Electrical Distribution System Analysis

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Lecture – 04
Nature of Loads in a Distribution System

Students, welcome to this fourth lecture of the course Electrical Distribution System Analysis and today's topic is Nature of Loads in a Distribution System. Before going to of nature of loads; we will just review what we have seen in the last lecture ah. In the last lecture we have seen various feeder components those are nothing, but capacitors, regulators, reclosures, sectionalizers and various types of laterals like single phase lateral, 2 phase lateral or lateral which is made off of underground cable.

Then we have seen various feeder configurations in that seen we have seen radial feeder configuration which is widely used configuration because it is very cost effective as well as protection point of view it is very useful.

Then we have seen to improve the reliability we use primary selective and secondary selective scheme. To improve the reliability further we use loop and ring means kind of network. And then to get the highest reliability there are spot and grid networks available.

So, we have seen all these 4 configurations of the network. So, this is a just review of last lecture; now we will go to the nature of loads. So, we know that the main objective of the distribution system is to supply electricity to the consumers at their premises. The consumer loads means nothing, but appliances which are connected to the distribution system. The community consumptions of these appliances, we can call it as a loads which are connected to distribution system.

Now, there are many different types of consumers there are some consumers which are say domestic consumers which are having consumption up to say 1 kilowatt, 5 kilowatt, 10 kilowatt, 20 kilowatt; however, there are some big consumers like having consumption like 5 megawatt, 10 megawatt which are basically industrial kind of consumers. So, we can classify these consumers into various categories.

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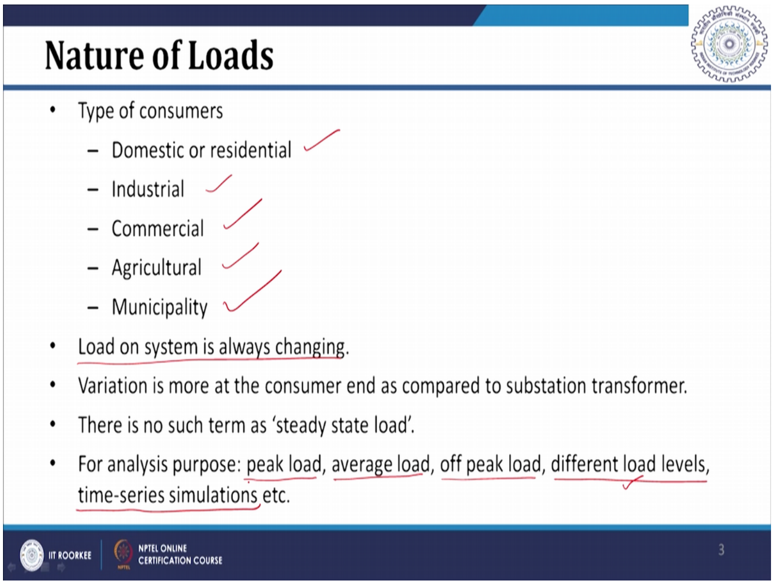

So, there are domestic and residential consumers; there are industrial consumers, there are commercial consumers, there are agricultural consumers, there are municipality type of consumers.

And if you observe the peak demand of these consumers may come at different times. If you observe domestic consumers; peak demand of domestic consumer generally comes at the evening; however, if you see the peak demands of industrial consumers may come at day times. And there is possibility there are 2 peaks in industrial consumer load curve. Then if you see the municipality kind of consumers; generally these consumers operate at of peak hours because these are nothing, but just pumping and lighting loads.

So, if you see every time the load on a system is changing. So, load is not at all constant on your system, it will be continuously changing because we do not know which customer will switch on or switch off its load at what time.

So, because of that load curve is continuously changing and if you see this variations of the load they will be highest at consumer premises means at if you measure the load curve at consumer terminal; these variations will be high, but if you go in upstream in the network we will see that these variation will be low. Means if you measure this load curve at substation transformer these variations will be less.

So,; so, there is no such term which is like steady state load. So, load will not be any time steady state between it will be continuously varying. So, while doing the analysis we know we should know some kind of load value; how a resource is loaded changing at every time instant we cannot have that steady state load conditions.

So, many times what people do while doing the analysis they use some kind of peak load or average load on a system or off peak load on a system. If you want to do some kind of more sophisticated analysis they use different load levels means in a day say full pole load curve is divided into 4 to 5 different load levels.

So, we can analyse at different load levels and if you want to further accuracy in the analysis; they use what is called as time series simulation where we can simulate of or you can do the analysis at number of instants over a day say; if you are measuring the loads at each 15 minutes you can do analysis at each 15 minutes.

Then it will become your time series simulation. Now when we are doing the simulation as I told you we need this load curve.

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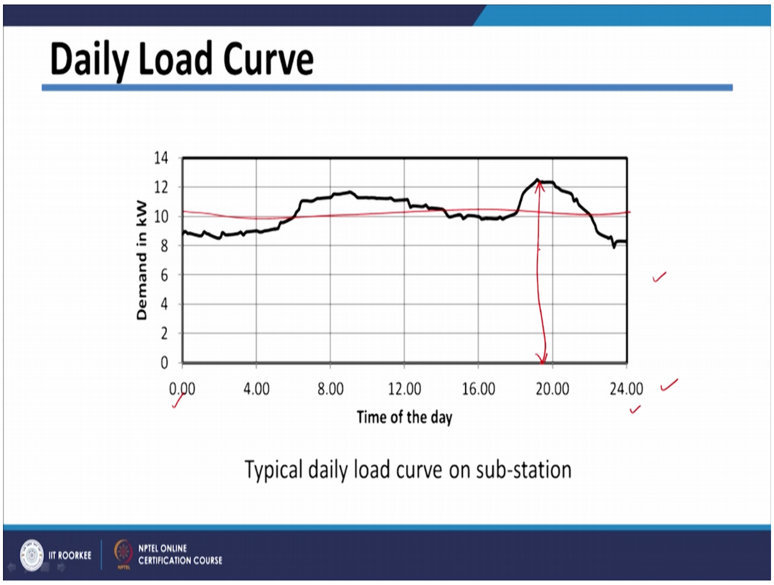

Now, if you observe the load curve one typical load curve is shown in this particular figure. where this shows your time of the day which is varying from night 12 o clock to again night at 12 o clock. So, 24 our are plotted here.

