Operation and Planning of Power Distribution Systems
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Lecture - 03
Introduction to electrical loads

This is the 1st module for this course and I will discuss in this particular lecture Load characteristics, ok. So, load is our fundamental unit for power distribution and as such in power system. It is because of the load we generate and thus we require this transmission and distribution networks, ok.

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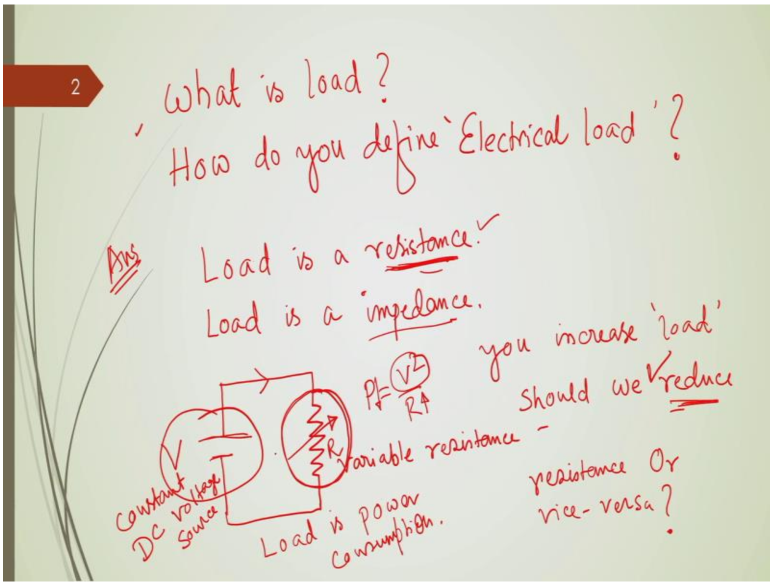

So, first I will start with a question, in this particular lecture that what is load? Or how do you define electrical load? This question is same question what is electrical load or how do you define electrical load? This question I used to ask undergraduate and post graduate level students. In laboratory course viva or even in starting a power system course I usually ask this question. And the students answer differently; some of them said that load is a resistance; load is a resistance. These are the possible answers that I got from the students; some said load is an impedance, ok.

When I get this answer, I do not say whether it is a correct answer or wrong answer. I ask another question to them, suppose I have a battery; I have a battery with constant voltage source; constant voltage source whose voltage is V, ok. And now I have a variable resistance or rheostat. So, this is variable resistance; this is a constant DC voltage; constant DC voltage source, ok.

Now, this is a very simple circuit, we have a constant DC voltage source connected to a variable resistance, ok. And you know this variable resistance is available in our laboratory; it is called rheostat, ok. So, even undergraduate level student at the very first semester they learn this, ok. So, they know what is variable resistance.

Now when I ask any question here at this point, since load is a resistance or impedance or whatever answered, here in this circuit this is my source and this is of course, the load ok as you said that it is a resistance. Now, I ask the question that, in this circuit you increase the load; you increase the load; now in order to increase the load should we reduce the resistance or vice versa?

So, when I ask this question to the student, because it is their answer only load is a resistance. So, when I say that this is a very simple circuit, you increase the load and in order to increase the load should we reduce the resistance or increase? So, when we ask this question to the student, some of them said that we need to increase the resistance and some of them said we need to reduce the resistance, ok.

So, those think that load is nothing, but a resistance, then they may think that increase of the resistance will result increase in load, ok. So, they think that if we increase the resistance that means, that we are increasing the load; some of them correctly think; they said no we have to reduce.

Actual answer is we have to reduce the resistance. Why we need to reduce the resistance? Because load does not mean that it is essentially a resistance rather it is the power consumption of certain device ok; it is the power consumption of the certain device.

So, if we consider this simple DC circuit, then the power consumption of this variable resistance suppose the value of resistance is R, so, power consumption would be equal to V square by R and as I said V is constant DC voltage source. So, therefore, if we go for increasing the resistance so, this will reduce the power consumption of this particular resistance. And if we go for reduction of the resistance, it will result in increase in power consumption of the resistance ok.

So, this is to be understood ok; load does not mean that it is a simple impedance or resistance; it has of course, some impedance some resistance, but it is load we represent by the power consumption. So, we represent load. So, load is power consumption or alternatively you can also tell that load is the current drawn by that particular device, ok.

So, if you go for increasing the load, then you have to make an arrangement such that this power consumption or the current drawn by that particular device should be increased ok. So, in a laboratory many times we say that while doing an experiment of electrical machines we say that increase the load. So, that time one has to remember that it does not mean that we have to increase the resistance; because normally in laboratory, we have resistance bank or rheostat which is treated as a load.

Although practical loads are not only resistance there are many other types of loads which I am going to discuss today, but if you consider a variable resistance as a load, then while increasing the load means you have to reduce the resistance so that the power consumption increases ok or the current drawn by that particular device increases ok. So, with this I will start this lecture.

