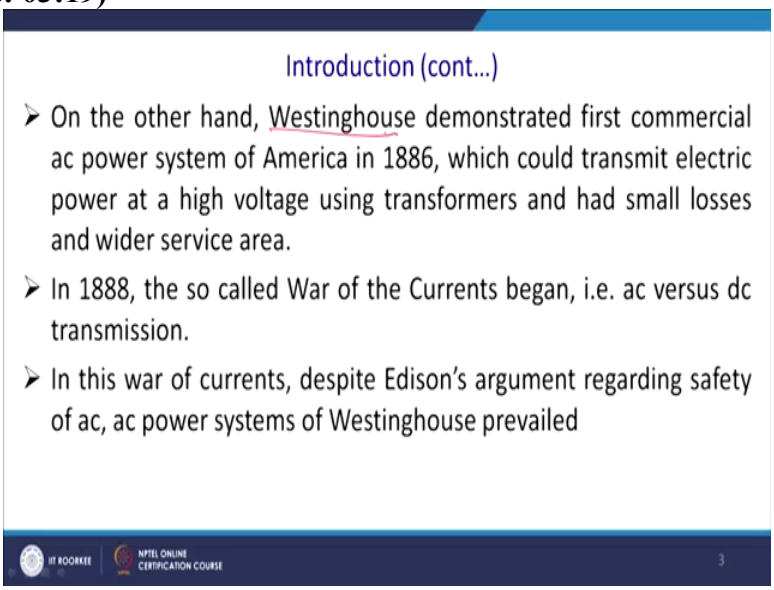

And on the other hand were Westinghouse where the; that person was the Nikola Tesla demonstrated it is because in the US it is 60 Hertz because all hour are multiple of 60. So, they wanted to have a 60 Hertz. Demonstrated first commercial AC power system in America and just 4 years later that is 1886 which would transmit the power and high voltage using transformer and since it is a stationary solution it will have a small losses and a small losses over the wide area. And in 1888 the so called where of current began versus AC versus DC the famous battle between the two school of thoughts one is Thomas Alva Edison that was supported by GE and another by this Westinghouse build by Nikola Tesla. This war of the; in this war of current despite Edison's argument regarding safety of AC.

AC power system of Westinghouse prevailed ultimately Nikolas Tesla win the battle conclusively why because you know we are all happy we have faced out this system nowadays. But again it is resurfacing why we require to know this.

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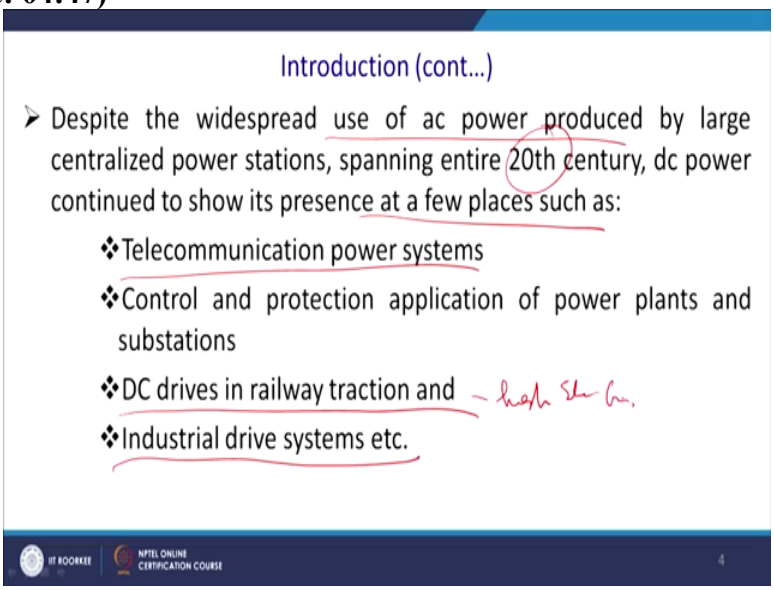

Now despite of the widespread use of the AC power produced by the large centralized power stations spanning 20th century or as well as a 21st century the DC power continued to show its presence at few restricted places such as communication system, communication tower require the DC power, control and protection applications of the power plants and substations you if you go to any power plant you will find huge battery bank to start the alternator.