And then here on this y axis demand in kilowatt is shown and you can see that it is continuously varying sometimes it is peak. So, this is called as maximum demand of this particular system.

And then if you take the average of it means integrate this curve divided by 24 hour will give you average demand which is basically this. So, this average demand and maximum demand are important values. We will see what are the uses of this in the few next slides.

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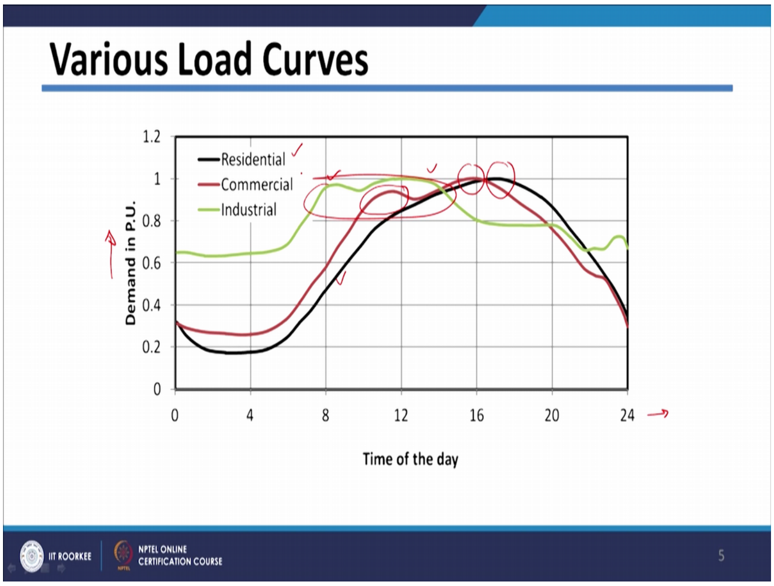

Now, if you observe load curves of different types of consumers they are shown in this particular figure. So, if you see the load curve of residential consumers; it is shown here which is in black curve. Again on x axis we are having time of the day in hours and then we are having a demand in per unit on y axis.

So, you can see that the peak of the residential consumers come around 6 or 7 o clock in the evening; however, peaks of commercial consumers we can see that they are coming around evening time as well as some peak in day time and if you observe the industrial consumers.

There are 2 peaks which are coming basically in day time because some part of the industrial operations will be of during night time. Also if you observe the load curve of industrial consumers is more flatter than domestic and commercial consumers.

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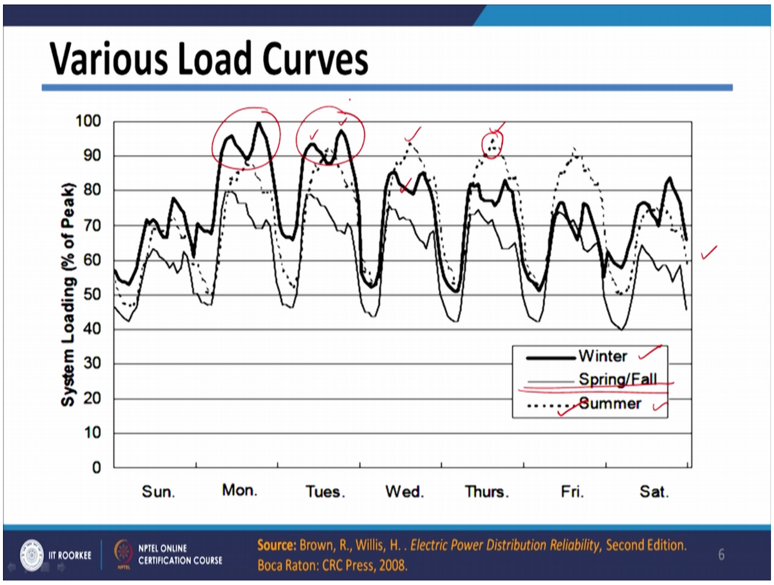

This load curves are again not constant for each day depending upon environmental condition each day these load curves will change. So, in this particular figure I have plotted the load curves for a week. And if you can observe from Sunday to again Saturday the loads are continuously changing and it is also depend on your seasons.

So, loads in winter season and summer season; they are different and then you can see that during the spring and fall the loads will be less because we do not need any heating as well as air conditioning system on during the spring and fall season.

Also you can see that because of environmental condition may be we can see that Monday, Tuesday; they are having higher loads during the winter heating load. And then there is possibility that these Wednesdays and Thurdays are sunny day because of that your consumption during the Wednesday and Thursday has gone down; again they depends upon your environmental conditions.

And then we can see that during the summer we need air conditioning load. So, which is basically on during the day time that is why day peak will be higher in case of summer loads. However in case of winter loads we can see that there is duel peak.

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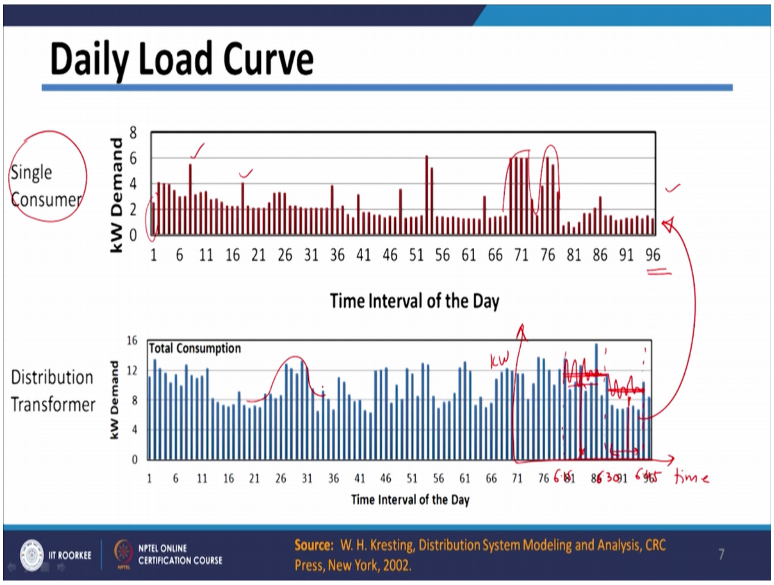

Now, if you observe this load curve; nowadays these load curves are measured in terms of what is called as 15 minutes 15 minutes demand. Now it is 15 demand is actually plotted as shown here. So, we are measuring the power at each 15 minute on average and because of that in our there will be 4 slots. So, there will be in a day there will be total 96 slots.

