Power System Analysis
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Lecture - 01
Structure of Power Systems and Few other Aspects- I

So, we will start this course as power system analysis. And So, power system is a core course power system analysis for particular for various places in the in India, that is the third year undergraduate electrical engineering course, it is a core course. And we will try to cover some of the important topics for this course.

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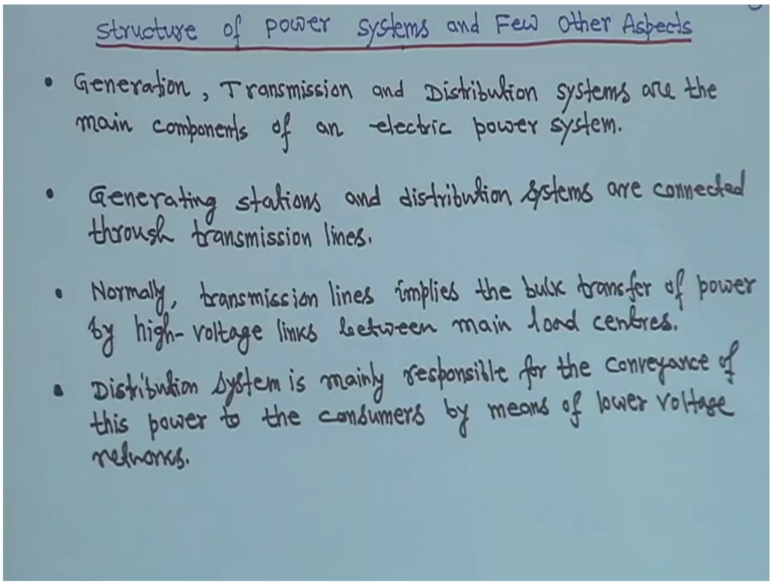

So, basically that your power system actually is the largest man made largest dynamic system on the earth, right. So, basically your first initially we will discuss about structure of power systems and few other aspects, right. So, first thing is generally there are 3 section we consider in power system generation, transmission and distributions system are the main components of an electric power system, right. So, generating station and distribution systems are connected through transmission lines, right. Normally transmission lines implies the bulk transfer of power by high voltage lines between main load centers. And distribution system is mainly responsible for the conveyance of this power to the consumers by means of lower voltage, so generation, then transmission, and then distribution. These are the 3 main components or these are main part of the power system, right.

So, next one is that if we look into that schematic diagram of power system, right.

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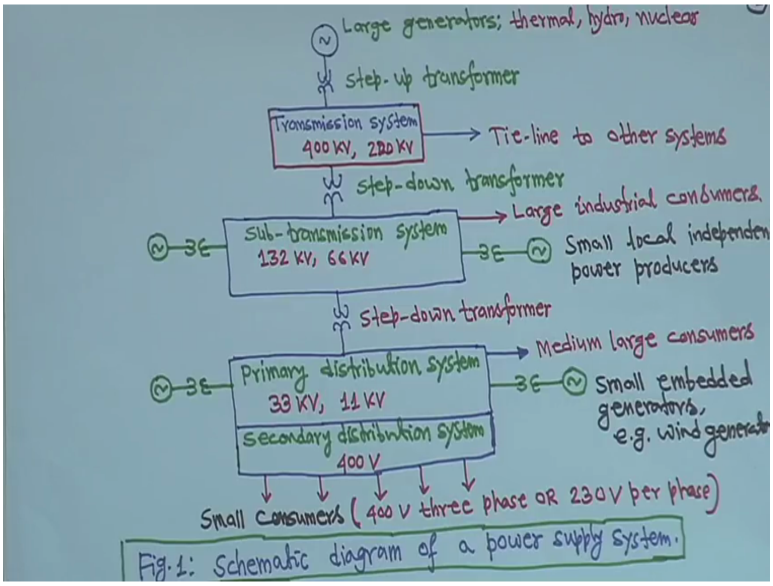

If we look into that schematic diagram of power system, so first one is a large generating station mainly they will be thermal, may be hydro or nuclear power station, right. Then we have a step up transformer. Generally generate terminal voltage in power system say it depends of course, on the rating of the machine and power generating capacity of the generator. But, generally it will be 10.8 kV or 11 kV or little bit more also, 11.2 depends on the design of the generator of this power you know, in the thermal power plant hydro power plant or nuclear power plant.

Then after this step up step up transformer is there then voltage will be stepped there is a transmission system is coming. It will be 400 kV or 220 kv, right. When it is stepped up after that this tie line to other system is, tie line means it is basically 3 phase transmission line and showing just by single line arrow that thing because, transmission system is a balance power system, balance your it is 3 phase by a all the 3 phase carrying that balance power. So, just showing like this by a single line that tie line into other system, right. Other system, means other power system it maybe power maybe it is connected to other power system, right. Or it is connected to or that gone to another substations somewhere, right. Then you have a step down transformer; that means, voltage will be stepped down to 132 kV or 66 kV this portion we call sub transmission system, right.