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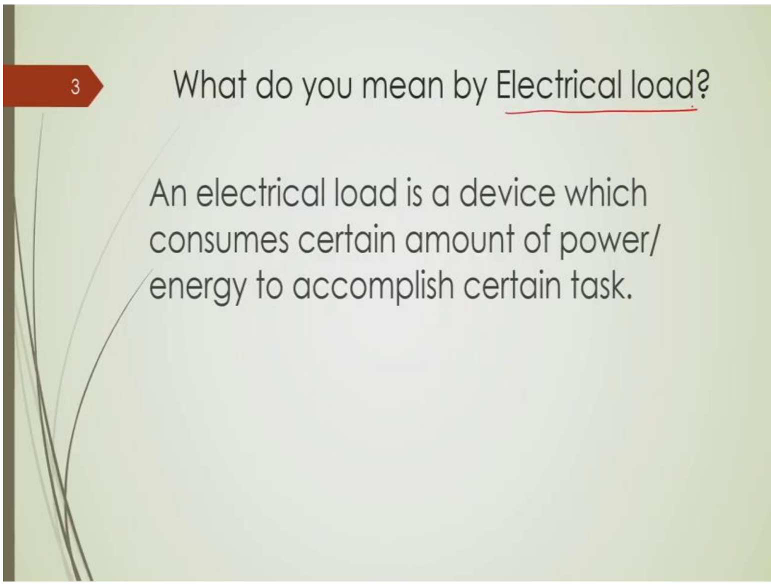

Now, that the very first slide as I mentioned, what is electrical load? Although this is not a formal definition or standard definition, but one can define load in that way that an electrical load is a device which consumes certain amount of power or energy to accomplish certain task ok.

So, of course, this consumption of this power is because of to get something out of it. For example, we have many appliances in our home that we use day to day life; our light lighting appliances for example, lamps now it is (Refer Time: 09:41) lamp is abolished. So, all are LED or fluorescent lamp so, like tube light.

So, those devices consume power in order to provide you lighting in order to convert this electrical energy to lighting ok. So, we also have electrical fans ok. So, what actually it does? It consumes power in order to provide you the required mechanical motion required mechanical energy so, that you get wind out of it ok. So, these things you have to understand.

So, electrical load is not a resistance. Whenever it is increasing load is increasing; no electrical load is rather any type of device, an electrical motor is also an type of electrical load. So, what it actually does? It takes electrical power it consumes electrical power to provide you mechanical work.

So, this is a kind of electrical load; because it consumes certain amount of power and in order to accomplish certain task. Because as you know although we are talking about so, many big power network.

But ultimately when it comes to the end user we do not have this provision to use electricity directly; because we have to convert it to some other form. So, that we get some other energy out of it ok. So, the this I think one has to understand.

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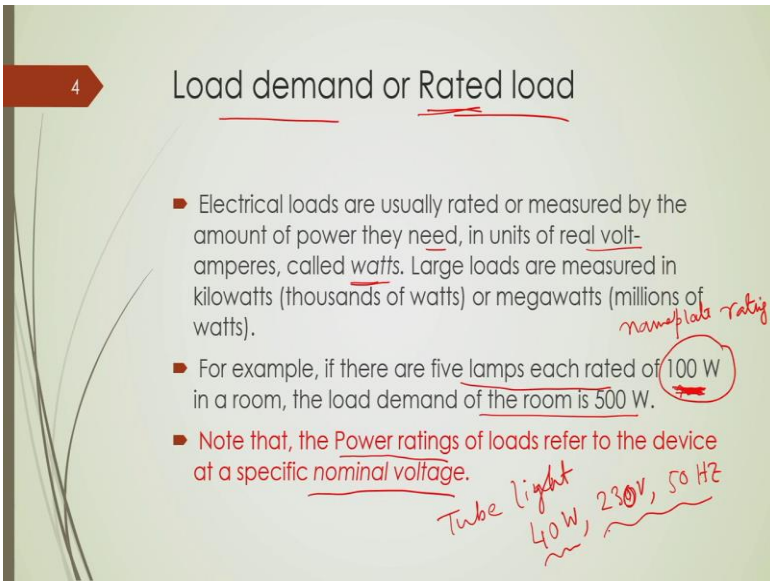

Now, load demand or rated load ok. So, electrical loads are usually rated or measured by the amount of power they need ok; already I mentioned in my last slide and usually it is the real volt ampere or watt ok. So, it is the real power consumption of a electrical appliances ok. Now large load are measured in kilowatt or megawatt, ok.

So, usually in distribution system, we use the load unit as kilowatt; we use the load unit as kilowatt in order to measure electrical load. For example, if we have five lamps each rated of 100 watt. In fact, if you go for a purchase of any electrical appliance, you will see that on the top of it there is a nameplate rating; there is a nameplate rating name plate rating ok.

So, if you go for purchase of any electrical appliances you will see there is a nameplate written clearly on the top of it that this particular appliance should consume that much amount of power so that is called basically rated capacity of that particular appliance.

And not only this watt or kilowatt rating is mentioned, but also this voltage corresponding to that rated load is also mentioned. So that means, if you go for purchasing a tube light; you will see it is clearly mentioned that it will consume 40 watt of power at 230 volt 50 hertz supply. So that means, if you connect it to 230 volt 50 hertz supply its rated capacity is 40 watt. So, it will consume 40 watt in order to provide you required light, ok.

Now, we have many appliances in a particular room and we have many appliances for a residential customer ok. Now if we have let us say 500 watt lamp in a particular room, then the total load demand of that particular room is 500 watt ok; at that particular instant of time provided that all are working ok.

So, I will come to that. So, here from this slide the take home message is that that every electrical appliances has some power ratings which is specified under a certain nominal voltage, ok.

So that means, as long as your supply voltage is 230 volt this tube light will consume 40 watt now if your voltage will vary and voltage comes down to 200 volt then; obviously, this value will also get change ok. And there are different types of load I will show you in my next slides, which may have a constant you know power demand or may have variable power demand ok.