So, each slot shows consumption during the 15 minutes and it is average. Even though consumer tion is actually changing continuously like as I shown it here. Suppose this is your consumption in kilowatt and this is your time of the day. And if you consider one slot say this slot is starting at say 6 15 and ending at say 6 30 between these.

Consumption is actually changing like this it may take any shape, but if you take the average, it will be like this and say next slot it is up to 6 45 and in this case also may be there is possibility it will be changing like this then you take the average.

So, this is nothing, but 15 minutes demand of this slot and this is 15 minute average demand at this slot and this average demands will be plotted into this.

Particular curve which is which will give you 15 minutes demand curve. Now this is actually curve of one single consumers. So, we can see that the load curves of single consumers will be in peak in nature, we can see that the abruptly there are changes in power consumption.

So, here we can see abruptly there is power is increasing and then again decreasing then increasing. So, there are abrupt changes in power consumption of single consumer; however, if you observe at distribution transformer level; where there are 4 or 5 such consumers are connected in Indian system there is possibility that 50 or 60 such consumers will be connected to one distribution transformer.

And because of that if you observe the load curve at distribution transformer level, it will not be having those kinds of abrupt changes in the load curve; there will be little bit smooth. Again if you see the feeder level the load curve will be more smooth.

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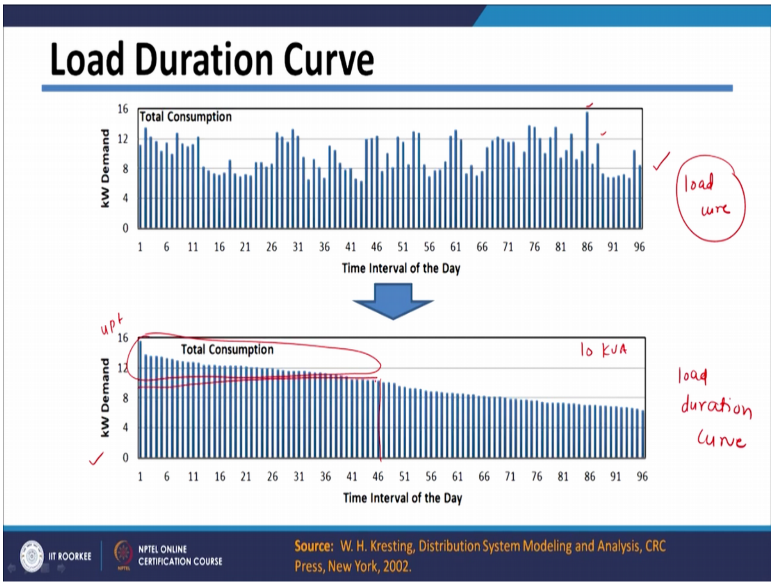

Then there is actually one term which is called as load duration curve.

So, what we are doing in load duration curve. So, again if you observe this particular figure here are taken that same load curve of distribution transformer which is plotted here. And if you arrange these 15 minute demand into descending order, you will get this load duration curve.

So, this is called as load duration curve and this is your load curve, where all these peaks are arranged in descending order. So, in this case all the peaks are arranged in descending order.

The application of curve is to get the overloading or how much capacity of the equipment is getting utilized. So, if you can observe here if there is say 10 kVA transformer which is feeding this particular load and then say this is kilowatt demand, but say it is at unity power factor.

Then you can see that this is your this 10 kVA line and up to this time, you can see that your consumption is more than 10 kVA means during this period your transformer is actually overloaded.

So, this particular curve here we will not get this information is from the load curve you will not get this particular information; however, from load duration curve will get this information because we are arranging in descending order. So, how much time your equipment is getting overloaded that can be calculated from this load duration curves.

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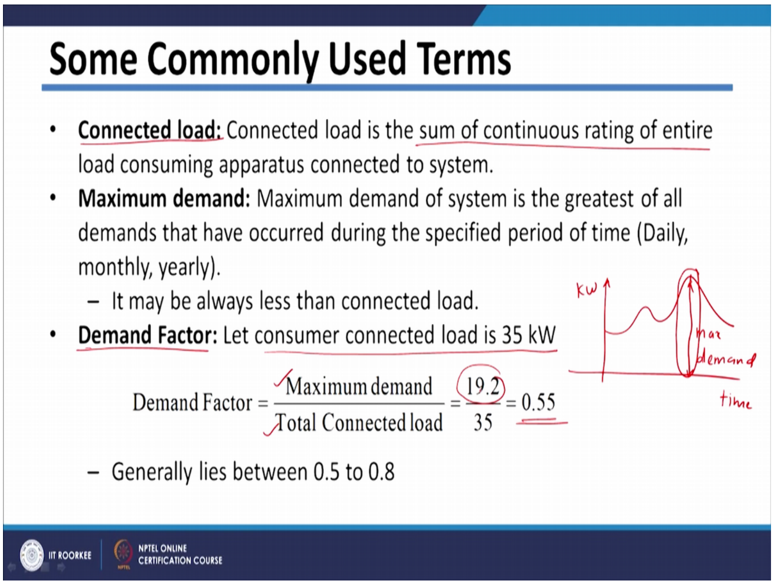

Now, you see some commonly used terms related to your load first term is connected load. This is nothing, but load which is connected at consumer premises and it is nothing, but addition of ratings of all the equipments which are connected to the grid from one home or from one consumer.

