Power System Analysis
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Lecture - 03
Structure of Power Systems and Few other Aspects- III

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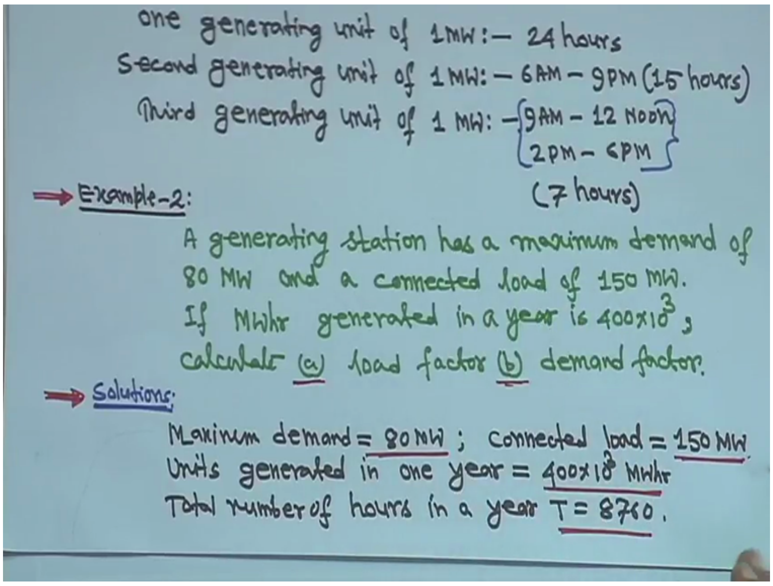

So, next is your second example; example 2, right, this one. So, I hope previous one, you might have under understood and it is very simple thing this all these things are. So, a generating station has a maximum demand of 80 megawatt and a connected load of 150 megawatt, if megawatt hour that is energy generated in a year is that is annual energy generation year is 400 into 10 to the power 3 megawatt hour, you have to compute load factor and demand factor. So, maximum demand is given 80 megawatt, connected load also given 150 megawatt units generated in 1 year is given 400 into 10 to the power 3 megawatt hour it is given in megawatt hour generated in a year is 400 into 10 to the power 3 and total number of hours in a year is equal to T is equal to 8760.

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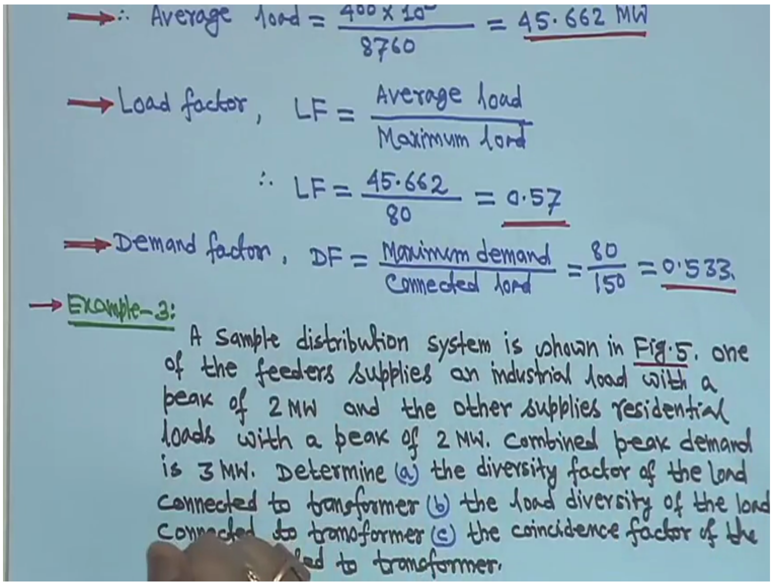

So, all data are known right therefore, average load you can find that it is annual energy generated divided by the total number of hours.

So, it is 400 into 10 to the power 3 divided by T; T is equal to 8760 is equal to 45.662 megawatt; a load factor LF is equal to average load by maximum load. So, average load is 45.662 megawatt and maximum is 80. So, load factor is 0.57 and demand factor DF is equal to maximum demand by connected load maximum demand was 80 megawatt and connected load 150 megawatt therefore, demand factor is equal to 0.533. So, these are simple example, but all these terminology whatever we have used. So, we will take one after another few example such that it will be understandable to you next is example 3.

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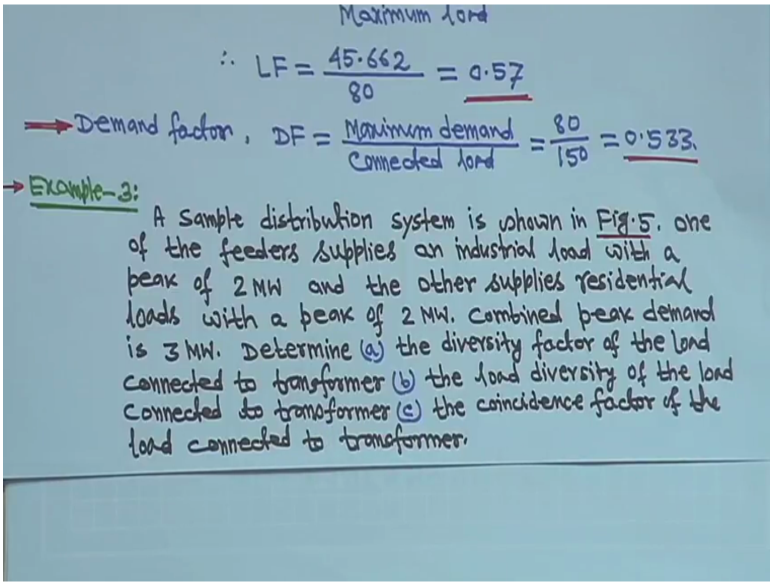

So, a sample distribution system is shown in figure 5; figure 5 I will show you later one of the feeders supplies an industrial load with a peak of 2 megawatt and the other supplies residential loads with a peak of 2 megawatt combined peak demand is 3 megawatt determine a the diversity factor of the load connected to transformer B, the load diversity of the load connected to transformer and C the coincidence factor of the load connected to transformer.

