Power System Analysis
Prof. A. K. Sinha
Department of Electronic & Electrical Communication Engineering
Indian Institute of Technology, Kharagpur

Lecture - 1
Introduction

Welcome to the lesson 1 in Power System Analysis. In this lesson we will basically introduce what power system is… And we will talk a little about what we are going to do in this course.

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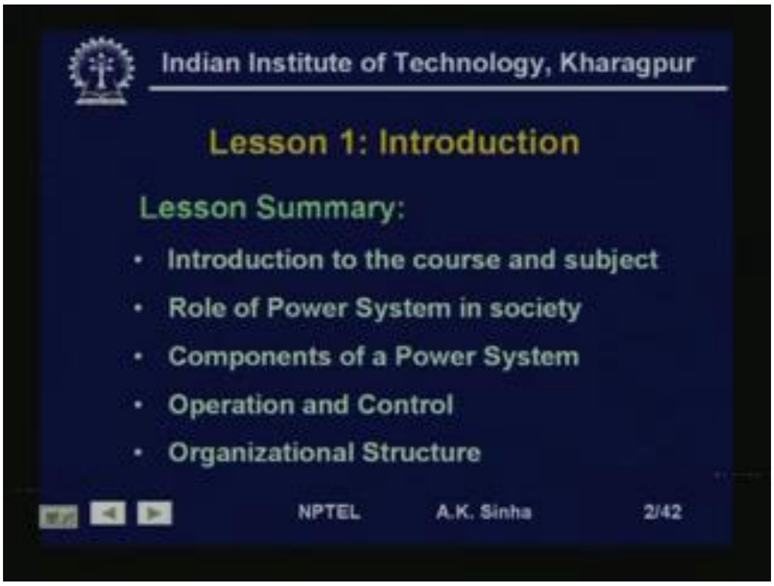

Well, we will start with an Introduction to the course and the subject. Then we will deal a little bit with the role of the power system. That is we will start with what a power system is, what is it is role in the society. Then, we will talk a little about the components of a power system. And we will discuss some aspects of operation and control of the power system. And finally, we will discuss a little bit about the organizational structure of the power system.

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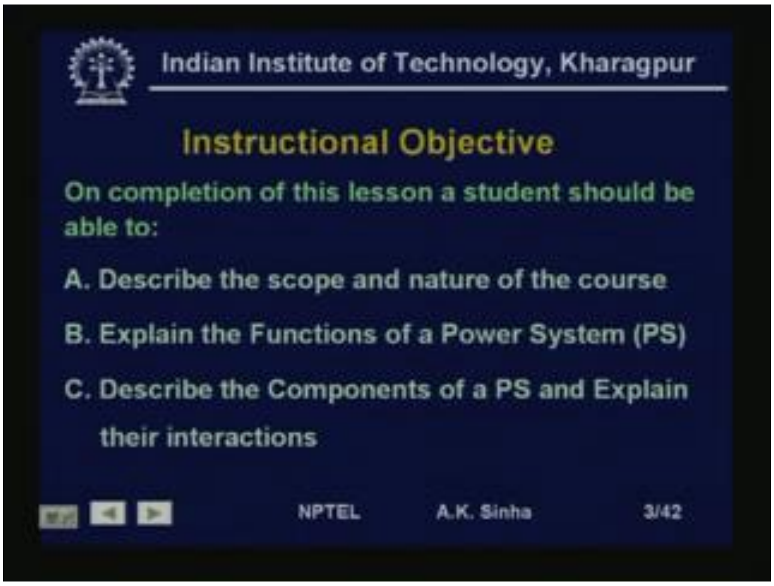

Well, the whole idea is that once this lesson is over, you should be able to describe the scope and nature of this course. That is what we are going to do in this course. You should be able to explain the functions of a power system. What a power system does and why it is used. Then, this you will be able to describe the components of a power system and explain their interaction. That is what are the basic components, which build this power system. And how do they interact with each other.