So, if you see the definition of this it is nothing, but connected load is some of the continuous rating of entire load consuming apparatus connected to a system. It is nothing, but addition of continuous rating of all the equipments which are connected to the grid from that particular consumer.

Next term is called as maximum demand already explained you maximum demand is nothing, but the where the load curve is at big position. So if this is your time and this is your consumption in kilowatt; so, this peak is nothing, but your max demand, this is nothing, but your maximum demand. And this maximum demand can be stated for daily consumption, monthly consumption, yearly consumption or weekly consumption.

And it will be always lesser than your connected load because all the connected equipments will not be on at a time. So, there will be always some equipments which will be off because of that even during this maximum demand period some of the consumer equipments will be off. So, that is why always maximum demand will be lesser than connected load and that is.

Defined by this demand factor demand factor is defined as ratio of maximum demand divided by total connected load. So, as I told you total connected load will be always more than maximum demand this demand factor will be n lesser than 1. So, in typical case suppose some consumer is having connected load of 35 kilowatt in that case your maximum demand is say 19.2 kilowatt.

In that case we can easily calculate demand factor which is 19.2 kilowatt divided by 35 which is 0.55 is the demand factor and generally it will lie between 0.5 to 0.8. Then next commonly used term is called as load factor and load factor is defined as your average demand divided by maximum demand.

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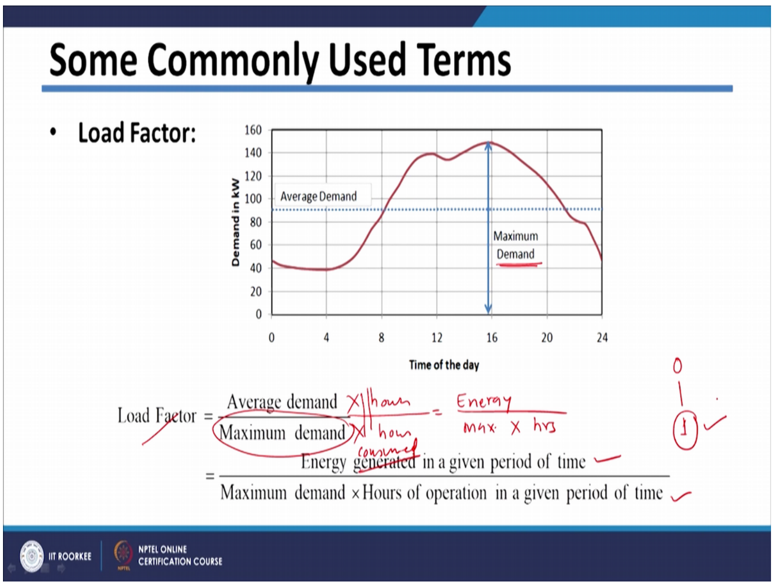

So, as I shown it here it is ratio of average demand divided by maximum demand.

So, in this figure if you see here your maximum demand is coming and the average demand is nothing, but the integration of this curve divided by your 24 hours will give you average demand, so this line tells you your average demand. Now if I multiply this by number of hours and this also number of hours, this will become total energy consumed. So, this will become total energy and this will become max demand multiplied by a number of hours ok.

So, this is nothing, but energy generated or consumed generated or consumed in a given period of time because it is average demand multiplied by hours. And at denominator you are having maximum demand multiplied by hours of operation in a given period of time.

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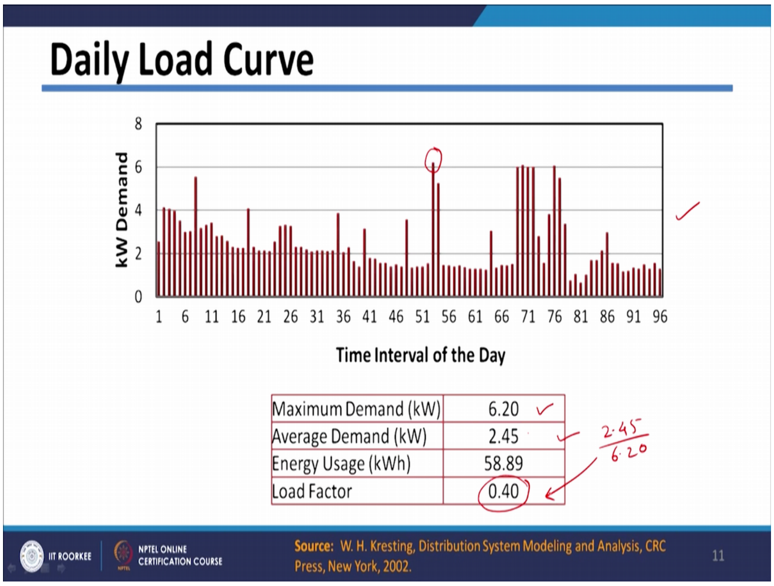

There are lot of advantages of this load factor.

Now, if you see this particular figure here I have taken the consumption of one consumer for say 24 hour and 96 slots. And if you calculate maximum demand of this consumer it is 6.20 which may be coming at some time here.

And then there is average demand which is 2.45 point which is nothing, but calculation of total energy from this curve divided by 24 hours will give us average demand. And if you calculate load factor of this consumer, it will be this average demand divided by a maximum demand. So, it is just 2.45 divided by 6.20 will give me this load factor.

Now, we will see the importance of loads factor.