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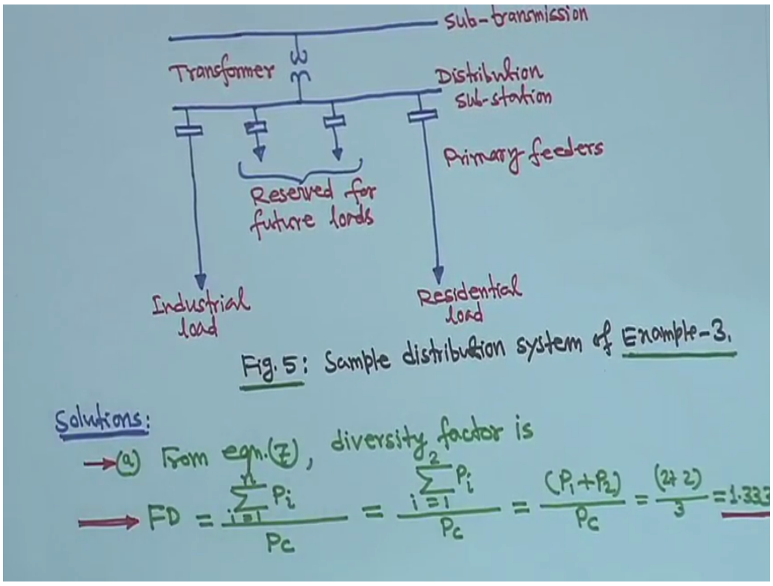

So, these 3 things you have to obtain now figure 5 for this example. So, it is given this sub transmission system transformer is there this is this is distribution substation and this is industrial load residential load and these are for future loads this is a diagram samples distribution system of example 3 right now from equation 7 diversity factor is that from equation 7 that diversity factor formula is FD is equal to sigma I is equal to 1 to n pi upon P c, but here you have a 2 consumers right your here it is given one for industrial another for your residential right industrial and residential. So, n is equal to 2. So, I is equal to 1 to 2 pi that is by P C that is P 1 plus P 2 upon P C right. So, it is given for both the cases industrialism industrial load with a peak of 2 megawatt and other supplier residential load with a peak of 2 megawatt; that means, P 1 is equal to 2 P 2 is equal to 2 that is 2 plus 2 and total and combined peak demand is 3 megawatt. So, P C is equal to 3 megawatt right. So, 2 plus 2 by 3, so, it is 1.333. So, this is your diversity factor.

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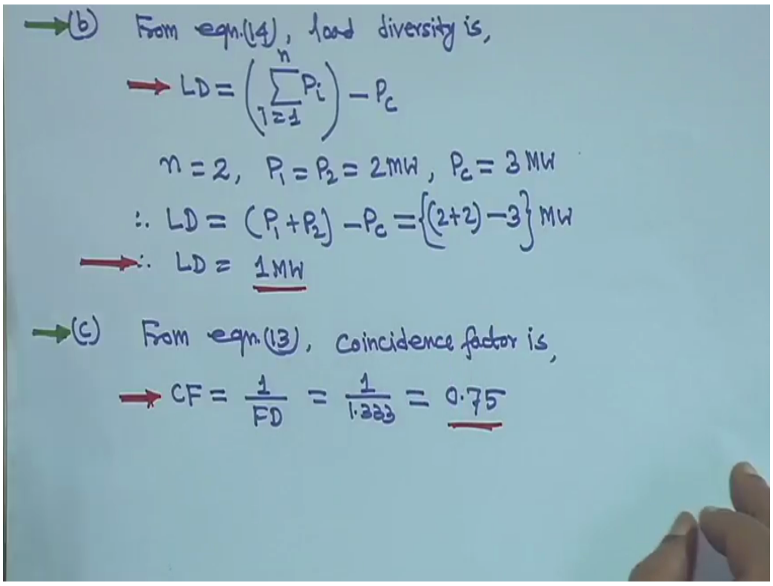

Now, from equation 14; from equation 14 that load diversity ld is equal to sigma I is equal to 1 to n pi minus P C n is equal to 2 P 1 is equal to P 2 is equal to 2 megawatt and P C is equal to 3 megawatt right therefore, load diversity is equal to P 1 plus P 2 minus P C that is 2 plus 2 minus 3 megawatt a load diversity is 1 megawatt and from equation thirteen coincidence factor is CF is equal to 1 upon diversity factor right is equal to 1 upon 1.333 is equal to 0.75.

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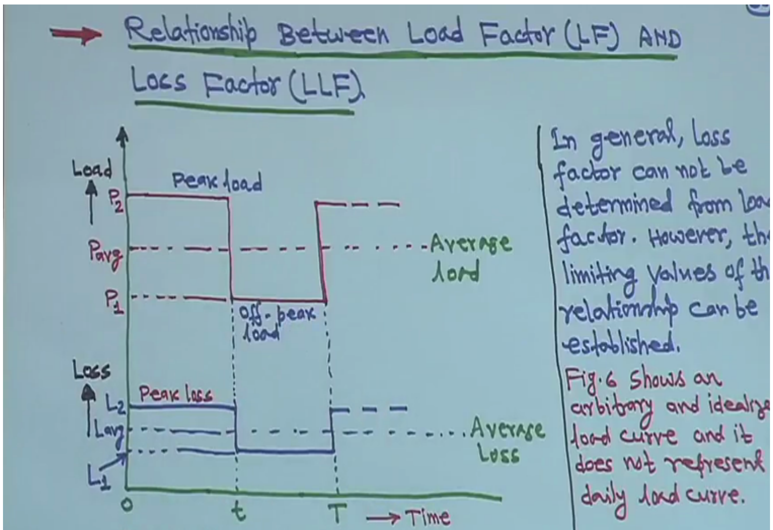