So, and after that they showing here the large industrial consumers, there are many industrial consumers large industrial consumers, they need power supply at the voltage level 132 kV or 66 kV. That is why it is shown like schematically it is shown like this. After that and here also small local independent power producers. Maybe private parties are there who were also generating power. Their power, this they are generating their generating unit this side same thing, right. And here also you have a this transformer a step up transformer generate site to this site, right. And voltage will be either stepped up to 66 or 132 kV. And they are also injecting power to stop transmission system. These are the local independent power producers we assume the private parties, right.

Then from 132 or 66 kV it will further step down, right. And then primary distribution system it will come. So, primary distribution system means it will be 33 kV or 11 kV, right. Here also medium large consumers there may be some small industries or medium large consumers, who need power at the voltage level of 33 or 11 kV. So, that thing also connected So shown like this. And here also at this voltage level 11 kV or 33 kV they have small embedded generator for example, wind generators, right. Suppose this wind power it may be, it may be utilities or it may be private parties also, right. And this owned by this generator, right. They own generator we say, right. We know solar also other distributing generating unit also no problem. In the case of solar you have convert your what you call form dc to ac, right. But, anyway as like shown ac power will be injected.

So, just to for that time you assume that is wind generator only, right. And here also this is a step up transformer and power been injected. This same meaning this side also small embedded generators both sides on, right. And then these are secondary distribution system the voltage there is a 400 volt you might have seen, that 4 mounted distribution transformer maybe near your collage, near your home, right. So, those transformer generally 11 kV by 400 volt, maybe 4 33 volt, right. So, these are small consumers that 400 volt 3 phase or 230 per phase, right. So, in this case if it is they line to line voltage then it will be 400 volt or 430 volt and if it is your single phase then line to neutral, then it will be 400, if it is 400 by root 3 or if it is 430, then 430 by root 3, right.

So, what about is comes. So, I just written 230 volt per phase, right. So, this is a schematic diagram of you know as a hole as a power system, right. So, that will this is this just for you know, how the power system is I mean from generating station to the distribution system between transmission and sub transmission systems are there. Particularly 132 or 66 kV or transmission line we are calling it as a sub transmission system, right. Then take this part of a power system.

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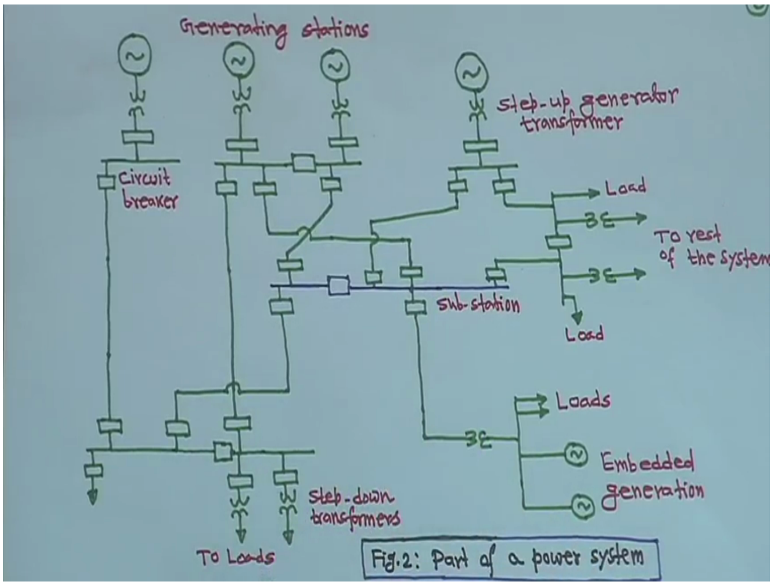

Fig. 2: Part of a power system

So, if you take like these are all small rectangular boxes are. So, on this are basically circuit breakers, right. And suppose you have a generating stations this is generating stations.

So, if we are have a this all transformers are step up transformer general transformers, right. This is I have drawn just to show that there is a part of a power system. Then it is all are coming to sub stations, right. This lines are coming here and there to sub stations. And again here it is all this it is going to the loads, this is step down transformer again. This is also same thing keep a loads and these are all load, these are all showing load, and here also it maybe going to the other part of the system. So, to rest of the system, and these are embedded generators, right.

For example, wind power generator. So, this is a simple structure of the part of the power system, right. And it may be basically this the simplest way, but in a in a power network you have so many generators and. So, many transmission lines, right. And those we will see how to you know how to solve all this things when will come to the; you are what you call that power flow studies, right.