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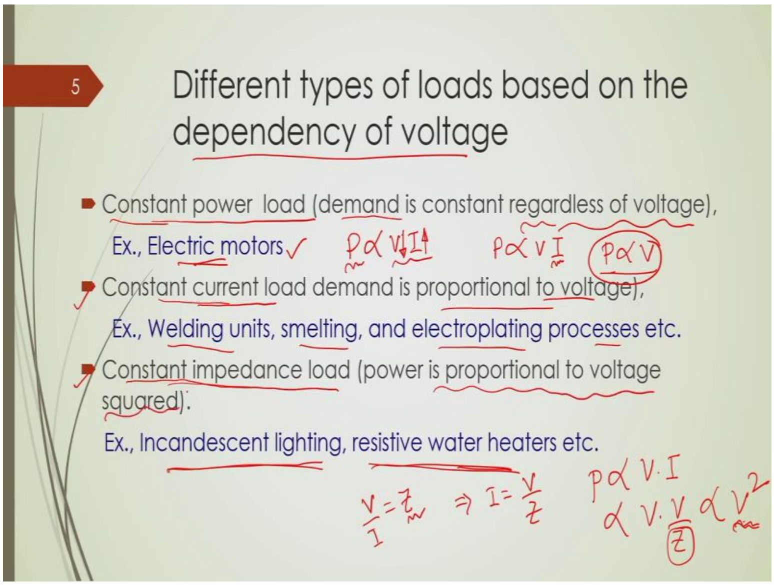

So, based upon this dependency of the voltage, we can categorize the loads in different types. There are certain loads who consume constant power irrespective of the supply voltage ok. So, they consume constant power irrespective of the supply voltage example is electrical motor.

So, what electrical motor actually does? You know this power is proportional to voltage multiplied by current. So, if voltage drops voltage is less than the nominal voltage or rated voltage, it will draw more amount of current so, that the power remain constant ok. So, they are called constant power load.

So, their power demand is constant irrespective of or regardless of the supply voltage; because as you know the supply voltage, I will show you in later point of time, supply voltage is not possible to keep at the rated voltage always ok. Although as you know residential customer we intend to have a 230 volt single phase supply in India, but we definitely will not get it constant throughout the day throughout the month; it depends upon various factors. I will discuss time to time.

But this electrical motor is a type of constant power load, because it can draw higher amount of current if voltage drops ok. Now there are certain loads which will carry constant current ok irrespective of the voltage ok. They will carry constant current ok they will carry constant current proportional to the voltage.

For them actually power becomes proportional to voltage because you know as I said power is proportional to voltage multiplied by current. So, if current become constant, it is basically similar to power proportional to voltage. So, for them you know the power demand is proportional to the voltage example are welding units smelting and electroplating processes. So, those appliances need constant current ok.

So, therefore, their power demand is proportional to the voltage ok. There are certain loads which are called as constant impedance load; constant impedance load. For example, water heater incandescent lighting; incandescent lighting is not existing in the present scenario mostly, but resistive water heaters you can consider it as a constant impedance load because their impedance remain constant and according to that they will demand the power.

Now, as you know V by I is equal to Z; now as long as your Z remain constant. So, I can replace this I as equal to V by Z. Now as we know this power is proportional to V multiplied by I so, I replaced this I by V by Z; Z is also a constant. So, it is proportional to V square.

So, this type of load demand, power proportional to the square of this supply voltage ok. So, that is why they are also called voltage dependent load where power demand is proportional to the voltage squared.

So, these are the classification of load based upon the dependency of the voltage based upon the dependency of the voltage.

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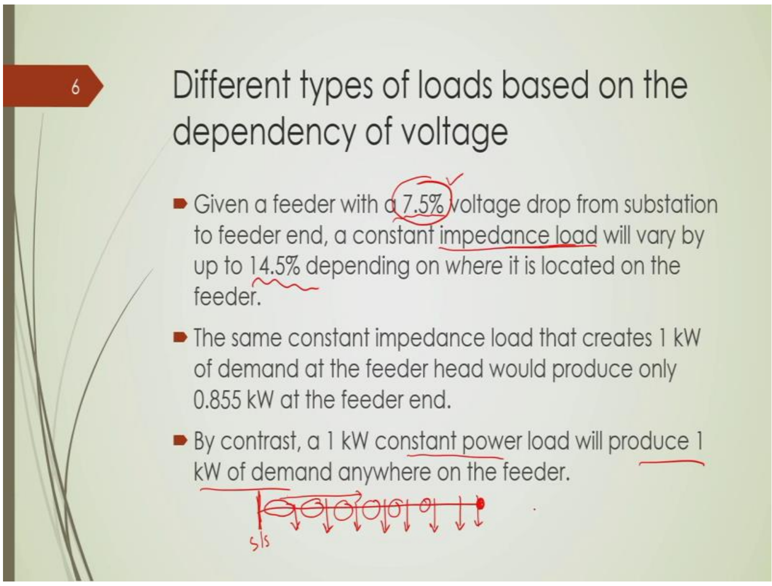

Now one thing one has to understand that as we discuss earlier and we will be discussing in detail in the later part of this course. So, voltage will be varying throughout the year. So, therefore, there might be a voltage drop for a feeder because of this internal impedance of that particular feeder ok. And due to that, it is not possible to have a uniform voltage profile throughout a particular distribution feed it is not possible ok.

So, therefore, there would be definitely a voltage drop. So, the customers who are located near to the feeding point or source point, they will have higher amount of voltage if I draw a small you know feeders like this. So, here is our substation or feeding point and here we have different loads, ok.