Because that field current should come from that storage element once you want to start it the electricity and for the system you require a backup power and that backup excitation current comes from DC. And though modern railway drives are AC but locomotive only in the local trains and all these are DC type and fractions. And there is a historical reason since that the same order was running and we know that DC motor control very well.

All the led machines which was running has a longevity may be actually 50 years they are still running that is by the DC motors ultimately we are equal to retrofit it. And thus we find that power electrics application of rectifier there and industrial drives and it is etc why DC finds is still been practiced because of the high starting torque because why we prefer in a railway because of the it starts as a DC series motor with a high starting torque thereafter will change you but to the shunt motor rate.

So, anyway and those kind and also in case of the as you know that this is shunt motor the torque speed characteristics is moreover constant and thus you can have a wide range of speed variation with a different kind of a wide range with a constant torque in the application DC motor were preferred. Because at that time the cause complex AC try playing PYF control and the vector control was not invented and thus it is gradually phasing out but again we have totally a DC system.

Because we added telecommunication is DC or mobile charger is DC and daily phone towers are DC control and protections of the control and protection of the power system units a relay and all those elements require DC power supply. Apart from that your traction mostly electrical traction which is used in electric drives mostly railways are DC and because of the high starting torque. And the industrial system because have the wide ranger speed variation with constant torque and high to low speed. So, these are the, few advantage since DC gives we fail to replace DC in totally.

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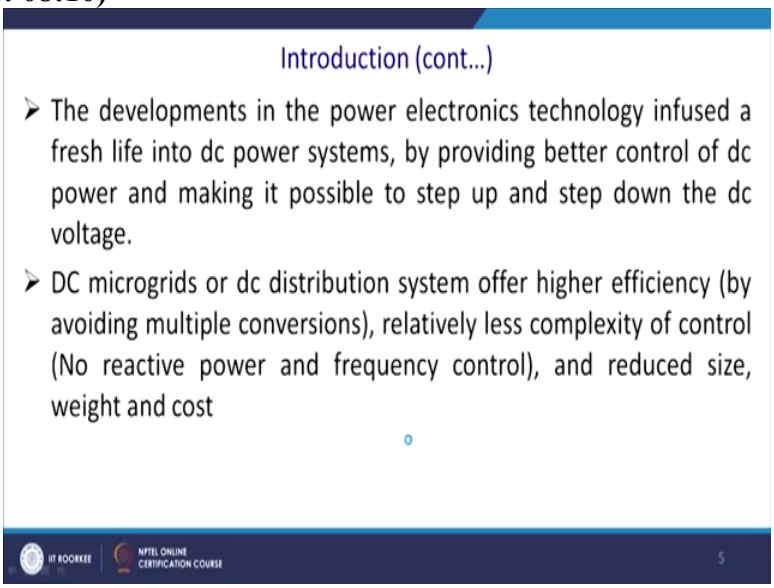

Now the development of the; now comes into the picture development of the power electronics also enable to use in AC system to have that features like you have a V by F control and thus you can have a varied free speed of variations and a constant torque. So, you know and you require a high starting torque also possible by V by F or vector control. And independent control of the torque and speed is also possible like separately excited DC motor in induction machine by vector control.

So, that when role of the power electronics comes into the picture and which is fitted to the front end of the induction motor. And but then we must say that then we would no longer require a DC but it is reverse since there is a rectification stage it is better to have a DC system. So, let us see that the development in power electronics technology infused in a fresh life of the DC power system. Because why power electronics exist in my opinion we do not have a transformer in DC and generally the induction machines are constant speed machine and a constant power supply.

So, you require a variable frequency power supply but and due to those two reasons mainly we require a power electronics. So, by providing the better control of the DC power and making it possible to step up and step down the DC voltages. So, again it rejuvenates the DC power supply DC power flow and all those issues. Now you have HVDC transmission also but we are talking about in a distribution limit not in a transmission layer for time being.