So, these are the schismatic diagram of a this thing part of a power system. Next one is that from shaft transmission system, this is typical distribution system, right.

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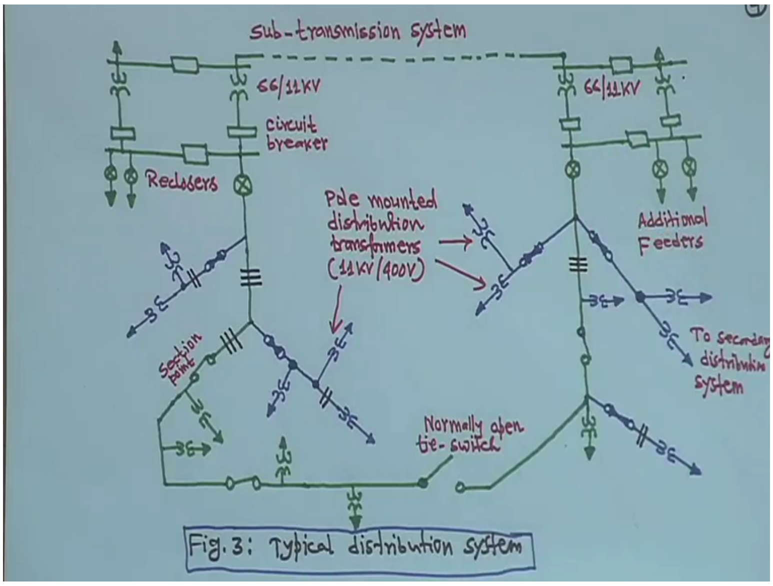

If you staying anything or in 3 h having this lines I am made this 3 phase line. And when 2 such light things are there that is single phase, right. Because sometimes you need 3 phase particularly for the commercial phases you need 3 phase power supply, but residential in a residential areas say what home you need 2 single phase power supply. These are fuses, right. And for example, this is 66 by 11 kV this things these are all boxes from circuit breakers. These are reclosers reclosers it is going to additional feeders, right. And this all transformer these are pole mounted distribution transformer they are 11 I have written 11 kV by 400 volt or it may be 11 kV by 430 or 440 volt also, right.

These are all pole mounted distribution transformer. And these are section point, these are section point it may close maybe this thing may be opened, right. And another thing is that this is your normally open tie switch, right. So, this is a, this a tie switch means this a your 3 phase basically a 3 phase line, but one sectionalize will be there, right. If you I mean if you want to operate manually, right. Nowadays, your, it may it you know it sophisticated your control technique it can be automatically switched on or off, but why this is normally open? As per as when power is being supplied by the both side and there is no fault or no out age of the line then things are ok.

But suppose, suppose something as happened some fault has occurred here for example, say, right. Or some fault has occurred here, then what comes and do is that, this line can be isolated. This can be isolated, and this should be closed such that power can come from through this and it can supply it can supply they affected your affected zone. But as soon as you open this, this portion on affected because power will come from this, but when something has happened here, this portion will not get power. So, suppose this is open and you close this one. So, power will come from this side, right. So, that is why it is called normally open tie switches. And this is something is written to secondary distribution system, right.

So, these are all pole mounted your transformer. And here it is showing 66 by 11 kv, but many parts or hill area it may not be 11 kV some cases it has low voltage level may be 6.6 kv, some cases even 3.3 kv, right, but standard in this thing 11 kV most of the places you can see, right. And these are the schematic diagram or typical distribution system, right. So, what we have discussed now little bit about power station or power system generating sites, then transmission and then distribution lines, right.

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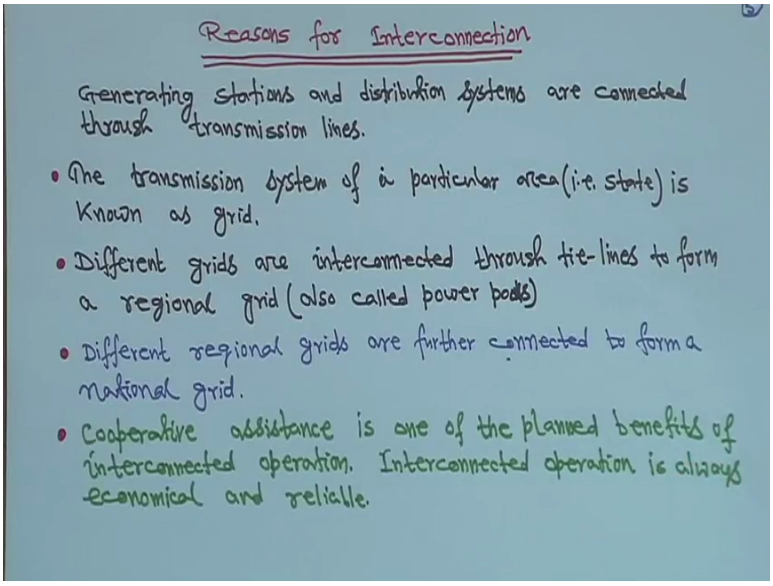

Next is that, next is the reasons for interconnection, right. Because many power system they are interconnected together. So, generating station and distribution system are connected through transmission lines.