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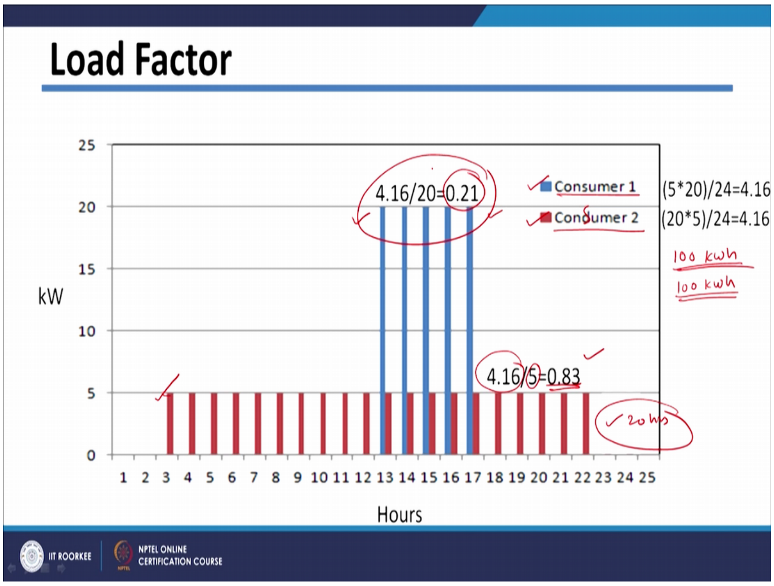

Why this load factor is important for utility point of view? Basically if you see the load factor load factor will be always lesser than 1. If you see this equation here, your maximum demand will be always more than average demand and because of this load factor will be between 0 to 1.

And utility point of view; it should be near to the unity. Why we need near to the unities can be explained in this particular figure. So, if you are observe this figure I have showed you 2 consumers; consumer number 1 and consumer number 2.

And suppose these consumers are charged only for their kilowatt hour consumption. So, if you calculate energy consumed by consumed by this consumer an energy consumed by a this particular consumer.

It can be easily calculated; so energy consumed by this consumer will be actually in 5 hours it is consuming 20 kilowatt. So, the total energy consumed will be actually 100 kilowatt hour and for consumer number 2 you can say 5 kilowatt is consumed for 20 hours. So, this consumer is also consumer consuming 100 kilowatt hour.

So, both the consumers are consuming 100 kilowatt hour. So, if you are charging only for kilowatt hour they will get same bill. How if you if you see this consumer is only operating for 5 hours; however, this consumer is operating for 20 hours. And capacity required by the utility to feed this consumer is 20 kilowatt utility need capacity of 20 kilowatt to need this consumer number 1.

However, to feed consumer number 2 utility need only 5 kilowatt capacity; so, to get this 20 kilowatt capacity utility need to have extra generation and that because of that utility cost will increase. So, utility point of view they will prefer this consumer because it is having higher load factor.

So, if you calculate load factor for this; so, this is average demand of the consumer and maximum demand of the consumer is 5 kilowatt. So, 4.16 divided by 5 will give the load factor of this consumer and load factor of this consumer if you observe it is coming 0.21.

So, utility point of view the consumer we will; however, having flat kind of load curve is better.

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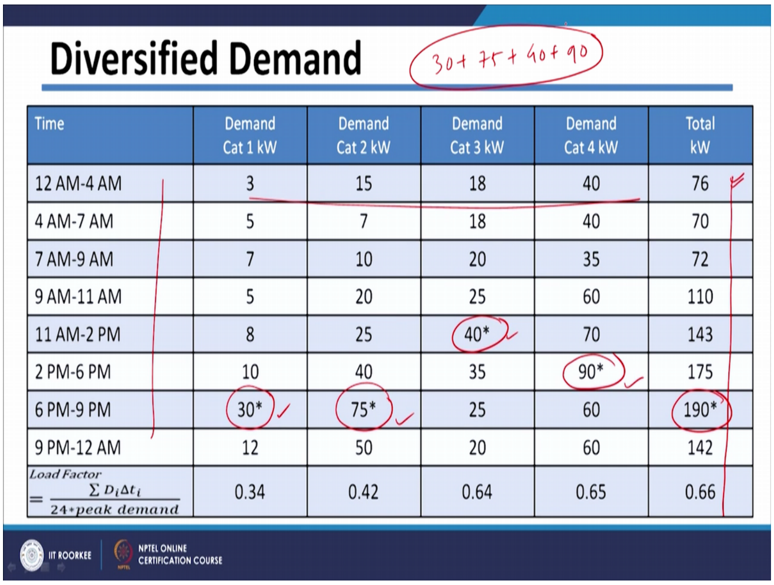

Time	Demand Cat 1 kW	Demand Cat 2 kW	Demand Cat 3 kW	Demand Cat 4 kW	Total kW
12 AM-4 AM	3	15	18	40	76
4 AM-7 AM	5	7	18	40	70
7 AM-9 AM	7	10	20	35	72
9 AM-11 AM	5	20	25	60	110
11 AM-2 PM	8	25	40*	70	143
2 PM-6 PM	10	40	35	90*	175
6 PM-9 PM	30*	75*	25	60	190*
9 PM-12 AM	12	50	20	60	142
Load Factor $= \frac{\sum D_i \Delta t_i}{24 * peak\ demand}$	0.34	0.42	0.64	0.65	0.66

Now, we will see what is called as diversity factor or diversified demand, to explain this I have put one table here which is consisting of different kinds of consumers. So, I have taken here 4 types of consumer they are categorised into category 1, category 2, category 3, category 4. So, category 1 is actually 1 kilowatt, category 2 two kilowatt, category 3 3 kilowatt maximum demand and category 4 four kilowatt. And this is actually communtive consumption of those consumers with respect to time I have just shown it here.

So, with respect to time I have shown and you can their 4 category 1 consumer; if you plot maximum demand of those consumers which coming around 6 pm to 9 pm which is around 30 kilowatt. And then for category 2 consumer it is 75 kilowatt it is coming around same time. And then for category 3 consumers it is 40 kilowatt it is coming between 11 am and 2 pm.

And then for category 4 that consumer it is coming around 2 pm to 6 pm and it is around 90 kilowatt. Now if this for all consumers if they are connected to say one system or one transformer substation transformer, the load on substation transformer will be just addition of all the loads at different times.

So, if you add all these 4 loads I will get total consumption in this period. So, if you see the total consumption in this period is coming around this time; is called as diversified demand because this peaks of different consumers they are not coming at same time, they are coming at different time that is why it is called as diversified demand.