Fig. 6: Idealized load curve

So, this numerical this problems are very you know very simple very simple right next stage we will try to establish a relationship between load factor or and the loss factor also direct is not possible, but we will try to establish some relationship. So, relationship between load factor and loss factor right first before coming to this in general loss factor cannot be determined from the load factor right. So, generally it is directly; it is not possible; however, the limiting values of the relationship can be established right. So, figures this is figure 6 it shows an arbitrary and idealized load curve and it does not represent a daily load curve this is just to establish a relationship something has been drawn. So, if you take this y axis first take the load say this is peak load for a this thing is P 2 and off peak load is P 1 and its average is this dash line is the average load; something we have drawn.

So, this peak load that your; the duration is from 0 to small t timing right and off peak load from your T to T the duration will be capital T minus small t. So, this is peak load P 2 and off peak load is P 1 average is P average this is the load curve this is something has been drawn it is the it is the idea ideal load curve right something has been taken corresponding this 2 a that peak load for the system suppose loss is peak loss is L 2 responding this peak load the loss is your peak loss this loss also peak loss also will exist from 0 to T only because peak load is 0 to T right and then here your off peak off peak due to for off peak load P 1 the loss is L 1 right this is that this is that off peak load L 1 right and then this duration is from small t to capital T; that means, T minus T right and this is also I know I know (Refer Time: 07:37)

This dash line blue dash line is the average loss. So, this kind of a just to establish the we will try to establish relationship between that your load factor LF and the last factor LF right, but this is nothing it is not reality, but for the sake of your you know for the sake of establishing a relationship we have make it may you are made it like this right.

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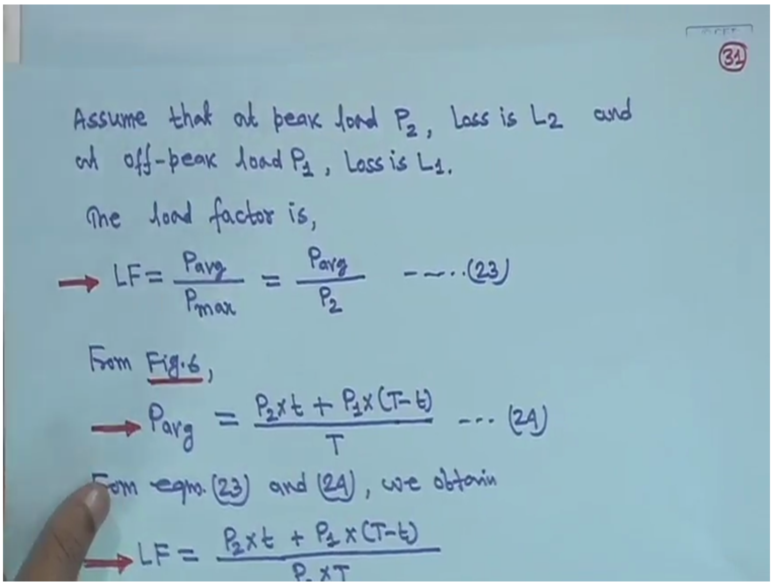

If we do; so then assume that the peak load P 2. So, the I told you peak load is P 2 this P 2 and corresponding loss is peak loss is L 2 I told you and at off peak load P 1 loss is L 1 off peak load is P 1 and corresponding loss is L 1 right and the load factor is LF is equal to P average upon P max here we have taken that this is some average load line. So, this is my P average divided by peak P max P max is nothing, but the P 2 right. So, this is equation 23 now from figure 6 I mean this figure from this figure if you see like this that from figure 6 if you see that your P average is equal to P 2 it duration is T. So, P 2 into T small t small T plus that duration of P 1 is this is now low load level P 1 duration is capital T minus small t. So, plus P 1 into capital T minus small t divided by total duration 0 to T that is that is your divided by T right.

So, that is your P average therefore, from equation 23 and 24 we obtain that is your load factor is equal to this P average this P average you substitute here right if you subs if you substitute here then load factor is equal to P 2 into T plus P 1 into capital T minus small t divided by P 2 into capital T right I hope this part is understandable to all of you right next; that means, this one.

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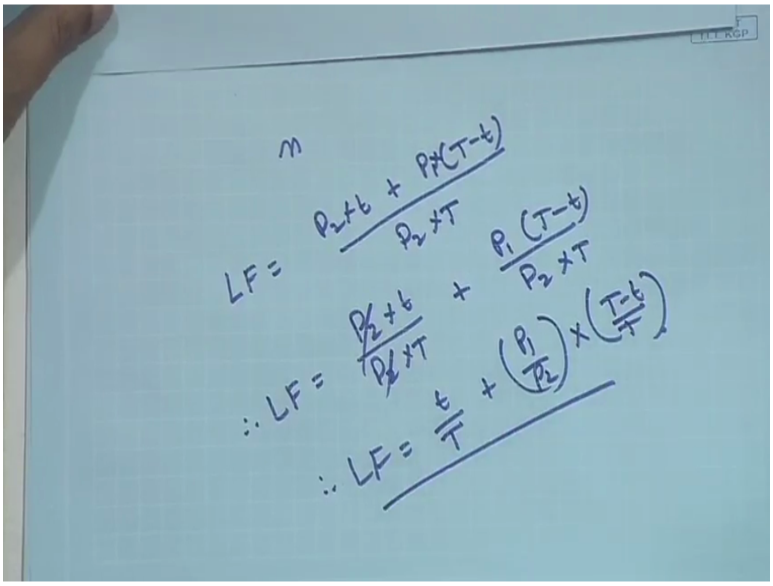

This one this load factor LF is equal to I am rewriting once again P 2 plus P 1 into T minus capital T divided by P 2 into t; that means, this one it can be written as P 2 into T divided by P 2 into capital T plus P 1 into T minus T divided by P 2 into T this way you can write therefore, L f is equal to P 2 P 2 will be canceled. So, T by T plus it will be P 1 upon P 2 into T minus T by T right; that means, this LF this lf.