It has to be because bulk power will transfer through transmission line only. That transmission system of a particular area say state is known as a grid, right. And this way this way you can define you can define anyone can define in other way also, but generally the transmission have particular area. Say it a reason is suppose for example, state is known as a grid now different grids are inter connected through tie lines tie line means it is a 3 phase transmission line, right. To form a regional grid so also called power pools, right. This is actually power pools, right. So, different grids so in there will be inter connected through tie lines; that means, 3 phase line that it will form a regional grid also and this is also called power pools, right. And different regional grids are further connected to form a national grid.

So, transmission system particularly is knows as a grids. And different grids are interconnected to 3 phase lines that is tie lines; that means, they tie together suppose, 2 grids are interconnected by you know, so through tie lines, right. To form a regional grid and different regional grids are further connected to from a national grid, right. So, these are the these are the meaning of this you know, your what you call that grid regional grid and national grid. So, next is that reason for interconnection. Now cooperative assistance is one of the planned benefit is of interconnected operation, because when 3 pool power systems are interconnected together.

So, basically this is for cooperative assistance, right. Interconnected operation is always economical and reliable, right. More we will see later, right, when we will come to the different topic, so it is always economical and very much reliable, right.

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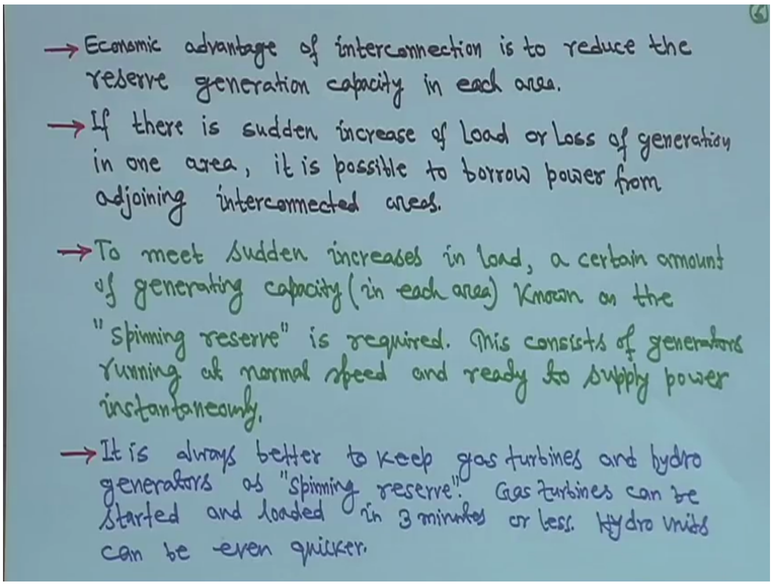

For this thing, economic advantage of interconnection is to reduce the reserve generation capacity in each area. Details to at this moment it is the just I am giving that your basic thing when we will come to a different topic more thing can we discussed, right later, right. But economic advantage of interconnection to reduce the reserve generation capacity in each area I mean each area means it is part a power supply system, right. So, when so many power systems are interconnected. So, in that case reserve generation capacity in each area it can be reduced, latter I will try to explain, right.

If there is sudden increase of load or loss generation in one area, it is possible to borrow power from adjoining interconnected areas, right. It is something like this for example, suppose you have, suppose you have this is one power system say area 1.

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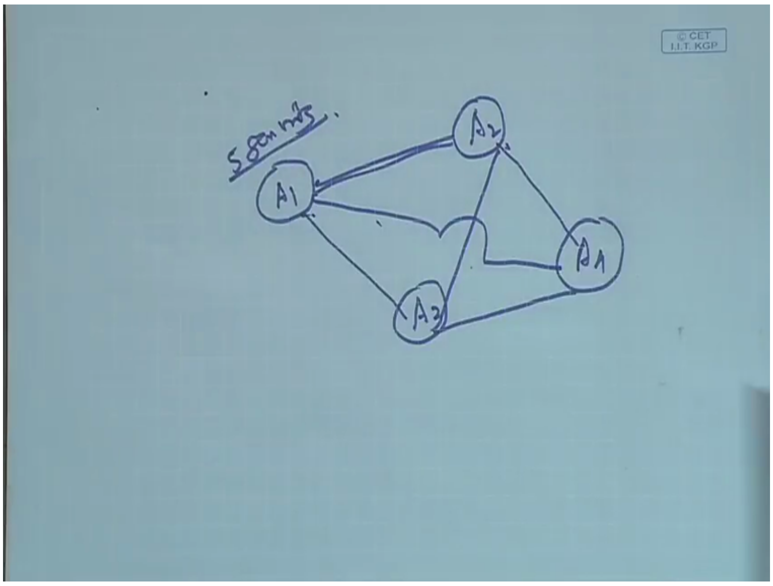

Suppose it is connected to another one area 2, suppose it is connected to another one area 3, right. Suppose another one is there, right. Say area 4 it is also connected, it is also connected, say this one also connected, right. So, suppose 4 areas are there. 4 different thing, but they are all connected, they are all interconnected.