If they would have come at same time then peak demand on the system will be actually just 30 plus 75 plus 40 plus 90. So, this will be peak demand on the system.

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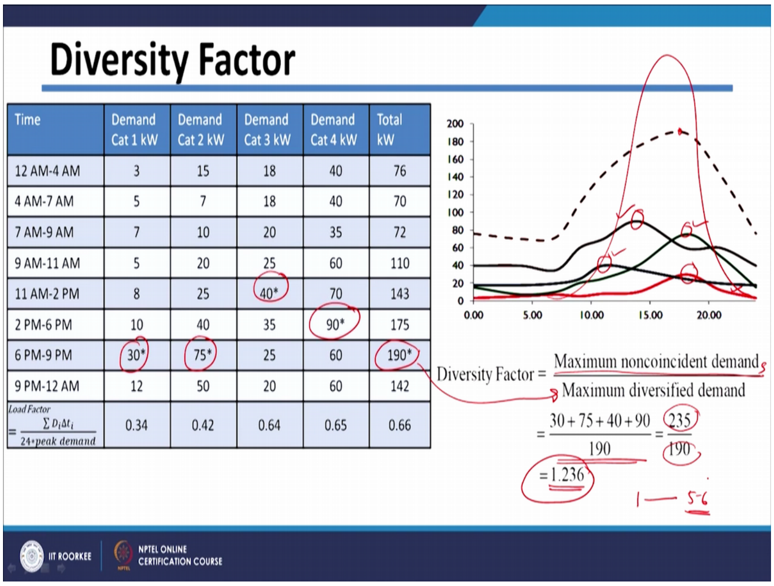

Time	Demand Cat 1 kW	Demand Cat 2 kW	Demand Cat 3 kW	Demand Cat 4 kW	Total kW
12 AM-4 AM	3	15	18	40	76
4 AM-7 AM	5	7	18	40	70
7 AM-9 AM	7	10	20	35	72
9 AM-11 AM	5	20	25	60	110
11 AM-2 PM	8	25	40*	70	143
2 PM-6 PM	10	40	35	90*	175
6 PM-9 PM	30*	75*	25	60	190*
9 PM-12 AM	12	50	20	60	142
Load Factor $= \frac{\sum D_i \Delta t_i}{24 * peak\ demand}$	0.34	0.42	0.64	0.65	0.66

So, based on this diversity factor is defined as here maximum non coincident demand which is nothing, but addition of all the maximum demands of individual consumers that is 30 plus 75 plus 40 plus 90 which are actually non coincident maximum demands of individual consumers divided by a maximum diversifies demand which is total demand which is coming 190.

So, addition of this divided by 190 will give me your diversity factor. So, this comes out to be 235 divided by 190 will give me a 1.2. So, in this case this diversity factor will be always more than 1 because your maximum non coincident demand if it is not coming at same time, tt will be always higher than maximum diversified demand.

So, maximum diversified demand is total demand on a system. Since these non coincident demands are not coming at same time, this will be always lesser than means maximum diversified demand will be lesser than maximum non coincident demand; so, you should say the demands here. So, this can be easily observed in this particular graphs if you see. So, for 4 different category of consumers you can see that peaks are actually coming at different types different time and because of that total system peak is coming somewhere here.

However, if if this all demands if they come at same time the your peak may be higher. So, it is always better to have higher and higher diversity in your loads so that overall peak of the system load will go down. So we want this diversity factor to be as high as possible, however it is not possible to make it larger than 4, so least value of diversity factor will be 1 and then it will be as high as 5 or 6.

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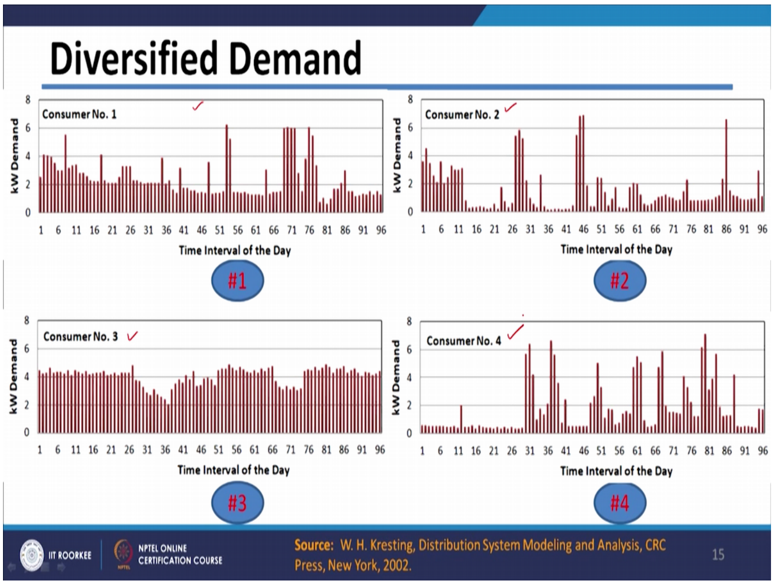

To explain this diversity factor further I have given consumption of 4 different consumers.

Ah If you can see this figures this is consumer number 1, consumer number 2, consumer number 3, consumer number 4. And these are actually load curves of all these 4 customers. And if you calculate that diversity factors or diversity factor.