The microgrid or the microgrid or the DC distribution system offer higher efficiency by avoiding multiple conversion. So, generally what happened once you have adjustable speed drive what I was talking because induction machine a constant frequency machine once you want to have a mimic the conductor restricts of the separately excited DC motor having a wide range of speed variation as a constant torque.

Then you require to rectify it thereafter you require to put a front end inverter and that is you require of multiple stage AC to DC, AC conversion. And for this is reason to avoid it, it is rather preferable let DC microgrid where the conversion stages will be less which we have seen in our previous lectures. And that is what you can say is that the microgrid or that the distribution system of a high efficiency by avoiding multiple conversion relatively less complexity of the control.

No reactive power and frequency control because you know that compared you mean even the AC system we have a droop control where both and frequency matters because frequency is related to the real power. And the voltage the; I tell to the reactive power in that way you require to control the peaking of the; of this section by of this microgrid. But if it is a DC then those complex controls is not required you can only control the voltage and your requirement will be fulfilled.

And for this reason the; it is relatively less complex to control and only reactive power and the

frequency control and thus you have a reduced size and cost and the weight. Because you know RMS if it is a fundamental forget; you know that DC does not have a skin effect. AC generally have a skinny peg and due to the advent of the power electronics we are putting the wedges of the harmonics into the power system.

And due to the skin effect that effective conduction, effective conduction area of the conductor get reduced. So, if you try to transmit the same amount of the power DC require less cross-sectional area thus less cost of the copper thus less cost of the conductor. But AC require more cost of the copper and more cost in the conductor though this is a whole issue of the power quality. But what we can say is that it reduces the size weight and the cost once you have a DC transmission.

Taking into the account of the advantage of the DC microgrid all those mentioned in previous slides their usage has been proposed in a number of different applications..

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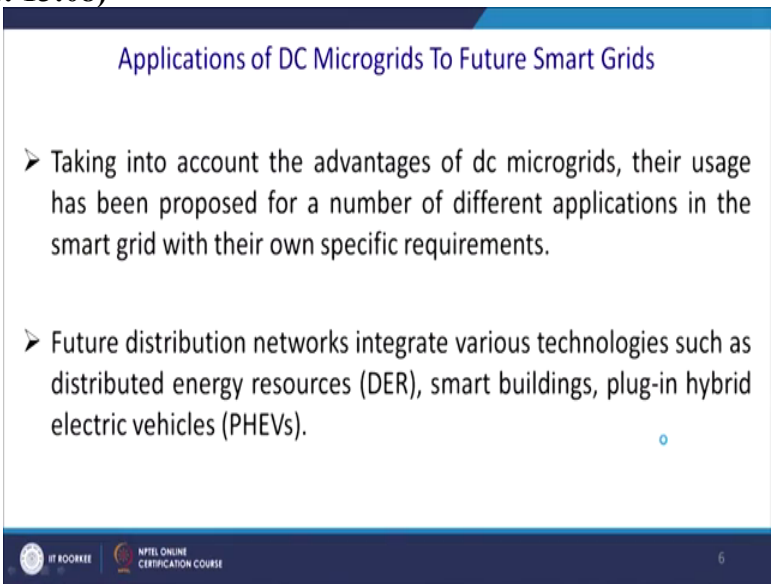

In the smart grid and their own specific requirement, so, once instead of a dumb grid we can have a smart grid smart load so while it can monitor its orientation and control of the load point of view and source point of view where source and loads are interchangeable. We require a bidirectional power flow all those possibilities which we have discussed. As well as future distribution network integrated to the various technologies such as distributed energy resources DER, smart building it will generate on consumption, zero pick building.

So, smart buildings has at many features it maybe have a zero peak building that your peak you

do not allow that load to be going to some peak. You have a; you have flattened your peak by the by your storage element. And plug-in electric vehicles do all those other features where DC to DC converter is used and where you find that DC microgrid has a huge potential or and I would rather say that it is already been used.