So, if suppose every are, every are, every are it is power system it is a here it is area 1 area 2 area 3 area 4. Each one is a power system everyone is having a power demand, every generating unit is generating power to supply it is load, right. Here also here also suppose sometimes it may happen, that your this area it needs power from the other areas. Because, here load demand is more, but it is generating capacity is less. So, at that time this particular area can borrow or purchase power from this 3 areas, if it is interconnected, right; that means, that means, although load is more generacy is less; that means, it is reserve capacity is less, but it can assuming that this power system they have the sufficient reserve capacity, then it can borrow power from other interconnected, other interconnected power system.

So, this is that that is your that is the advantage; that means, economics advantage of interconnection is to reduce the reserve generation capacity in each area. Now if there is a sudden increase in load or loss of generation in one area, it is possible to borrow power from adjoining interconnected area; that means, suppose load has increased, I told you that it can borrow power from this or from this power from this 3 power systems. Or suppose you have suppose you have for example, here you have 5 generating unit is say 5 generating unit is, right. Suppose one of the generating unit is right, you what you call suddenly stopped I mean loss of generation. So, 4 units are there. So, load generation will be much less load will be more, right. So, in that case from these adjoining areas interconnected power supply systems that this additional load can be supplied from this power system. So, if they are assuming they have the sufficient generating capacity right, such that they can supply that this additional load.

So, that is why that if there is certain increase of load or loss of generation in one area it is possible to borrow power from adjoining interconnected areas. So, these are the major advantage of interconnected operation, right. Now to meet sudden increase in load a certain amount of generating capacity in each area known as the spinning reserve is required, right. I mean load suddenly increases and initially we want to and immediately we want to supply this additional load, right. And; that means, a certain amount of generating capacity in each area known as the spinning reserve is required. This consist of generators running at normal speed and ready to supply power instantaneously; that means, I mean they should, I mean as soon as the load has increase right, that this generators they means spinning reserve means this required this consist of generator running at normal speed and ready to supply power instantaneously.

For example, it is always better to keep gas turbine and hydro generators as spinning reserve. The reason is gas turbines can be started and loaded in just 3 minutes or less. Because, it is very it can generate power every quickly, gas turbine or hydro unit is can be even quicker, right. So, this gas turbines and hydrogen is this 2 generating, your what you call a power generating unit is they will be very useful as a spinning reserve. Suppose you load has suddenly increase suddenly increase, but as you do not have sufficient this thing, your what you call sufficient capacity to this thing, that you have to immediately supply that load. So, in that case your gas turbine or hydro unit is will be very, very effective because they can generate power very quickly, right.

Thermal power plant there will be the thermal unit it has some limitation. Later if possible I will tell you thermal hydro generate power generate very quickly does not have any I mean that constant is not string in type or has high hydro case for thermal case that is constant is very (Refer Time: 19:26) type sorry, but hydro case it is it can generate power very quickly, right. So, that is why gas turbines or hydro turbines hydro generating unit is they should be you know, they should be kept as spinning reserve. Next is, so these are general ideas that some advantages of interconnected power system, right. Next is that load characteristics.

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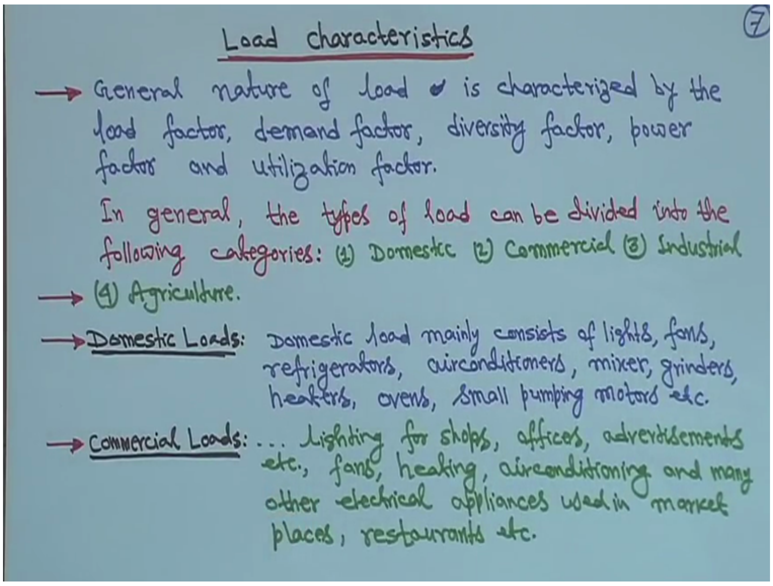