Now, as we go for distance away from the substation there would be certain amount of voltage drop due to this line impedance due to this line impedance. And obviously, the customer who is located here that is furthest part of the substation they will experience highest amount of voltage drop and that is why lowest amount of voltage; this I will discuss. Now and that is why you know if they have that type certain amount of voltage drop let us say 7.5 percent voltage drop.

So, and if they have a constant impedance type of load, which will vary the power demand proportional to the square of the voltage, then they will experience 14.5 percent variation of their power demand due to that particular type of voltage drop, ok. So, that is why you one has to understand that although this all this nameplate rating is given to you that does not mean that all these appliances are consuming power based upon their nameplate rating, ok.

So, one device if its power demand is variable with the voltage then; obviously, its demand will be somewhat varying then, you know, its rated power demand based upon the voltage condition of that particular point of the network ok. Whereas, constant power load they can always have this constant amount of power demand irrespective of this voltage, but other than that voltage dependent loads their power demand varies with the magnitudes of the voltage, ok.

So, therefore, where they are located it is very important. Sometimes in India for rural distribution network you know the customers who are located at the furthest point of the network, they hugely suffer from this voltage drop. I will discuss this in the later part of the course.

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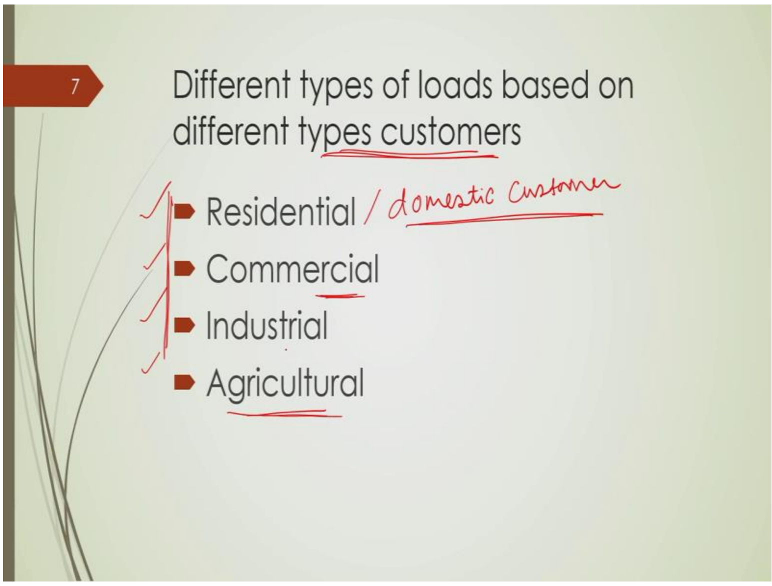

Now, based upon the types of the customers, we can also categorized this loads are of four different types; one is called residential type; one is called commercial type; one is industrial type; one is called agricultural type. Sometimes agricultural is kept aside, but we normally work with these three different classes of groups; one is residential; one is commercial; one is industrial.

So, residential customers are those who are like us. They are also called domestic customer who lives in a particular locality and use different appliances. Commercial customers are those who have certain commercial activity. So, they have certain amount of power demand that includes small shop to large shopping complex ok. Similarly, industry also as you know it is a very big customer ok who demands lots of power ok to operate their machineries and so.

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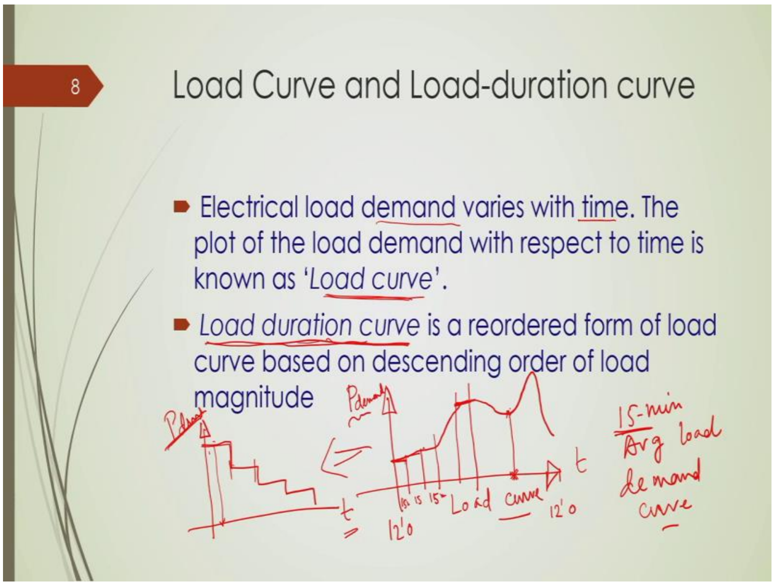

Now, at this point one has to understand that load is a time varying parameter; it continuously varying with time because at what point of time we are using what number of appliances that depend upon our need and that does not remain constant throughout the day and that is true for all the different types of customers.

So, what we will do in order to model the load or in order to analyze the load in a better way we plot this load demand with respect to time and this plot is called load curve plot is called load curve.

So, if we plot suppose I will show this plots are there in the next slide, but suppose I have a residential area or rather I have a small distribution networks and this is the power demand and this is the time. And time I can start with let us say 12 O' clock midnight to 12 O' clock midnight of the next day, ok.