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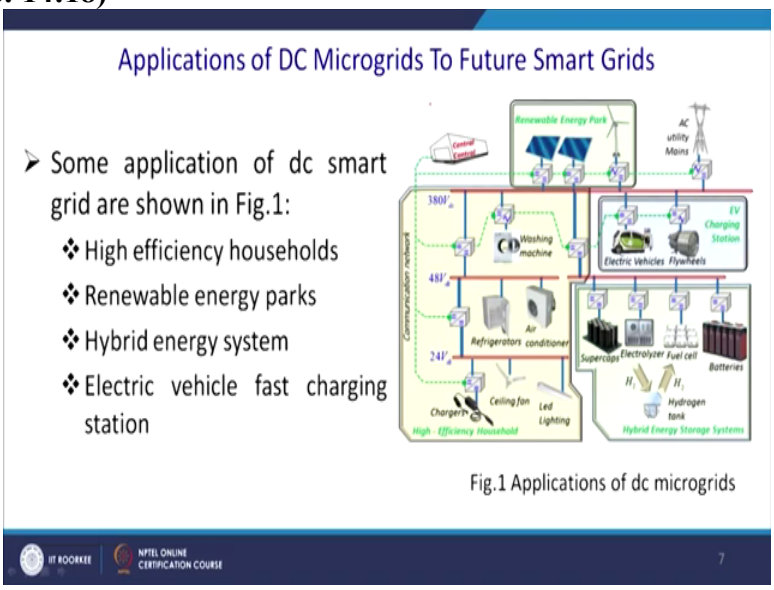

Fig.1 Applications of dc microgrids

So application of the DC microgrid to future smart grids. You see that since I am telling future it is in a research domain it is a full concept proof of concept is quite fine and there are many papers on a smart grid. But very few are practically operated in the system and for this reason here telling it future otherwise it is not at a future it has come. And we will find only over a decade only the smart grids.

So, this is the renewable energy part and you have a AC utility vents and from there you may have a electric charging stations. And these are the different kind of loads you may have a centralized washing machines with drag. So, that will take power and wash it and wash the cloth and when pottery or the is less and that energy is available from the renewable energy sources. There this is a high voltage DC bus of 380 volt.

Then you may have the; your household utilities which is generally connected in single phase that will be connected. So, these are your refrigerator your, a air conditioning you record to boost it 48 to the required voltage level but nowadays you are filling with bizarre of control it does not matter. And thereafter you may have a 24 volt and there you will use a ceiling fan please understand what H matters.

In the 24 volt then nowadays your present technology will the VLDC motor your ceiling fan can consume around 50 watt. So, there you can use you can use this motor with the revive up control and you may have required to boost it little bit and thus you can apply it properly. There are; these can be the mobile charger and this is the LED lighting. Similarly these are these two other large voltage applications for charging battery it may be 400 volt or 380 volt charging.

Apart from that you require a huge storage element you may have a super capacitor. Super capacitor you will ensure that any miss instantaneous mismatch over a period of minutes has been catered. So, they are trying to minimize the transient response or the power mismatch in minutes you will be supported by; because if you have a if you of all of a sudden if you throw out an external load then bus voltage will swell up.

And you cannot take that amount of extra power extra transient instantaneously by the your battery bank. And so extra power has to channelized into the ultra capacitors. And similarly if you have a plug-and-play kind of system you switch on the load and definitely once you switch on load this battery are the slow systems it cannot increase the current instantaneously. So, that extra current are the; to balance this power balance in the in that particular bus can be catered by the alter capacitor.

Thereafter you may have a storage in the form of the chemical energy. So, you may have a different kind of concept electrolyser then you store it as a hydrogen fuel since you burn hydrogen and you will gain only the water you would not cause any pollutions. And apart from that you have a batteries and thereafter maybe you have got a fuel cell and you are supplying the hydrogen into the fuel cell and that is converted into the electrical energy and that also pump power.

So, in that way it is will work so you could electrolyser essentially we will produce hydrogen then you store into the tank and ultimately it will fed the power to the fuel cell. And whenever there is a power in the fuel cell the; it will be actually again transmitting this power to this battery and other. There is a multiple storage element with depending on the time and size different storage element are possible.