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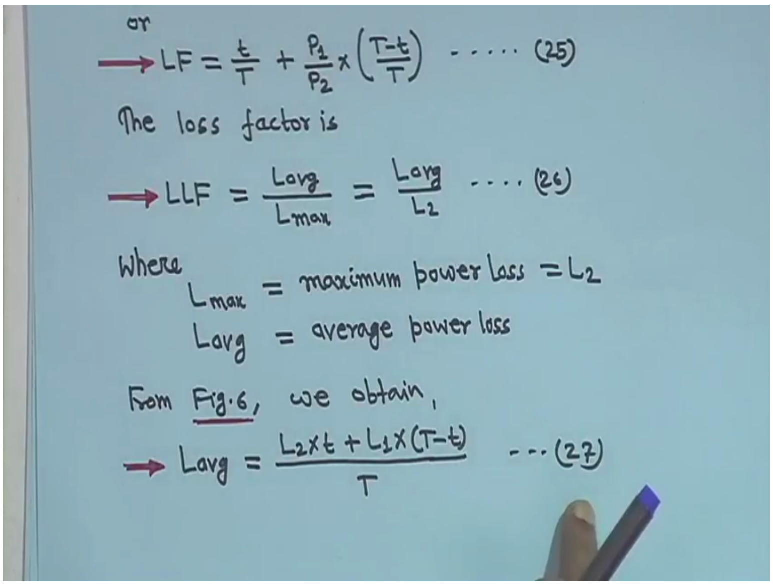

So, here we are writing this L f is equal to therefore, whatever I wrote that T by small t by capital T plus 1 upon P 2 into T minus T upon T this is equation 25 right similarly the loss factor is double LLF right LLF is equal to L average upon L max right. So, from this from third figure it is your this; this line is L average L average upon L 2 right L 2 is the peak loss; that means, during peak load this is the peak loss L 2 right. That means, L max is equal to L 2 this is equation 26 L max is equal to maximum power loss is equal to L 2 and L average is equal to average power loss from figure 6 similarly you will obtain same thing that peak loss is existing from 0 to t. So, L 2 into T plus your L 1 is L 1 is that the your; off peak power loss.

So, it is L 1 into T minus T divided by your T right. So, that is your L average total duration is t. So, that is your equation 27 similarly this loss also you can write. So, this L average this L average you substitute here you substitute this L average expression in 26 here; here you substitute if you substitute here then you will see that is why I am writing from equation 26 and 27 we get LF is equal to L 2 into T plus L 1 into T minus T divided by L 2 into T same as before.

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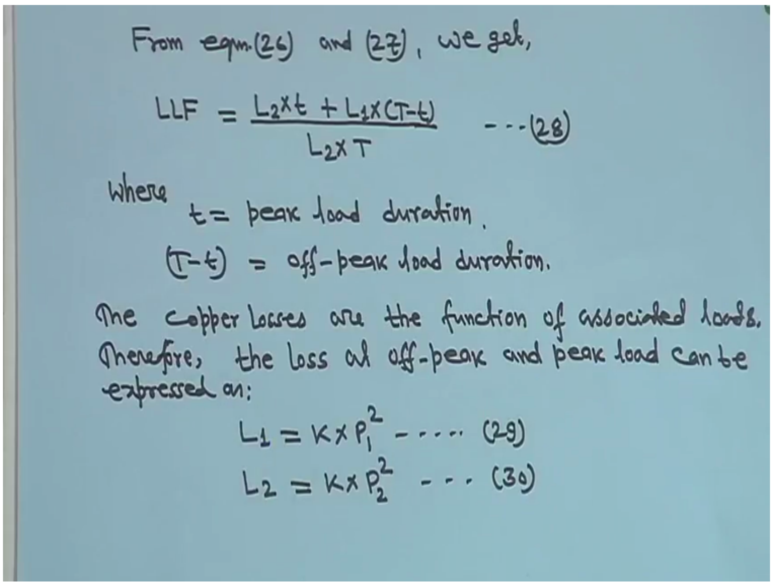

So, this is 28 right now (Refer Time: 12:39) small t is the peak load duration and capital T minus small t is equal to off peak load duration. Now the copper losses are the function of associate load we know that your power loss is in general I square r loss right and I means the current and hence that current is depend on the load only right are the function of the associate loads. Therefore, the loss at off peak and peak load can be expressed as at off peak hours loss is L 1 is equal to some constant into P 1 square because as because loss actually is proportional to the square of the load I mean approximately proportional to the square of the load (Refer Time: 13:19) load have different characteristic, but for the establishing this relationship the loss is. So, off peak hours off peak hours load is P 1 and loss is L 1 this K is the constant of proportionality it will remain same for both right.

So, L 1 is equal to K into P 1 square similarly at peak hours loss L 2 is equal to K into P 2 square right this is quite valid this is quite true because loss is proportional to I square and I depends current depends on the load hence the loss also to some extent relate to the square of the load right. Therefore, this L 1 this L 1 is equal to K into P 1 square right and L 2 is equal to K into P 2 square you substitute in equation 28 this L 1 and L 2 expression you substitute here in equation 28 if you do. So, therefore, you are writing from equation 28 29 and 30 therefore, from equation 28 29 and 30 we get.