And then, if I determine the instantaneous power demand throughout that particular day, and we plot it and suppose this plot is something like this as you know during this midnight this power demand is less then slowly it is increasing then may be during day time it reaches to a particular peak, then it may go little bit of less then finally, during evening it becomes higher and then again at midnight it becomes low.

And suppose this is the instantaneous load demand characteristics under a particular distribution substation or under a particular distribution freedom then this curve if you plot then it is called load curve ok. So, sometimes we plot this load curve with instantaneous power demand as I have shown to you. Or sometimes we sample the overall this timing period with 15 minutes or 30 minutes. So, these are 15 minute sampling; let us say 15 minute sampling and we take the average of demand during that time.

So, if we sample like this 15 minute then we take the average demand for during this 15 minute and then we plot it then this type of plot would be called as 15 minute average load demand curve. Now instead of 15 minute one can also take 30 minute average of the instantaneous demand and it can plot then it is called 30 minute average load demand curve.

So, load demand curve is essentially this characteristic for power demand with respect to time. And there are different types of load curve exists. Those things I will be discussing right.

Now, there is another type of this characteristics it is called load duration curve; it is similar to this load curve and it is drawn from this load curve itself what it is actually done. So, it is just sorted this load demand in a descending order and plot. So, this will be something like this. So, this plot will be something like this it is a step size plot and each step you can consider as the average of 15 minutes.

So, this is also a load curve, but where this you have plot this power demand with respect to time, but here this power demand when this power demand happens those information is not available ok.

But here you can see that this particular power demand happens at that particular instant of the day ok at maybe 5 O' clock in the evening, but here you know this demand, since it is sorted and plot in a descending order. So, this does not provide that when this type of demand took place. So, this is the difference ok.

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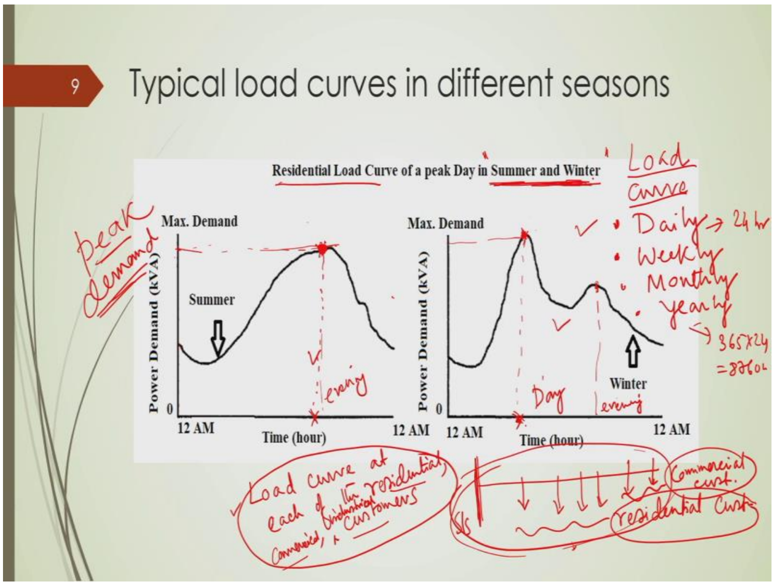

Now, we have some typical load curves ok. So, first thing that I would like to mention that there are different types of load curve; one is called daily load curve. So, if you plot this load demand for 24 hours duration then it is called daily load curve; then, it is also possible to have weekly load curve, then monthly load curve, then yearly load curve. So, here daily load curve duration is 24 hours ok; yearly load curve this duration is 365 multiplied by 24 hours, i.e., something 8760 hours.

Similarly, weekly load curve is 24 multiplied by 7 ok. So, there are different types of load curve and also one has to understand that this load curve whatever we are talking about exists for individual customers. So, we have load curve at each of the residential customer or residential or commercial or industrial customer ok.

And when we have a network with a number of residential customers, commercial customers and industrial customers then overall this load curve is basically aggregation of all the load curves of all the different types of customers. For example, suppose I have a distribution network like this. So, I have you know four numbers of residential customers.

So, they are residential customer. So, this is our substation and we have two commercial customers; these two are commercial customer ok. Now when we talk about this load curve of whole feeder, then it is basically the aggregation of this individual load curve of all these residential customers four residential customers and two commercial customers.

They might have individual load curve, but when we will talk about the load curve of overall this distribution feeder, this means it is the aggregation of this load curves of individual customers who are present in that particular feeder. Now here you can see in this plot the typical two load curves for a residential area under different seasons one is in summer another is winter ok; one is in summer another is winter and the characteristic is something like that.

So, you can see this load curve and that load curve characteristics are completely different characteristic that means, that as I said load not only changes in a day, but it also have a seasonal variation ok. So, when there is a hot summer these load characteristics would be something different. When there is a chilly winter the load characteristics will be something different.

So, this load curve also varies for a particular customer depending upon the pattern of the usage of their appliances. For example, during hot summer we use our air conditioning load. So, that time not only our power demand increases in magnitude, but also its consumption pattern particularly during night is high.

Whereas, in during chilly winter our pattern will be something different because we did that time we had to use water heater during morning time or during evening time. So, power demand magnitude wise will be also something different as well as this timing will be also different.

So, these two characteristics if you see not only they have different shapes, but their magnitude of demand will be also different which is not mentioned here ok. So, here you can see from these characteristics here one thing is important that is the peak or maximum demand of that particular load curve. So, this is basically this peak demand of this load curve; whereas, this is basically the peak demand of this load curve.