So, general nature of load is characterized by load factor, then demand factor, then diversity factor, power factor and utilization factor. There are some more factors later you will see. In general, the types of load can be divided into following categories. There are 4 categories. Domestic, commercial, industrial and agriculture, right.

So, domestic loads this you will be knowing what is domestic load. Domestic load mainly consists of lights, fans, refrigerators, air conditioners, mixer, grinders, heaters, ovens, small pumping motors etc. These are domestic loads, right. Similarly, commercial loads basically lighting for shops, then offices, then advertisements etc. Fans, heating, then air conditioning, again and many other electrical appliances used in market places restaurant etc. So, domestic load then commercial loads, right. So, so generally so loads of and different loads domestic, commercial, industrial, agricultural they have different type of you know characteristic. So, next is this thing that industrial loads.

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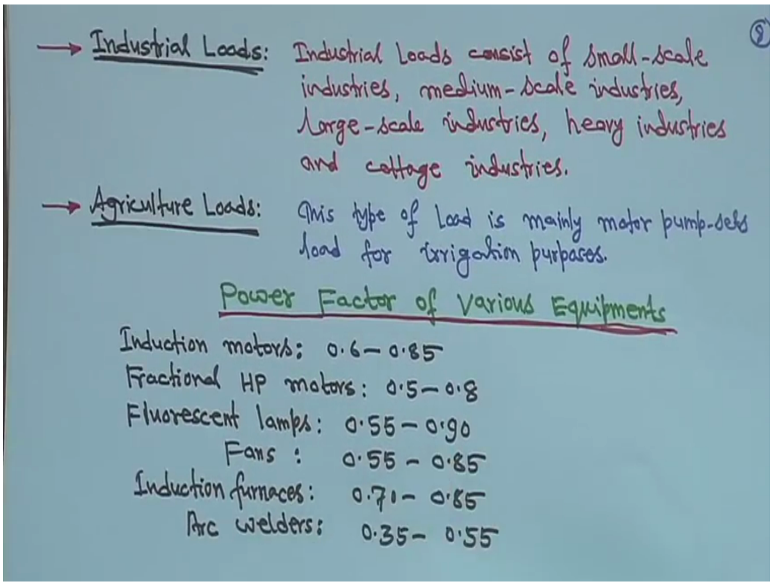

So, industrial loads that the time of talking about this power system I think I told you, that industrial basically it takes power at very high voltage level, particularly large industries.

So, industrial loads consists of small scale industries, medium scale industries, large scale industries, heavy industries and cottage industries. These are, these are following under industrial loads, right. There load curve will be different commercial will be different, right. Then domestic will be different may if the agricultural load basically is a mainly motor pump sets, right. For this integration purposes say agricultural loads. So, there are 4 different type of loads. Now after this, that power factor of various equipments, right.

For example induction motors. Generally 0.6 to 0.85 then fractional horse power motors 0.5 to 0.8, then fluorescent lamps, 0.55 to 0.90, then fans, 0.55 to 0.85. As you see that some data inductant induction furnaces 0.7 to 0.85. And then arc welders 0.35 to 0.5 these are the range of power factors for you know, various your equipments, electrical equipments. Some ideas regarding the power factor of the you know, some your equipments, right.

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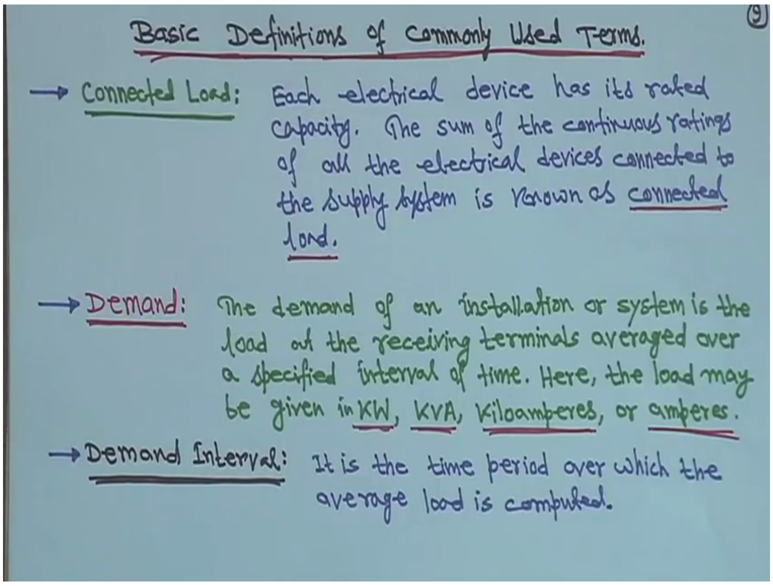