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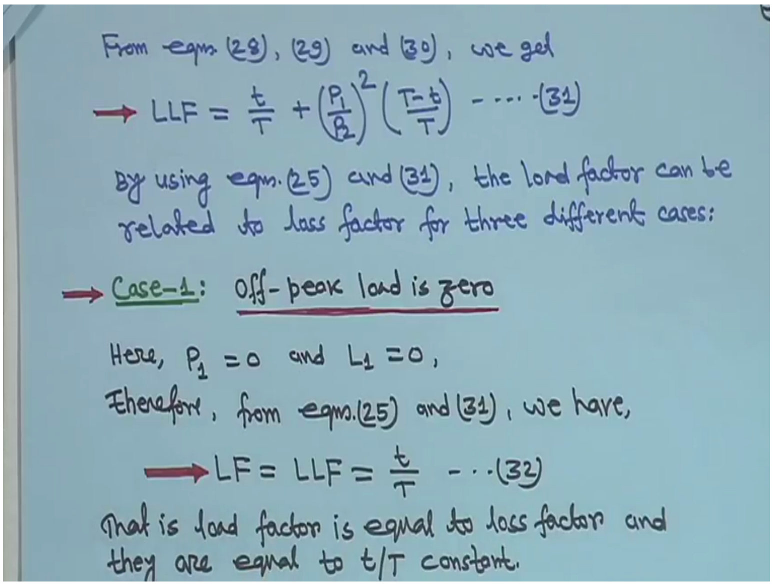

Lf is after simplification LF is equal to small t by capital T plus P 1 upon P 2 whole square into T minus capital T minus small t divided by capital T this is equation 31 you substitute and just simplify same as before right therefore, loss factor is expression is this one right no by using equation 25 and 31 let; that means, this equation. That means, using this equation this is the load factor your equation and this is the loss factors equation using this 2 equation we will try to establish a relationship between load factor and your loss factor. So, how to make it? So, for 3 different cases we will consider from that we will try to establish some relationship case one off peak load is 0; that means, there is no off peak load; that means, if no off peak load then P 1 is 0; that means, your L 1 is also 0 loss off peak load P 1 0 means at off peak load 0 means off peak loss is also 0 therefore, from equation 25 and 31. So, equation 25 is this one. So, here you put P 1 is equal to 0 and your what you call L 1 your if you put P 1 is equal to 0.

In this expression then what will happen that a your LF will become if you put here let me write down if it is take this take this equation 25 for the case one is off peak load is 0; that means, this case one off peak load is 0; that means, if P 1 is equal to 0 and then L 1 is then L 1 is also 0.

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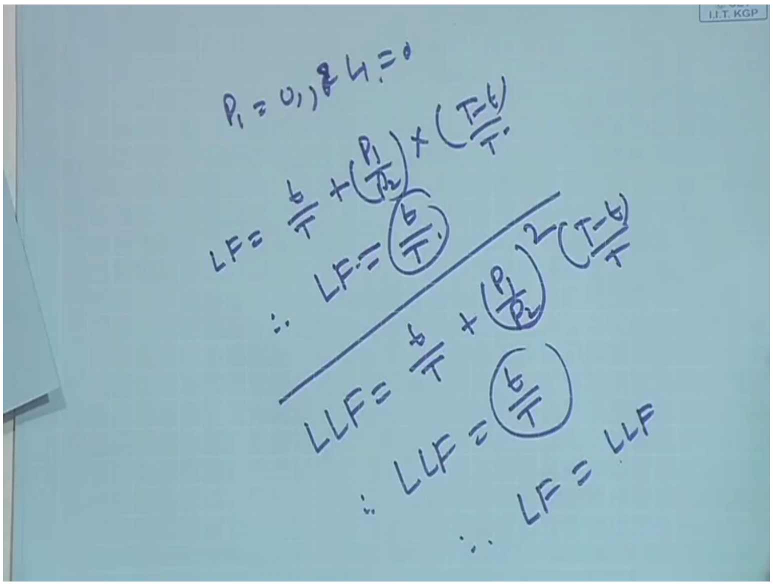

Therefore your equation your 25 equation 25 here it is LF is equal to T by T plus P 1 by P 2 into T minus T by capital t, but here pone is 0; that means, L f is equal to small t by capital T right similarly in equation 31 equation 31 is this one this is for LF equation 31 this expression is there loss factor is equal to small t by capital T plus P 1 by P 2 whole square into T minus T by capital t, but P 1 is 0 if you put P 1 0 this term will not be there therefore, loss factor also is equal to T by T right this one here also this one. That means, for the case of for where off peak load is 0; that means, load factor is equal to loss factor that is why here we are writing that if off peak load is 0 then therefore, equation from equation 25 will get that LF is equal to this is from equation 25 LF is equal to small t by capital T and from 31 also we get it, this LLF is equal to T by T.

Therefore, this thing and this thing they are same LF LLF LF is equal to LLF therefore, this we have LF is equal to LLF is equal to it is your T by T small t by capital T write therefore, it is your equation 32 that is load factor is equal to the loss factor and they are equal to small t by capital T is equal to constant, this is for the case one this case one we have assumed right because we have to establish some relationship that is why you have assumed right similarly.