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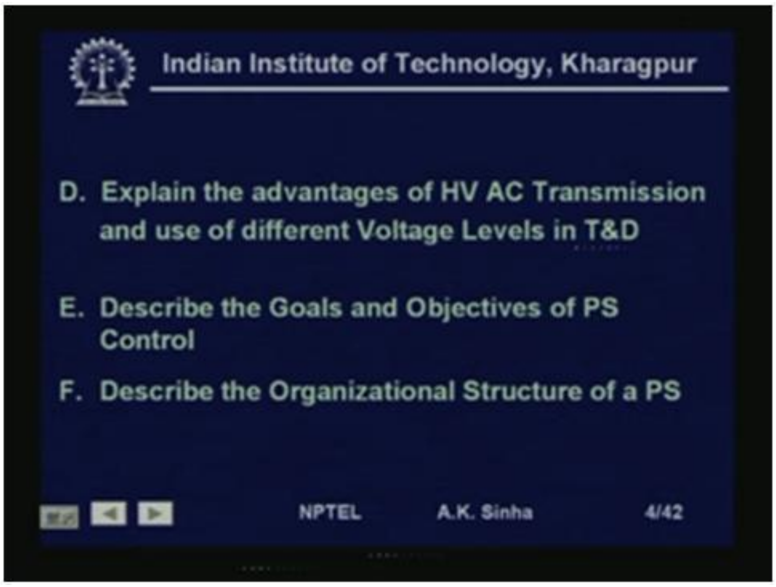

We will also talk about or you should be able to talk about the advantages of high voltage AC transmission. And the use of various voltage levels in transmission and distribution. You should be able to describe the goals and objective of power system control. Why we need this control, what is the basic objective, what we want to do with it. And some aspects of the organizational structure of a power system also you should be able to describe.

Specially with the new structures that are coming in. That is the old what we used to call vertically integrated system structure. Is now giving way to the deregulated structure, where most of the components of power system are unbundled. So, we will talk a little about that.

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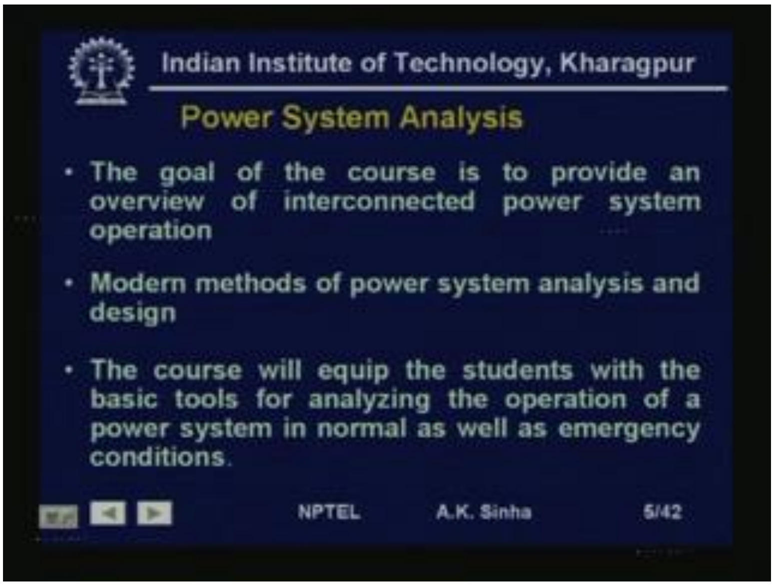

Well, to start with the what we are going to do in this course. The basic aim of the course is to provide an overview of the interconnected power system operation. That is what this power system does, how it operates and what it is going to achieve or what it is giving to the society. Then, we will also discuss some aspects of the modern methods of power system analysis and design.

That is what we would do in this course is, we will discuss how we can analyze the operation of the system. And try to design the system to work in a better manner. After completing this course. You will be equipped with the basic tools for analyzing the operation of a power system in normal, as well as emergency condition. That is you would be able to analyze the operation of a system. Both under normal conditions as well as underwent emergency conditions.

That is when faults occurs in the system and the system behavior is pretty stressed. So, we will talk about some of those things. And you should be able to analyze the system under all operating conditions.

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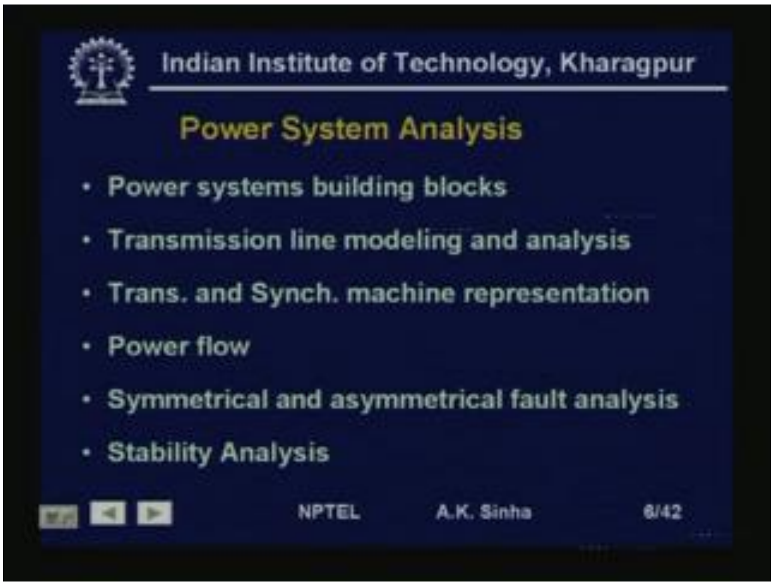

To start with in this course we will start with the power system building blocks. That is what we are going to do in this first lesson. Today, that is what are the basic building blocks of a power system? And among those blocks if we want to analyze the system, we will have to see how they interact. And we will also need to model these blocks. So that, that is we need to get mathematical models for these blocks. So, that we can analyze the system.