So as I have explained it, so this is the figure 1 shows the high efficiency household. So, we have all these households are very intelligent V by F control modern machines V by F or vector

control inverter fed modern machines. And we have a renewable energy park from there we have a solar wind and all those energy pumped into the system, this one. There were hybrid energy systems so this is the hybrid storage energy system.

And the electric vehicle first charging though all integrated in a single place will be said to be smart DC grid.

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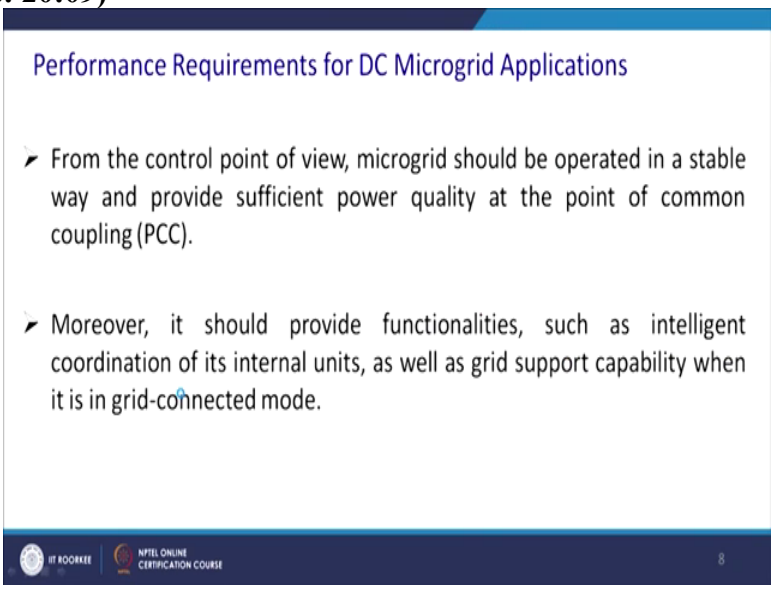

So, let us discuss about the performance requirement of the DC microgrid and applications. From the control point of view the micro gate should be operated in a stable way to provide sufficient power quality at the point of common coupling that means once it is a entry point of the grid there it should not throw any garbage. So, if energy has to be through the active rectifier. Moreover it should provide functionalities such as intelligent coordination and its internal units as well as grid support capability.

When it is it is in the grid-connected mode that is also required in cruise you do require to have a PQ control or other in a other way so that you will be taking the desired power or despite desired power into the grid. Performance requirement for that DC microgrid application the control point of view it can be summarized as the stability. So, DC microgrid has to be stable and for this reason we have a stabilizing element like ultra capacitors and all those batteries.

And it has to be controlled properly by the droop control or any other method. So, what it says that sufficient stability margin during normal and thus transient operating mode? So, when there is a load change it should not throw the system out of instability, power quality that is that issue

comes into the picture in a point of common coupling from the point where grid and the microgrid interacts. There you should not put the harmonics.

Satisfactory voltage waveform in the common DC bus, coordinated control that we have discussed earlier so that is also required to do.

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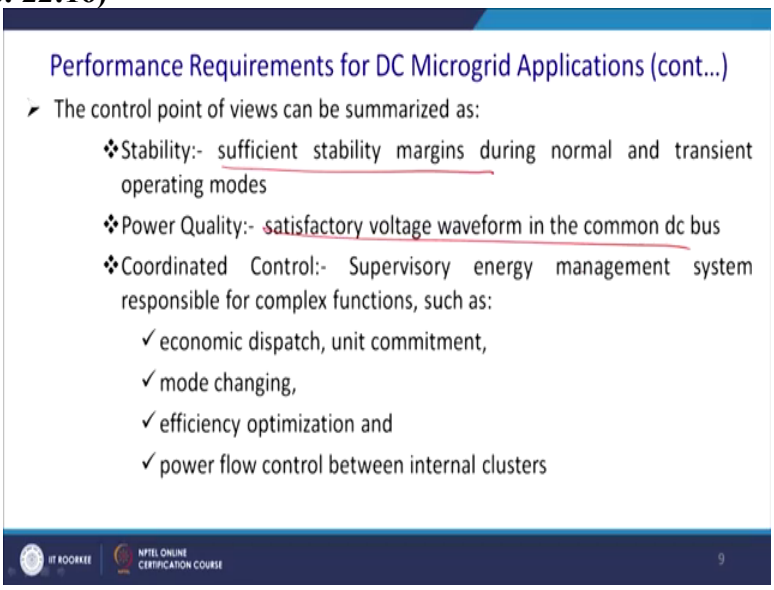