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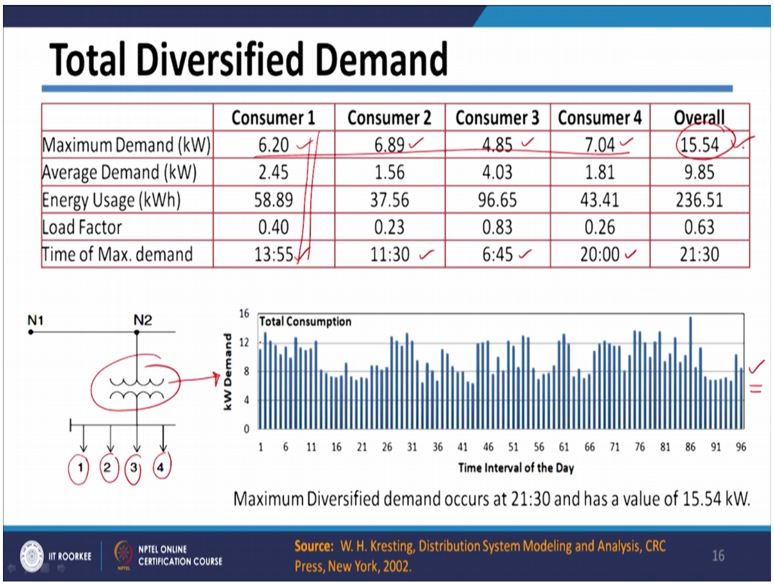

If all these 4 consumers are connected to one distribution transformer. So, whatever customers which shown in last slide; if they have connected at same distribution transformer ok, the load on the distribution transformer can be just addition of all the 4 load curve at each instant it will be actually load curve which is given by this one.

So, this will be nothing, but load curve at distribution transformer. Now if you observe the peak demand, average demand and energy usage of all the 4 consumers they are listed down it here. And then you can see that these are the peak demands of each of the consumer; however, system peak demand is not just addition of addition of all these 4, it is lesser than that it is because all these peaks are there coming at different times.

So, it is always better to have higher and higher diversity so that your overall consumption will go down that meaning as this is actually your load curve will be come as flat as possible.

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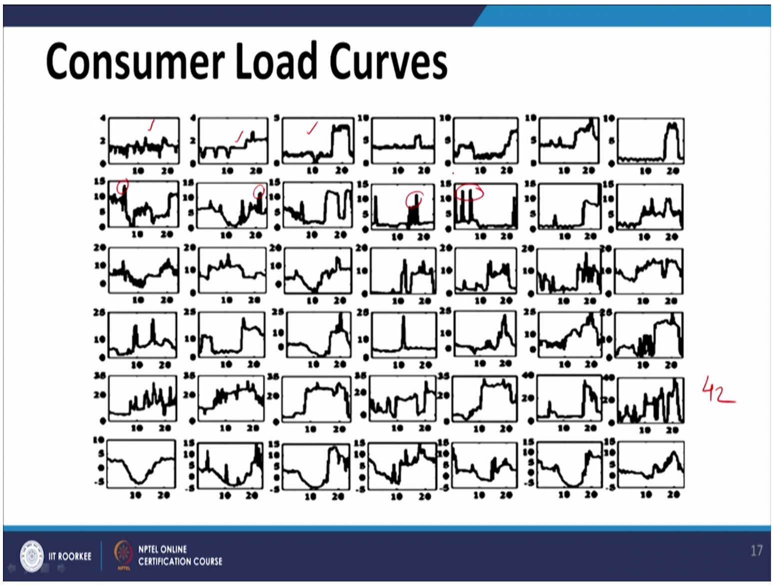

So, if you see the load patterns of various consumers; they will not be same. So, the consumption patterns of different consumers they will be very very different from each other to show some example.

I have shown the load patterns of various consumer in into this particular slide. So, you can observe there are around 42 consumers. And if you observe the curves load curves of all these consumers, they are actually very different from each other.

And if these consumers if they are connected to one distribution transformer, the load curve of distribution system distribution transformer will be come as flat as possible because if you see the peak loads of these consumers they are coming at very different time. So, as I explained here there are 42 consumers and peak demand of those consumers they are coming at different times.

So, diversify demand on a system will be low it is not just addition of all the peak demands of each customer. So, diversity factor is one of the important parameters while judging your distribution system ah. Distribution operator point of view it is always better to have higher and higher diversity factor, but as I explained you cannot make it very large value.

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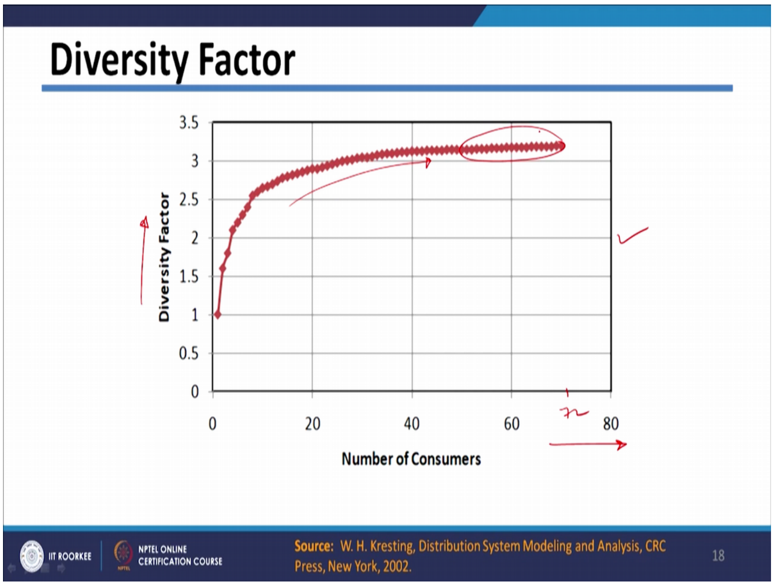

So, in this particular figure I have just shown you the curve, which shown number of consumers versus diversity factors. So, on this x axis I have plotted number of consumers which is ranging from 0 to 80, generally where we are plotted up to 72 consumers.

And then diversity factor which is ranging from 0 to 3.5. Now if you go on adding more and more number of consumers, your diversity factor will go on increasing as I explained in last slide because peaks of those consumers.

So, they are they are basically coming at different times because of that is if you add more and more number of consumers your diversity factor curve will go on increasing; however, after sometime it will get almost constant it is around 3.4 or something.