Now, if you look at this two characteristics, you can also understand that when this peak demand happens ok. So, this is the time at when this peak demand happens whereas, this is the time at when this peak demand happens. So, this is probably the day time because this is closer to this morning time ok whereas, this is of course, during evening.

So, here basically there are two peaks in this particular characteristics; one is called day peak or morning peak; another is evening peak; this is evening peak and evening peak is much lower than this morning peak; whereas, here we have only one peak during evening. So, those things are important.

So, here the maximum demand correspond to your morning peak whereas, here maximum power correspond to the evening peak ok. Now this peak demand is another important factor one you have to understand; because based upon that we have different indices to discuss ok in later part of this module.

So, what we can understand from this? One is called peak demand from this load curve. So, this is the maximum demand corresponding to the load curve then also as I said this characteristic whatever we are talking about this is basically an aggregated characteristic corresponding to a number of customers under a particular service territory under a particular distribution network ok.

And also we learn that this is called maximum demand or peak demand corresponding to a particular load curve. Also, we learn that load characteristics change with different season.

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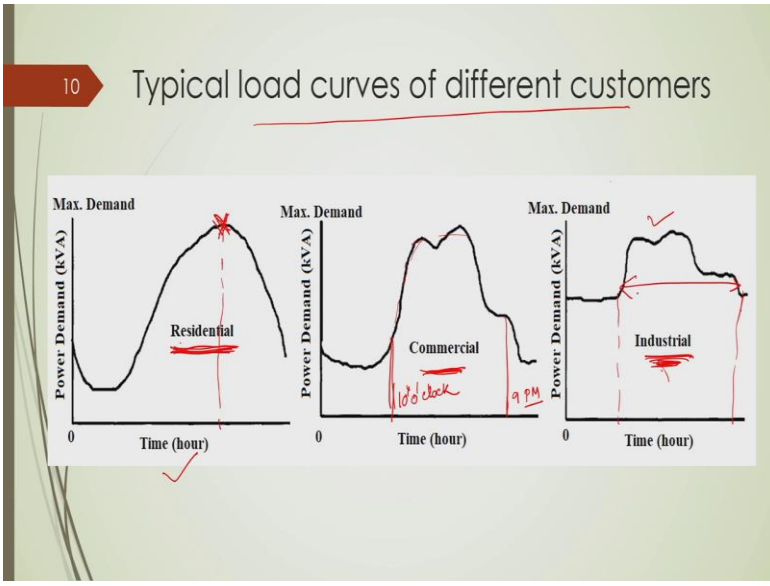

Now, this slide is to give an illustration that how different the load demand characteristics are for different types of customer. This is the typical load demand characteristics for not residential customer, but I can say that a distribution network which is serving in residential area ok.

This is a typical characteristic you know for a commercial complex and this is a typical characteristics for industrial complex. So, not only they are different in shapes, but also their magnitudes also are different which are not indicated here in this figure ok this one has to understand.

So, for example, this industrial customers their power demand is pretty high than this residential customer because they are having different machines or machineries which consume huge amount of power. Now one thing is important that you know as I said when this peak demand happens.

So, peak demand in residential area normally happens during evening time. Whereas, this commercial customers their operation is mostly during this certain amount of certain period of time. So, this starts at let us say 10 o clock in the morning 10 o clock in the morning and they sat down by 9 PM in the evening ok.

And there most of the demand is restricted within that period of time because they use whatever their appliances their appliances they have. So, they have certain amount of flat type of characteristics during this period of time. Similar to that in industrial customers they are also demand is restricted in a particular time of the day which starts from let us say 9 O' clock or 10 O' clock from the morning and it shut down at let us say 7 O' clock or 8 O' clock in the evening ok.

So, this timing I am talking about tentative and this will vary from one country to another country ok. So, these are the some typical characteristics of load demand curve for different types of customers.

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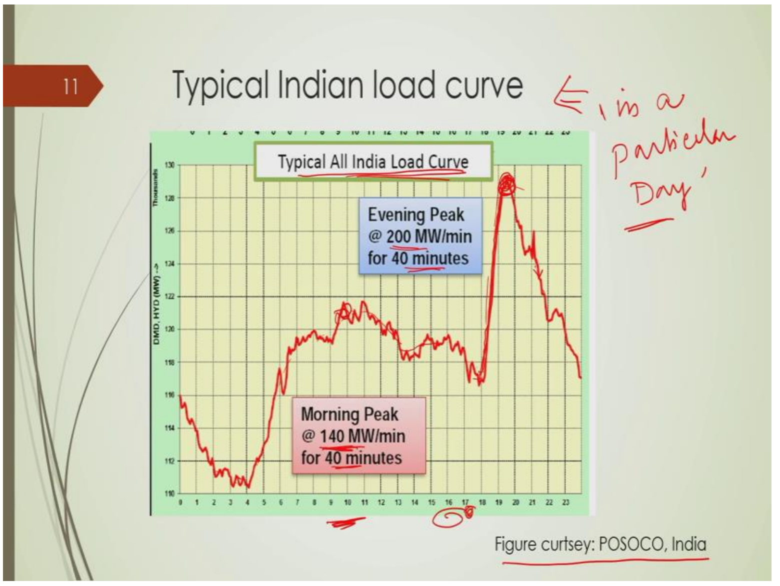

Now, here in this particular slide I will show you all India load curve ok. So, this I sincerely acknowledge this from this POSOCO site. I took these characteristics. So, this all when you talking about this all India load curve; means it aggregates the whole power demand of overall of a particular country. Then it is taken I think, date is not given, but whatever it is. So, you can see this characteristics we have some morning peak; we have some evening peak.