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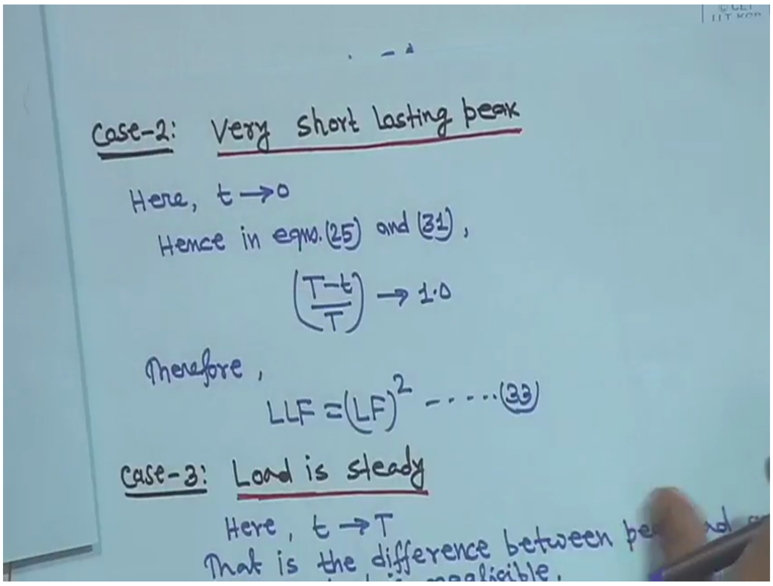

Now, case 2 very short lasting peak right in this case the time T tends to 0 therefore, equation if you look at equation 25 just hold on equation 25 equation 25 when T minus your T very short lasting peak. That means, here T tends to 0 hence in equation 25 that T minus T divided by T tends to 1 therefore, we can make it loss factor is equal to this thing from equation 25 and 31 come to this 31 where is equation 31 this one right when T tends to T tends to 0 right where it has gone yes, yes, when T minus T upon T your distance to 1 right and LLF is equal to your here T tends to 0.

So, from this 2 condition from this 2 condition you will get that loss factor is equal to load factor square you take T tends to 0 and equation 25 and 31 if T tends to 0 means T minus T upon T tends to your what you call your one right and in the end in the 20 and in that equation your load factor equation when just hold on ill make it here such that the things will be easier for you right first you consider 25.

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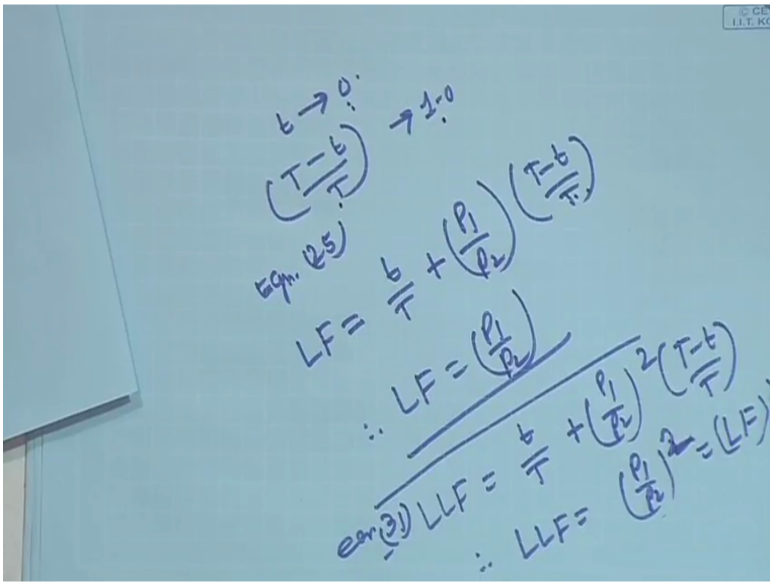

And the condition is that your case 2 that very short lasting peak; that means, T tends to first you come T tends to 0 right; that means, T minus T by capital T it tends to 1.0 because T tends to 0 then this term tends to 1 therefore, equation 25 you take equation 25 it is load factor is equal to T by T plus P 1 by P 2 into T minus T by T as T tends to 0.

This is this, this terminology tends to 1 and this is 0; that means, LF equal to P 1 by P 2 this is your load factor for this condition similarly if you look at equation 25 right not 25 31 that loss factor expression that loss factor expression is I am writing here LLF this is equation 31 it is T by T plus P 1 by P 2, whole square then T minus T by capital T as T tends to 0 and this T minus small t upon capital T tends to 1; that means, LLF is equal to your P 1 by P 2 square this term will vanish and this tends to 1 it will P 1 P 2 whole square right and your LF is equal to P 1 upon P 2.

That means, this one is equal to load factor square; that means, loss factor for this condition is equal to square of the load factor therefore, we are writing this one that here T tends to 0 therefore, from equation 25 and 31 loss; loss factor is equal to load factor square this is equation 33 another condition is while load is steady that is here T tends to T constant load is steady T tends to T that is the difference between peak and off leak load is negligible almost constant in that case you will get same thing from equation 25 you will get loss factor is equal to load factor.

So; that means, your small t is tends to your capital T right therefore, load is steady.

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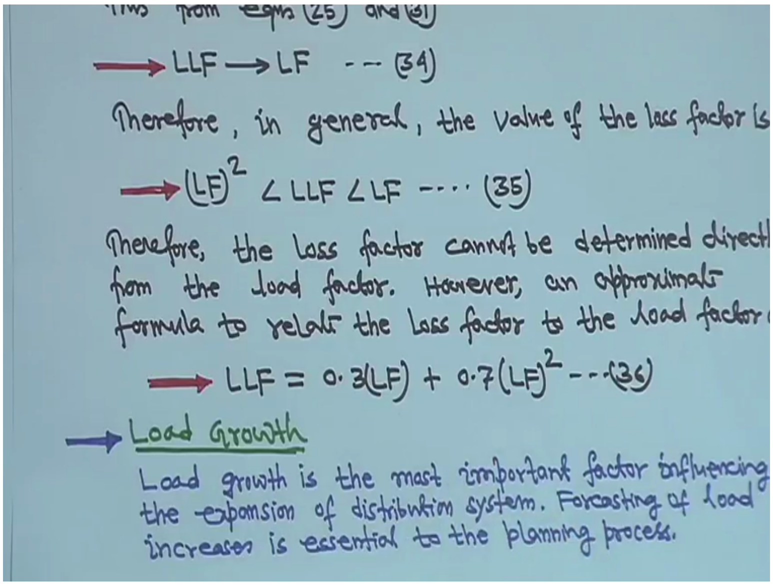

In that case you will get it that loss factor is equal to load factor; that means, one condition we got 3 different conditions, but therefore, in general the it is coming like this first condition whatever we saw that loss factor is equal to load factor then another condition you took it is your equal to LF square. So, generally load factor is less than less than 1. So, so and therefore, loss factor will be greater than LF square; square of the load factor, but less than your load factors.