So, starting with the transmission line, modeling and analysis. Then we will go into transformer and synchronize machine representation, that is again the mathematical models for the transformers and synchronize machines. After we have got these models we will try to do the steady state operation. That is the normal system operation of a power system in steady state. We will be done by means of power flows.

So, we will talk about what is power flow and how we perform this power flow analysis. Under faulted condition, how do we analyze the system this we will discuss in symmetrical and asymmetrical fault analysis. And finally, under faulted conditions or under emergency, how the system behaves in a dynamic manner. That is whether the system is going to remain in synchronism, or will go out of step. All those aspects we will discuss in stability analysis of power system. So, this is basically what we are going to do in this course. We will start first with what a power system is. That is we will try to provide an overview of the power system in this lesson.

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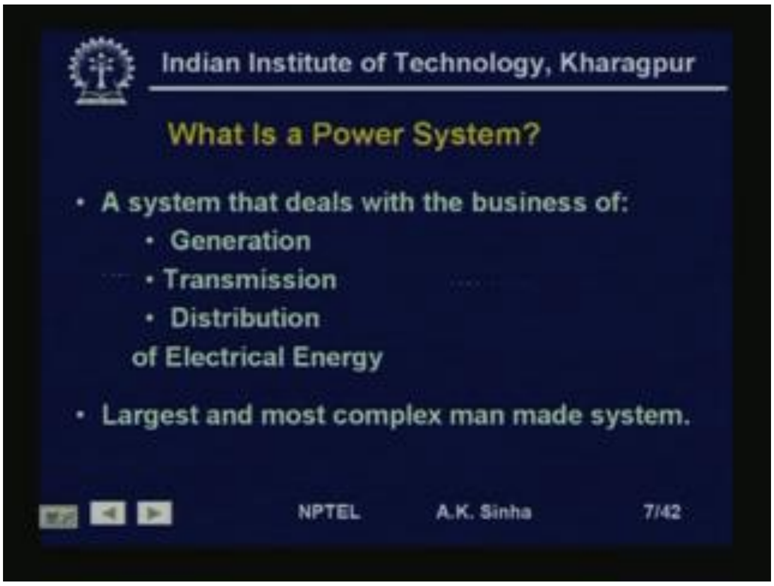

So, what is a power system? Well, a very broad definition of a power system can be given as a system. That deals with business of generation, transmission, distribution of electrical energy is a power system. That is a business which deals with all the three aspects. Generation, transmission and distribution of electrical energy up to the consumers consist of a power system. That is these makeup the power system.

Arguably the power system is the most complex and largest manmade system. In fact, if we see power systems are, there all over the continents. In the most of the continents and many continents also they have been interconnected. So, we have very large system, which is working almost all over the globe. So, it is of the huge network and a very complex network, because it has large number of interconnections with different systems.

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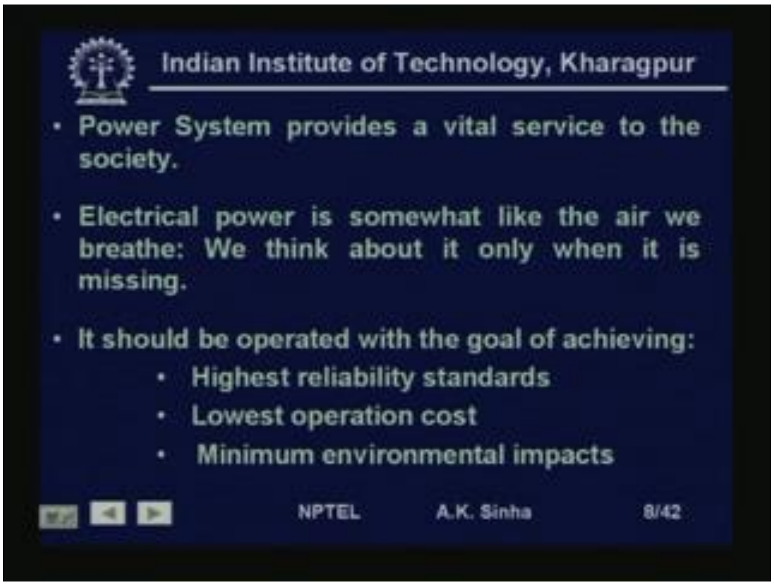

Well, what does a power system do? It provides a very vitals service to the society, we all know how critical electrical energy is. We can think of it as the life of any industrial system that is, it is like something like air for us. It is same for any industrial or modern society. We in fact, do not think about this until, unless we it is absent. That is we think about it only when it is not there.