And morning peak is mentioned that it is 140 megawatt per minute. This you know characteristic is bit older; it is not up to date characteristic; it is of several years back. I took this curve just to indicate this how this country's load characteristic may look like and this is a load curve in a particular day ok. So, as I said this load curve changes with season with different day.

So, this is taken in a particular day one thing you can understand that this evening peak is 200 megawatt per minute and sustains for around 40 minutes average they have taken and morning peak is 140 megawatt and sustains for 40 minute, ok. And you can see overall characteristics.

So, starting from the midnight demand is lower. Then, from 4 O' clock in the morning, it starts increasing and it increases and reaches to the morning peak during this office hour of this when the office schools will start ok; that is 9 to 10 am and then it sustains; it has a little bit of dip during this when your industry offices close that is you know 4 O' clock or 5 O' clock during evening.

And then it again goes for a very steep peak. Why this steep peak occurs? because during that time all you know people will come back to their respective home and they use all these appliances they have in their house. And that is why this residential you know demand hugely increases during this period of time and it reaches at evening peak at this point and it sustains for some minute.

And then eventually it gradually reduces and it reaches to that point of time. So, this is the typical nature of this load characteristic of all over the India.

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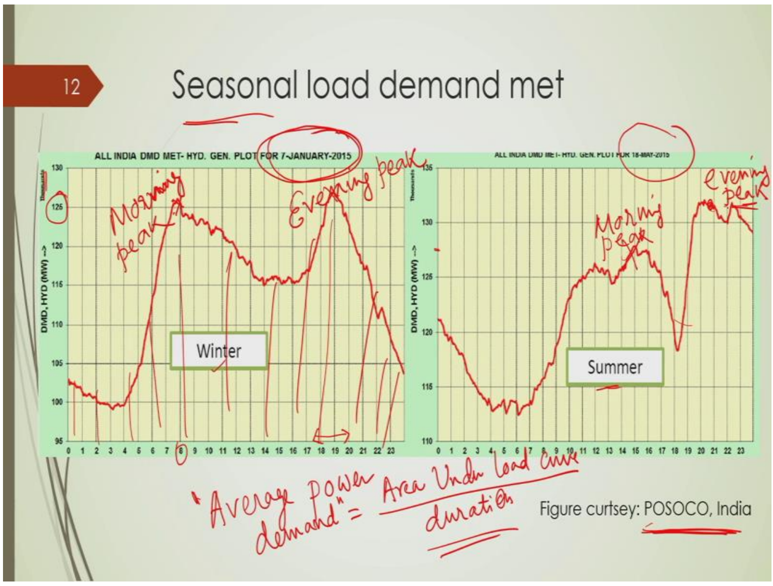

So, this characteristics again I sincerely you know thank for this POSOCO for having these characteristics. So, this is basically load curves for 7th January 2015 all over the country and 18th May 2016 I think. So, you can have a understanding that how these load curves change with season or what is the seasonal effect of this load characteristics, ok.

Now, you can see in winter we have this is morning peak and this is evening peak. So, this is morning peak this is evening peak during summer; this is somewhat morning peak this is evening peak. Actually this peak demand is the maximum demand, but we have two peaks and one is basically the maximum demand.

Now, here you can see during winter, this morning peak and evening peak are slightly different which means magnitude wise they are almost similar and morning peak occurs during this 8 o' clock in the morning 8 to 7 to nine and evening clock occurs during 6 o' clock to 7 o' clock during evening ok. And their peak demand is somewhat close to 125 megawatt ok not 125 megawatt this should be 125 gigawatt, ok thousands of megawatt it is mentioned.

So, but during summer you can see this morning peak is around 125 gigawatt and evening peak is much higher it is more than 132 gigawatt ok. So, not only magnitude wise these peaks are different, but also they are characteristic wise shape wise different. So, those things you have to understand ok.

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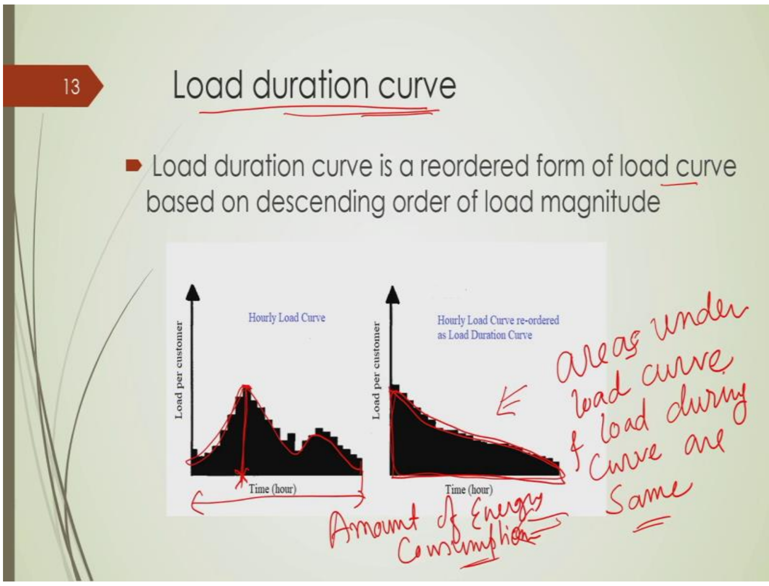

Now, again as I said in my previous slide that load duration curve is a reordered form of load curve. So, in load curve we can actually find out that when this load demand happens that for example, this the peak demand happens at during this particular of time.