So, greater than square of the your; LF square and less than LF. So, this is this is the that this is that your what you call the condition for the loss factors something can be established, but in general it has been observed that the loss factor cannot be determined directly from the load factor it is not possible right. However, and approximate formula to relate the loss factor to the load factor as that loss factor is equal to 0.3 into load factor plus 0.7 into your load factors square this; this equation or this terminology is used by many particularly for the you know for the city areas or this thing this formula is quite valid, but if it is a rural areas right rural feeder or this thing in that case instead of 0.3 it comes 0.2 into LF plus 0.8.

Lf square right; so and approximately it has been found that this equation what relates between loss factor and the load factor. So, this is the relationship between loss factor and the load factor these are all these general thing I am telling in the at the beginning right after that we will see something different. But you one should be familiar with all sort of terminology loss factor load factor everything, but for rural feeder rural load if this instead of 0.3; it is 0.2; they take and it is 0.8 some other relationships also comes because loss factor or load factor depends on the load growth also which I will not tell anything yet, but it depends on the load growth also right.

Next is your load growth actually whenever you see any sort of thing load is increasing right continuously right. So, some cases some places maybe it is at a rate of 3 percent, 4 percent, 5 percent annually or even more. So, load growth is always there. So, if load inc load increases. So, general your load increases means demand is increasing right and demand increases means suppose in a particular network load demand is increasing means that you need to supply the need to supply that load.

So, in that case if load increases you have to think many thing because power loss will increase then every every year load is increasing; that means, voltage will also at different point will go down right all these things you need to maintain at a appropriate level. So, load growth is the most important factor that is inevitable that load will increase right influencing the expansion of distribution system forecasting of load increases is essential to the planning period. So, one has to forecast the load that how things will happen I am what I am telling you here just the preliminary thing or basic thing right, but load growth is the important part of our power system, right.

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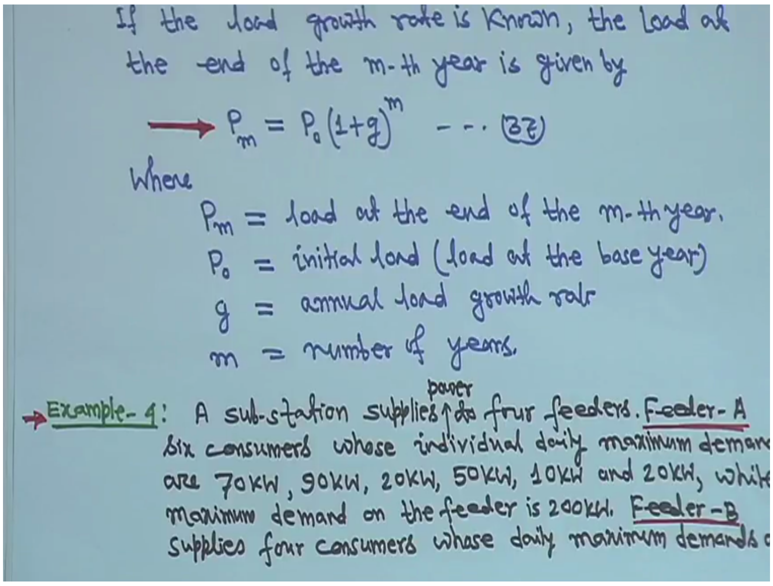

So, if the if the if the load growth rate is known right then load at the end of the m th year is given by. So, suppose pm is equal to P 0 1 plus g to the power m this is equation; 37 where pm is the load at the end of m th year suppose today at this point it is the base year that is initial load right.

So, suppose this 2017 at this point load is P 0 next year at this time it will be it is suppose it is increasing at a rate of say 5 percent. So, g is the annual load growth rate say g is the 5 percent and it is number of years; that means, pm is the load at the end of the m th year P 0 initial load at the base year g is the annual load growth rate and m is the number of years for example, a.

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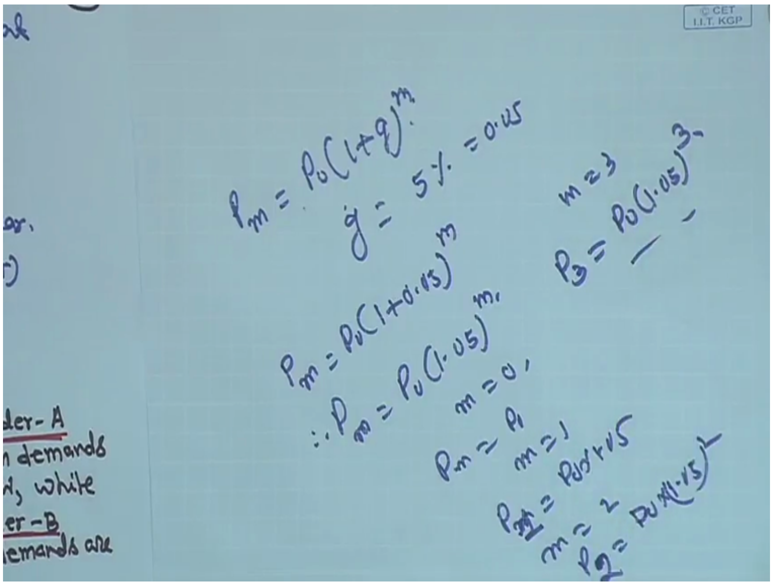

For example suppose; suppose your pm we are writing that P 0 1 plus g to the power m right P 0 is the load at the you know or this thing base year; that means, at this suppose this year right and g is the annual your load growth rate. So, suppose g is equal to 5 percent that is 0.05 right therefore, your pm is equal to it can be written as P 0 1 plus 0.05 to the power m; that means, pm is equal to P 0 1.05 to the power m right when base year when m is equal to 0 pm is equal to P 0 say its automatic. Now when m is equal to 1 pm is equal to P 0 into 1.05 when m is equal to 2 pm is equal to P 0 into 1.05 square and so on.