Whenever there is power cut, then only we think about it. We are so use to it that, we always expect that we switch on something the power should come and the device should operate. We need to see how this happens in a power system. How power system is able to provide you this power, whenever you switch on instantaneously. Of course, in certain areas this kind of reliability is not there. And we will have to think about how to improve those reliability.

Since we know that, power system is of vital importance to the society. Therefore, when we are trying to operate the system, the goal should be to achieve the highest reliability standards. That is we would like to have no power cuts at all. Whenever we want to switch on a device, we should get the power the device should work properly. Again since it involves huge amount of investment, the another goal of operating this would be to achieve lowest operation cost or the highest efficiency of the system.

So, that we can cut down the cost of production and thereby the tariff that we pay for this power. Another major aspects, since it is huge system it involves huge amount of energy conversion. Therefore, environmental aspects are also very, very important. We have to think in terms of global warming, in terms of deforestation. All these aspects have to be looked into, when we are building newer generating plans. Or putting new transmission lines, all these things need to be taken care of. So, that we develop a system which is not only reliable, most economical and also environment friendly as well.

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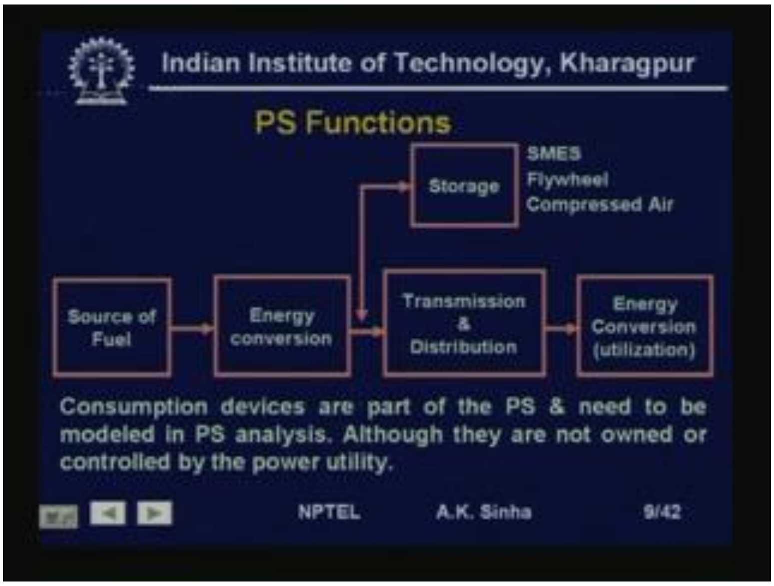

Well, what a power system consists of starting with the source of fuel. It can be different kinds of fuel that we have, it can be either the potential energy of water. Or it can be mechanical energy stored in coal or oil. It can be the solar energy, it can be various kinds of sources of energy that we have. So, first we have source of fuel. This is sent to an energy conversion device from where it gets converted into electrical energy. Once it gets converted into electrical energy.

It is transmitted and distributed by means of wires, that is transmission lines and distribution lines. And goes up to the energy conversion devices, which are at the consumer premises. You want to switch on a bulb to get light. So, the power comes from some source of fuel, that is used in a power plant. Which is converted into electrical energy, then transmitted by means of transmission lines up to your house.

Where you plug in your device, which may be a bulb. And when you switch on it provides you light. In between sometimes we use some storage devices. Though power system being such a huge system. And the amount of energy, that we are dealing with is very, very large, the storage is almost minimum. We though there have been various methods of trying to store large amount of energy. But, again as a percentage this is almost negligible.

Some of the storage devices that I used for large energy storage, can be there is super conducting magnetic energy storage. That is we have a very large super conducting. Coil in which we can store this energy as a magnetic energy. And when we needed, we can draw it from that coil. So, this is a one of the device which has been used in a couple of places, but this is again very expensive.