Supervise an energy management system and reserve all fall for the complex function these are the base may be you know power system microgrid time duration may be the unit switching it may be in a microgrid to the decade. So, you have to consider this item also this is the economic dispatch, unit commitment, mode of changing, mode for aligning to the grid-connected more than my super share.

Efficiency optimization and power flow between the two internal clusters. So, those are all required to be featured in a coordinated control.

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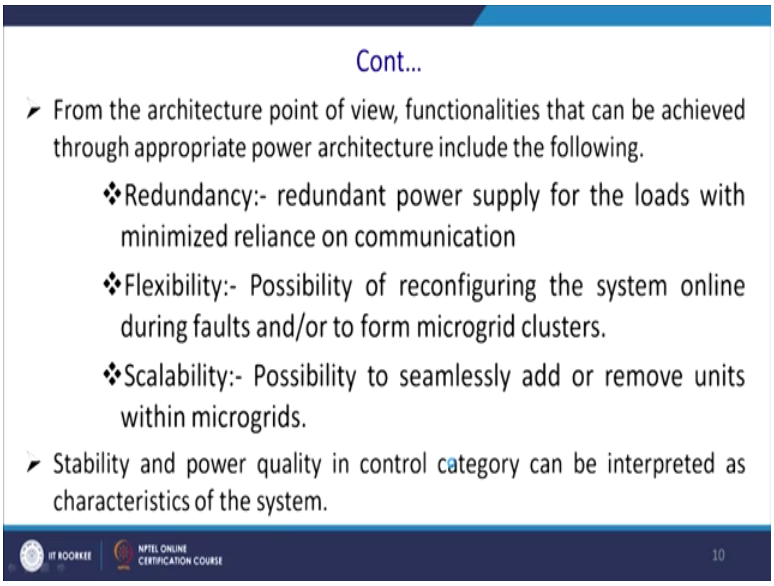

And from the architecture point of view the functionalities that can be achieved so the appropriate power architecture could be following that is redundancy. If one of the converter put off then it is not that all grid will shut down. So, you have a fault tolerant and the redundancy features. Redundant power supply for the load with the; load with minimize reliance's on the communications. So, if the communication challenge channels are broken then also you should be able to run your microgrid system.

Let us say you communicate over Wi-Fi, if Wi-Fi is not there your communication is lost and that is a one of the problem on the master slaves schemes. So, it is highly dependent on the communication channel. Flexibility possibility of the off configuring the system online during faults and/or from the microgrid clusters, scalability possibility or to seamless add or remove unit within microgrids. Stability and power quality in control category can be represented as a characteristic of the system. So, that something we require to be revisited again.

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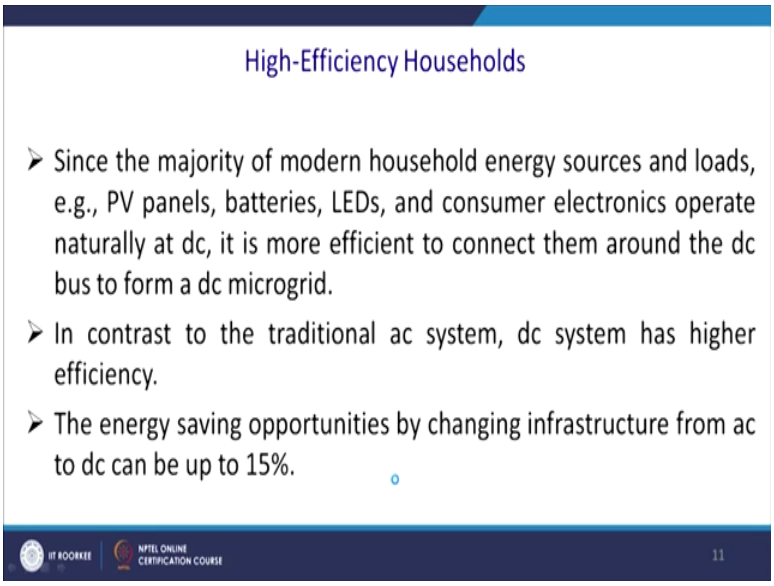