Similarly, for m is equal to 3 pm is equal to sorry I can put pm m is equal to 1 P 1 after first year when m is equal to 2 after that P 2 is equal to this one similarly when m is equal to 3 P 3 is equal to your P 0 1.05 cube right suppose P 0 if you take say 100 kilowatt for example, right. So, first year load will be 100 kilowatt. Next year it will be 100 into 1.05 right 100 5 now second year it will be 100 into 1.05 square third year it will be 100 into 1.05 cube and so on this is that load growth rate formula right that pm is equal to P 0 1 plus g to the power m right. Next actually take another example a another example a substation it supplies power to 4 feeders right feeder a has 6 consumers whose individual daily maximum demands are 70 kilowatt 90 kilowatt 20 kilowatt 50 kilowatt 10 kilowatt and 20 kilowatt right while maximum demand on the feeder is 200 kilowatt similarly for feeder B it supplies 4 consumers whose daily maximum demand are 60 kilowatt 40 kilowatt 70 kilowatt and 30 kilowatt, right while maximum demand on feeder B is 160 kilowatt.

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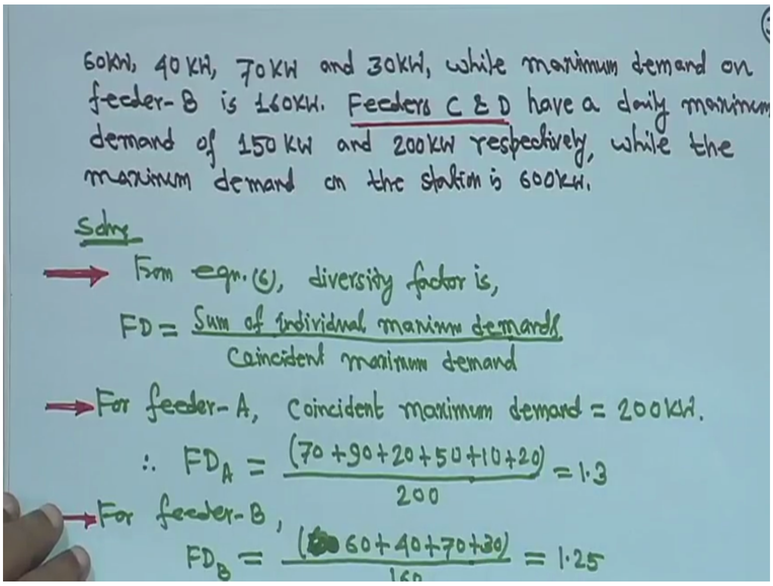

Feeder C and D have a daily maximum demand of 50 kilowatt and 200 kilowatt respectively while the maximum demand on the station is 600 kilowatt right. So, in this case you have to find out right dive diversity factor I did not write here that what you have to obtain you have to find out diversity factor for feeder A and feeder B.

So, from equation 6 diversity factor is FD is equal to sum of individual maximum demands divided by coincident maximum demand for feeder a coincident maximum demands is given 200 kilowatt it is given right and therefore sum up individual maximum demand. So, 6 are there 70 90 20 50 10 and 20 watt they are all kilowatts divided by coincident maximum demand 200 kilowatt. So, for feeder a diversity factor is 1.3 similarly for feeder B 4 consumers are there 60 plus 40 plus 70 plus 30 all are in kilowatt and their peak is 160.

Therefore diversity factor for this one is 1.25. So, next one is for feeder B then diversity factor of the 4 feeders FD is equal.

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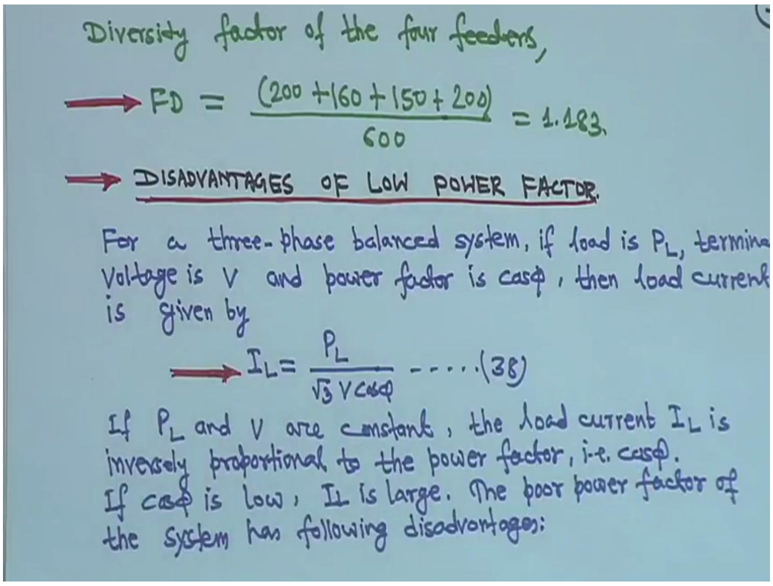

Then add 200 plus 160 plus 150 plus 200 divided by 60 it comes about 1.183 the diversity factor of the 4 feeders right feeder a feeder B and for the 4 feeders. So, for feeder B 1.25 and for the 4 feeders other 2 feeders data are given feeders C and D they were daily maximum 150 and 200, here we have made other 2 are 200 and 160 and maximum demand of the station is 600 kilowatt. So, diversity factor of the all 4 feeders will be 200 plus 160 plus 150 plus 200 that is 1.183.