Next is basic definitions of commonly used terms, right. So, first is we talk about that connected load. This are common sense you can apply that what will be the connected load. So, each electrical device has it is rated capacity. Every, every device electrical equipments or component you know it has it own rated capacity. The some of the continuous ratings of all the electrical devices, connected to the supply system is known as connected load. For example, you take the example of your home, right. You know light fans AC and other thing geezer another things, right. So, if you add their total rated capacity then that will be the connected load of your home, right. So, these are the commonly known as a connected load, right.

Then demand the demand of an installation or system, right. Is the load at the receiving terminals, right. Averaged over a specified internal of time. I mean demand of an installation of system is the load at the receiving terminals averaged over a specified internal of time. That means you have some time definition and take the load at every hour and half an hour what say hour. After that you make the take average of it over a given interval of time, right. Here the load may be given in kilowatt may be kilovolt or kva or kiloamperes or amperes the way you define, but generally in power system mostly we will define kilowatt or kva, right.

Then demand interval it is the time period over which the average load is computed. Suppose, suppose for a day you have a 24 hours. So, every hour every hour load you know then if you try to compute the average load for 24 hours, right. So, that it is the time 4 per hours is the demand interval, if you that is mean the time period over is the average load is computed. We will take an we will many examples at the time you will see, right. So, so connected load demand interval.

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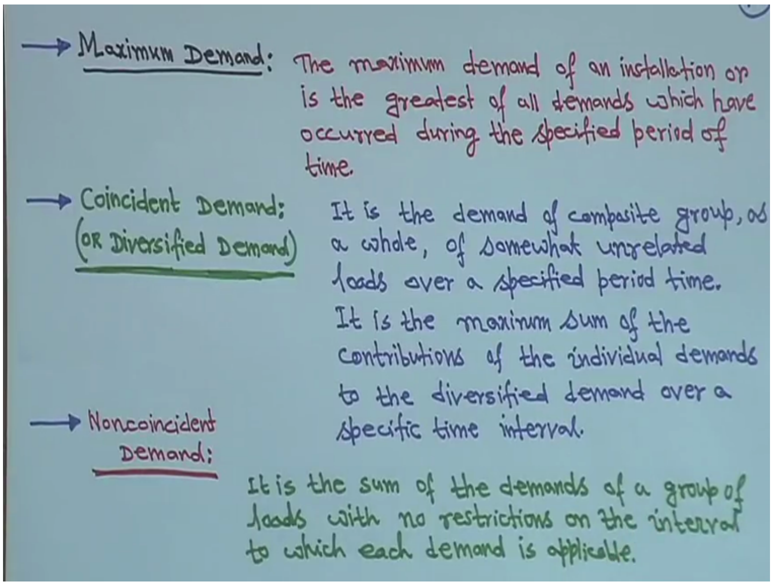

Next is maximum demand. This maximum demand of an installation or is the greatest of all demands which have occurred during the specified period of time. So, specified period of time specified time is appeared is specified, and then maximum demand of an installation is that greatest of the demands which have occurred during that specified period of time.

Suppose you have a, you have a say you take from your today this thing from mid night to next mid night. So, 24, 24 hours during 24 hours you see that for a particular installation of system demand is increasing and decreasing. So, this 24 hours you take note down what is the maximum demand. So, that is why during the specified period of time that will be the maximum demand, right. Then another thing is another terminology they use that coincident demand or diversified demand, right. It is the demand of the composite group as a whole, right. Of somewhat unrelated loads over a specified period of time, right.

So, you have a different composite group not only on the single load there may be many, right. And some industrial commercial agriculture domestic say different group you have, right. over a specified period or that it is the demand of composite group as a whole, as whole of somewhat unrelated loads over a specified period of time. It is the maximum sum of the contributions of the individual demands to the diversified demand over a specific time interval. So, everywhere has time interval is specified, right. So, it is it is the maximum sum of the contribution of the individual demands, right. To the diversified demand over a specific time.

That every hour, Suppose you have a 4 groups of load, every hour you are adding those load and trying to find out what is the maximum sum, right. Of the individual demand to the diversified demand over a specific time interval, right. So, this is called coincident demand. Then noncoincident demand, it is the sum of the demands of a group of loads with no restrictions on the interval to which is demand is applicable. So, in that case d or what you call that your into interval is not no restrictions of the interval. So, it is just sum of the demands of a group of a loads with no restrictions on the interval to which the demand is applicable, right. This is called sometimes noncoincident demand, right.