So, now we talk about the highly officiates part buildings so thus the high efficiency households. Since majority of the modern household energy sources and the loads are pre panel batteries LEDs, consumer electronics operate at proper it actually in DC. So, it is more efficient to connect them around the DC bus in the microgrid and in contrast to their traditional AC system DC system has higher efficiency.

Because what happened you your conversion efficiency will be more and since you have a if you put these are all are essentially this is source and you have to convert AC to DC, DC to AC and battery you require to charge and discharge and you have to convert and use the help of the power electronics and thus you have you have to compromise the efficiency. Same way LEDs and most of the AC systems you know you talk about the fluorescent valve and all those lights and all those AC system.

You will find efficiency is less because of the fact of the power factor. In absence of the power factor DC systems are more reliable. If you say that 40 watt incandescent lamp in sorry 40 word fluorescent lamp it will be around 10% less it, will be less than 36 Watt in case of the DC. You can find it out and also you may find that if it is not running in AC it may run in DC. Longevity also will be higher.

So, they are after energy saving opportunity by changing the infrastructure form AC to DC and it can leads to the saving of the energy by 15%. So, economics comes into the pictures what is the cost of pay out of your investment.

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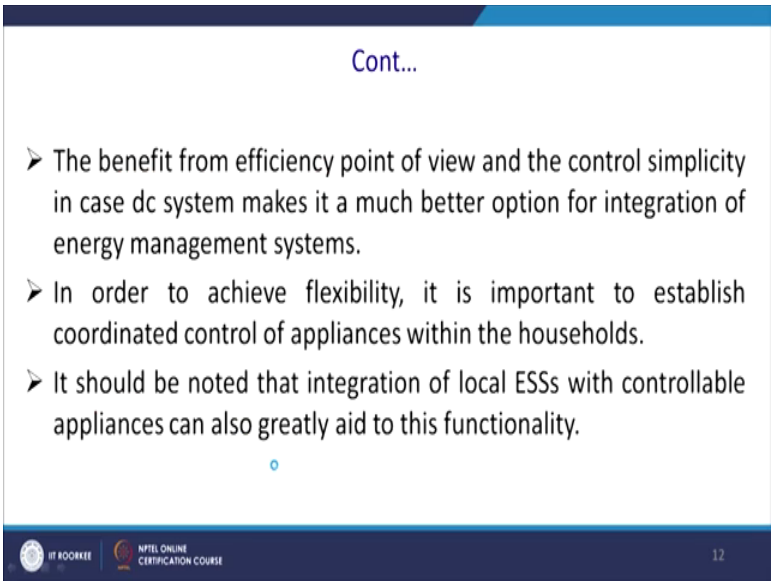

The benefit from efficiency point of view and the control simplicity in case of the DC makes it better option for integration of the energy management system. And so we are gradually when we were scope of the solar installation actually we look for the DC microgrid. In order to achieve flexibility it is important to establish coordinated control. Because you have to receive a responsibility a particular task to the particular entity and like who will be the slack point who will be the power point which we have discussed in the previous lectures please refer my previous lecture.

So in order to achieve the flexibility it is important to establish the coordinated control of appliances within the household. And it should be noted that integration of the local energy storage with controllable appliances can greatly aid the functionality. And that will help us to achieve the zero peak building and all those modern concepts.