Now if the same load demand data you sort and you plot over here in a descending order so that the area under this load curve will be same, but you know this timing will not be actually reflected the actual time of the consumption then this is called load duration curve.

And this load duration curve is basically drawn in order to have a better calculation of this area under this curve. Now this area under this curve is also an important factor area under load curve or load duration curve are same load curve and load duration curve are same. And this area is basically representing the amount of energy consumption and this is basically representing amount of energy consumption ok.

For example if I go back to this slide and if you take the area under this curve area under this curve if you integrate and if you find out then this will give you the amount of energy consumption for 17th January 2015 all over India ok.

And this area if you divide with the time duration then whatever you will be getting that is called average demand. So, average power demand is equal to area under load curve divided by duration. So, this average power demand is also another index ok, which I will talk about little while, ok.

So, similarly this area under this curve and area under this curve actually magnitude wise this will be same. And this is basically representing the actual energy consumption and if you divide with the duration if the duration, if it is a daily load curve this duration will be 24 hours; if it is a yearly load curve accordingly this duration will be changed. So, if it is a daily load curve. So, if you divide it by 24 hours. So, whatever value we will be getting will be average load demand ok.

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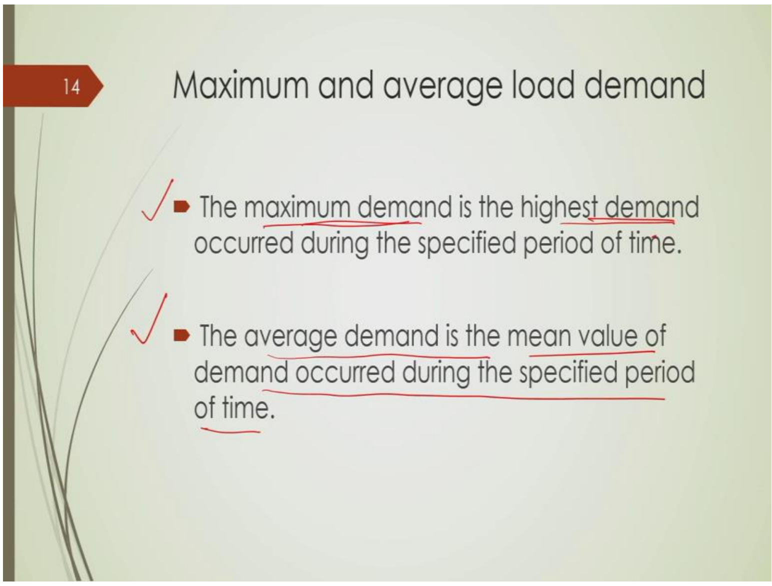

Now, as I said these two are important indicative parameters one is maximum power demand, which is highest demand or out of whatever peaks exist the highest peak in a load curve which is called maximum demand. Or sometimes we call it simply as peak demand instead of calling it morning peak evening peak we simply take the highest peak as a peak demand ok.

So, this is an important parameter; another important parameter is the average demand as I said which is the mean value of the demands occurred during the specified period of time this is nothing, but as I said area under a particular load curve divided by the duration.

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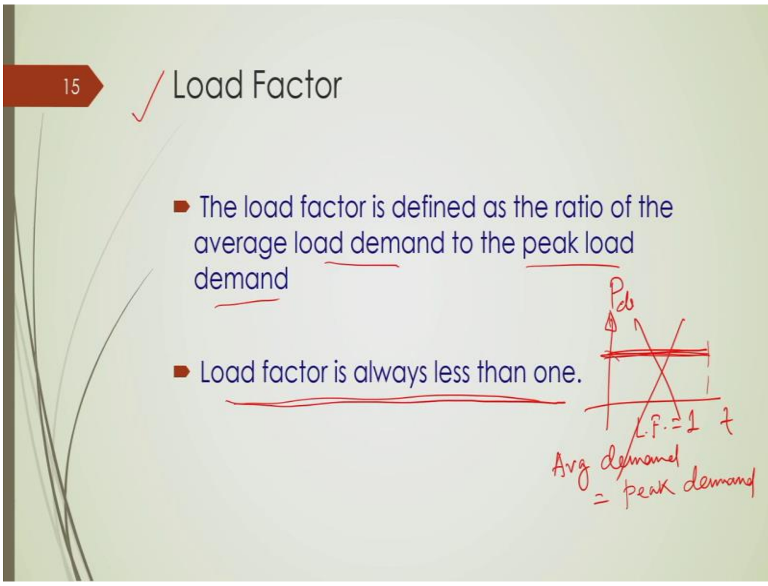

Now, we will be talking about certain factors or indices in order to model this load; one is called load factor ok. What do you mean by load factor? Load factor is basically defined as the ratio of the average load demand to the peak load demand ok.

So, load factor is basically equal to the ratio of average load demand to the peak load demand and load factor will be always less than equal to one; it can be equal to 1 if you know average demand is equal to peak demand and that is a hypothetical situation. When your average demand can be equal to your peak demand? when your load demand remains constants throughout the period.

So, if your load curve is like this is your P demand and this is your time then if your load curve is a flat, i.e., constant throughout the time then only this load factor would be equal to 1. So, under this condition your average demand average demand equals to peak demand, but this is a hypothetical load characteristic which does not exist ok, so that is why load factor is always less than one ok.

So, with this I will stop and we will continue in the next lecture.

Thank you for your attention.