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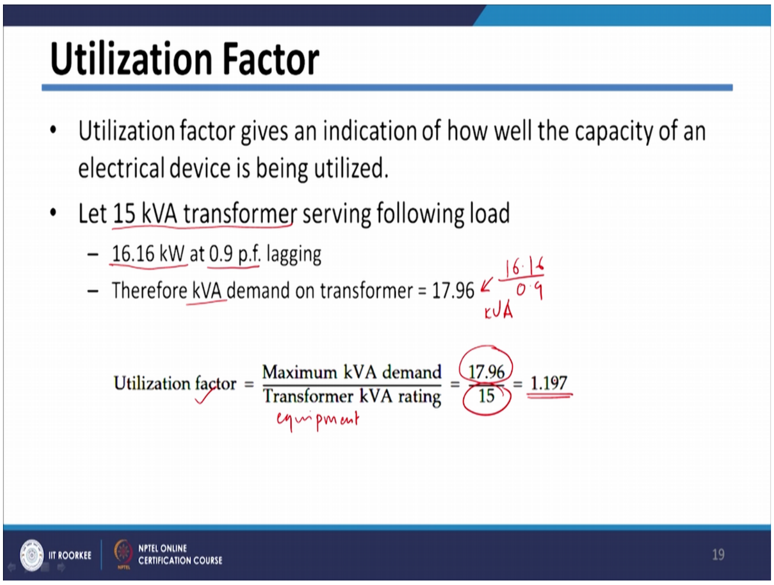

Then one more factor which is called as utilization factor which gives an indication of how well the capacity of electrical devise is being utilized. It is basically tells you how much utilization of your electrical equipment is happening?.

Like one example are given it here let there is say transformer which is 15 kVA and it is serving the load of say 16.16 kilowatt at point 0.9 p.f power factor lagging. In this case if you calculate kVA of this transformer it is just if you take 16 by 16 by 16 divided by 0.9 we will get kVA rating of this transformer.

So, it will be actually kVA demand 17.96. So, in this case utilization factor you defined as maximum kVA demand maximum kVA demand of the equipment divided by your transformer kVA rating or instead of transformer we can say equipment of kVA rating; so, you can say equipment also. So, for this particular transformer the utilization factor will be the kVA which is served divided by rated kVA which will give utilization factor.

So, it may be more than 1 or less than 1 depending upon how much of loading is happening on that particular equipment.

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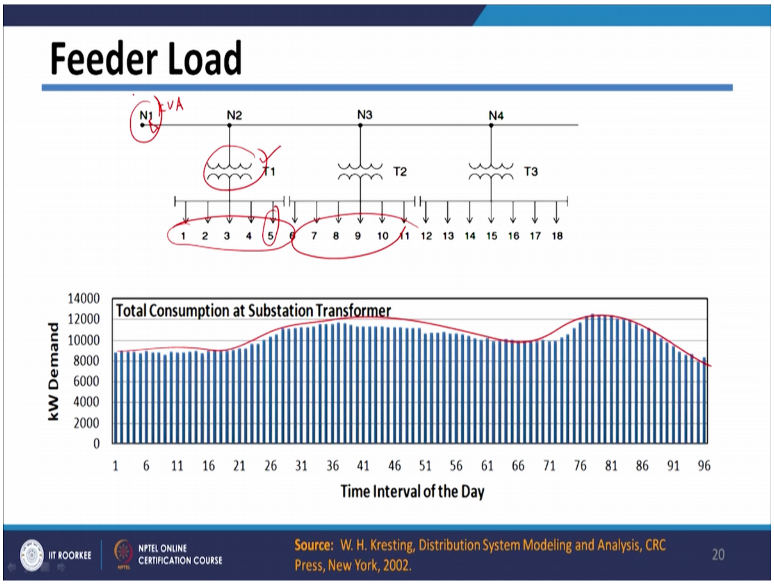

And finally, as I told you if you are having many number of distribution transformer and if you add these loadings together, you can get at the substation level means if the kVA which is flowing through this particular feeder will be almost flat, there will not be abrupt changes like which we have observed in case of individual consumer or which we in case of individual transformer ok.

So, variation in load curve will be highest in case of individual consumers then the abrupt changes will decrease in case of distribution transformer. And this these abrupt changes will be further decreased in case of substation transformer. So, and if you go to the transmission level; these abruption means almost negligible.

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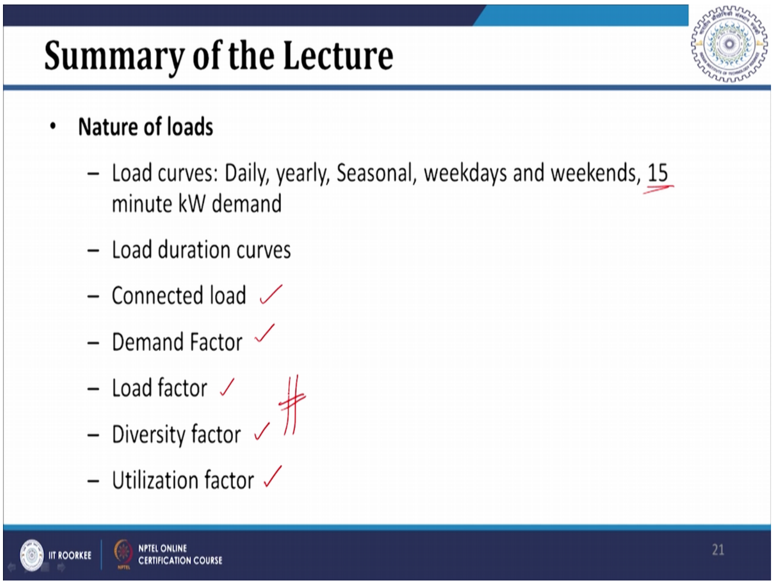

So, in this particular lecture we are started with different load curves. So, basically we wanted to see the nature of loads. So, we started with load curve.

I explained you what is load curve and we have seen that they can be plotted daily, yearly, monthly or weekly load curves. And nowadays with electronics meter available we can plot load curve which is called as 15 minute kilowatt demand load curve.

Then we have seen load duration curves basically to find out over loading or utilization of your equipment. Then we have seen various factor that is those are connected load, demand factor, load factor diversity factor and utilization factor. And we have seen that these load factor and diversity factor; they are very important from the point of view of the utility.

Thank you.