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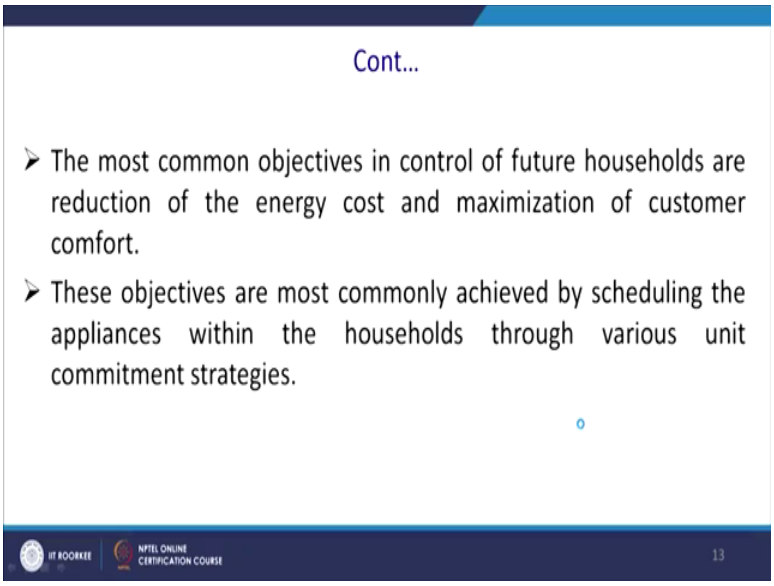

Most of the common objective in control of the future households are reduction of the energy cost and the maximum of the customer companies these are the whole requirement. if you are energy is generated less instead of the shutting down you may run your AC a little higher temperature and we it is causing a really less in uncomfortable through the consumers but ultimately you can save the energy.

So that is the challenge, so you ensure the comfort smartly and without hampering and also you cut down the cost. These objectives are most commonly achieved by scheduling appliances that is once you have a more power you put those bulky loads at that time within a household through various unit commitment strategies.

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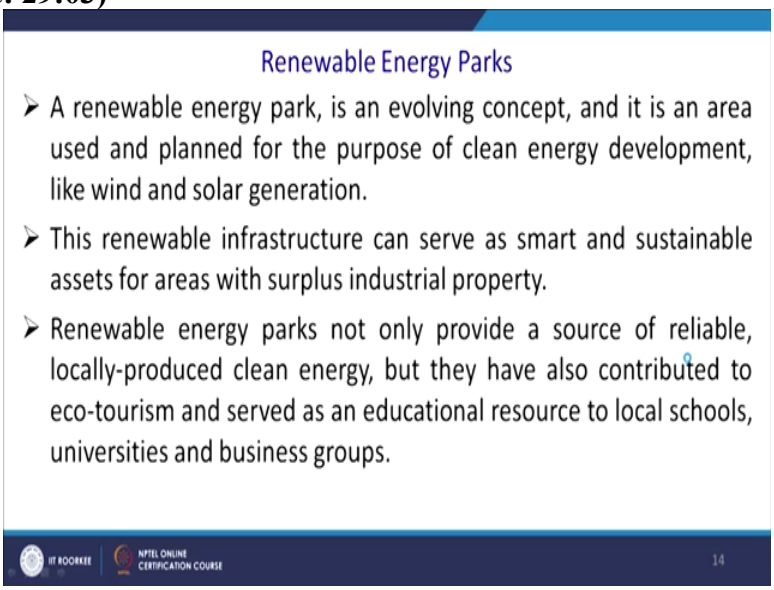

Now we have discussed about a renewable energy park. So, renewable energy Park is an

evolving concept previously when we were we were kids so there was energy Park for the academic interest. Now it is also a commercial interest you can have a renewable energy park that is solar wind all those concept has been put into the place. And in that area; use plant for the purpose of the Clean Energy Development like wind and the solar.

And this renewable infrastructure can serve as a smart and the sustainable assets it can be it can promote the eco tourisms. Since, it is a park so it is a natural habitat so you can go for the healthy breathing so these assets areas are surplus of the industrial property. And these renewable energy parks not only provide a source of the reliable locally produced clean energy but they have also contributed to the ecotourism that is what I saying.

And serve as a education and resources to the local schools, University and the business groups so it has huge advantage to it. Ok, we shall continue with these discussions application on an AC microgrid in our next class thank you for your attention.