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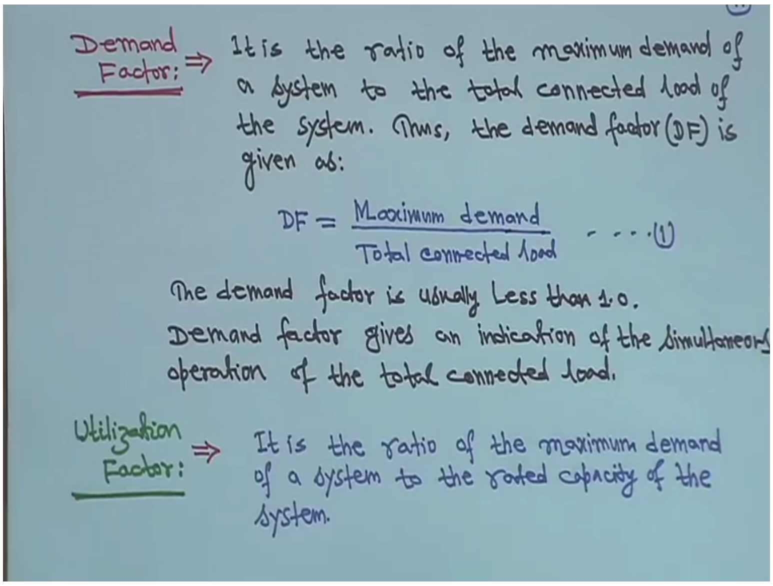

Next is another one is demand factor. It is the ratio of the maximum demand of a system to the total connected load of the system. Thus, the demand factor is defined DF is given as. So, it is the ratio of the maximum demand of the system to the total connected load. So, demand factor can be given as maximum demand divided by total connected load. So, this is say equation 1, right. The demand factor is usually, less than 1 because generally if maximum demand is equal to total connected load then it will be your what you call only one otherwise generally maximum demand is because at a home you have all light fan switches everything, light fan TV refrigerator geezer, everything is there all your not switching on switching on at one time. So, naturally maximum load is less than the total connected load, usually less than one, right. So, demand factor gives an indication of the simultaneous operation of the total connected load, right.

Next is utilization factor, utilization factor. So, it is the ratio of the maximum of a system to the rated capacity of the system, right. So, later this is we define, that is the ratio of the maximum demand of a system to the rated capacity of the system.

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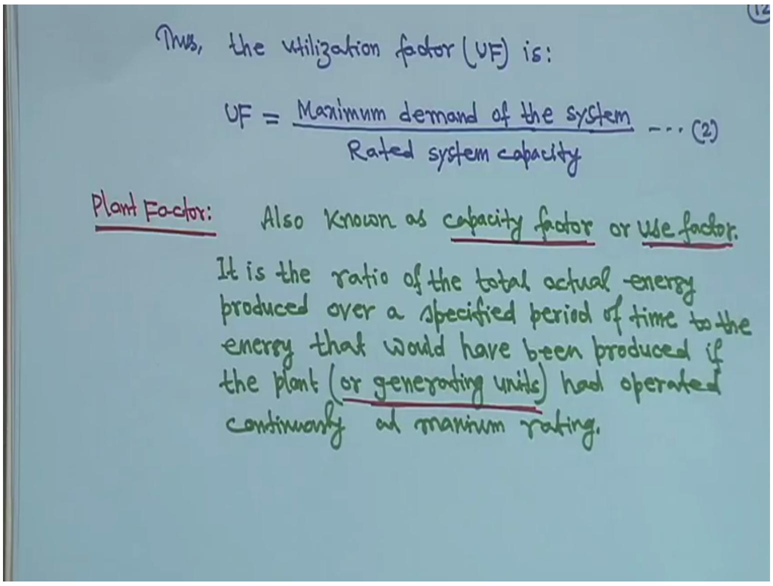

So, utilization factor you define UF is can be given as, maximum demand of the system divided by rated system capacity, right. So, this is equation 2, and next one is plant factor. Sometimes this plant factor also known as capacity factor or use factor. It is the ratio of the total actual energy produce over a specified period of time to the energy that would have been produced if the plant or generating unit is had operated continuously at maximum rating, right. So, this is known as plant factor.

Capacity factor or use factor this is particular for the generating station this terminologies 2, right. So, it is the ratio of the total actual energy produced over a specified period of time say annual to the your say, annually how much energy that that was produced to the energy that would have been produced if the plant or generating unit is had operated continuously at maximum rating. So, this is called plant utilization sorry, plant factor or capacity factor or use factor.