Another method which is being tried as flywheels, very huge flywheels which can store it as energy in it is inertia. And that kinetic energy can be converted into a electrical energy later, when it is needed. So, that is another way of trying to store it. Compressed air of course, you can use large storage spaces, in which you can compress air to very high pressure. And when you need these can be used to run engines or turbines. And again generate electric energy. Still these devices are very small as compare to the kind of energy, that we are talking about.

And therefore, they are not highly insignificant, in terms of power system operations. So, this part is moral as very very small, though lot of effort and research is going on in this areas, because this is extremely important for proper operation of power system. We also known of some the storage elements in most of the houses, specially in cities another places.

We use inverters and we use what we call UPS, most of computes systems that use. We are using UPS on un-interrupted power supply. Where, we are doing as basically using this electrical energy to choice the battery. And when there is a power cut or something the battery provides us the electrical energy. Needed by means of this DC power in the battery is converted by means of inverter, and is supplied to the device.

So, this is the way it is done of course, consumption devices are part of the system. That is devices which are at consumers premises or in industries, they are part of the system. And if we want to analyze the systems properly, we need to model them. Though we that is the power system, as such are utilities which generate, distribute and transmit power. They do not have any control on this. That is they are not part of the utility, but then need to be modeled. That is loads need to be model, when we are analyzing the power system.

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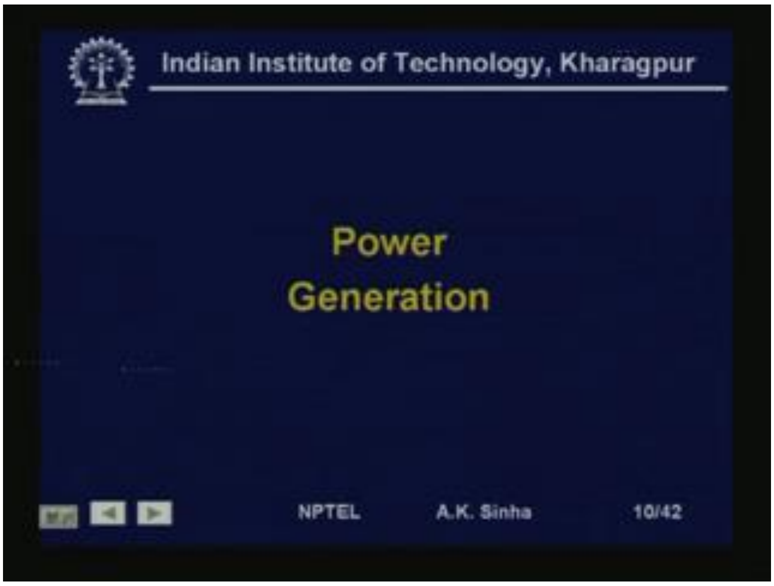

So, we will start first with the generation aspect of power. Then we will go into transmission, distribution, then a little bit an operation control and finally on the structure of the power system.

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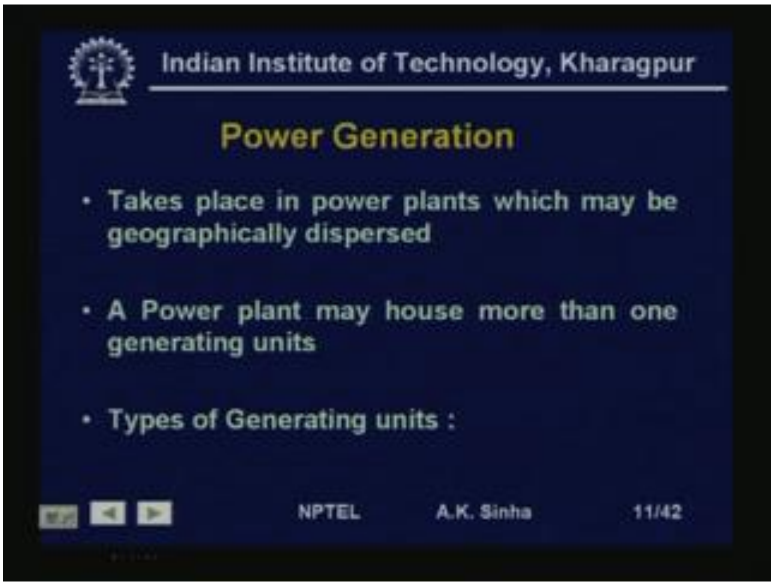

Now, power generation, we all know or many of you must have seen and a power stations and some place. Now, these power plants are geographically disposed. They are generally build either near the load center. That is near the big cities, where huge amoun of load is there. Or they are built at places, where you have the energy source that is the fuel available. Most of the very large once which we call super thermal power plants.

All these are generally build very near to the mines. Because, then we do not need to carry the coal up to the load center. So, instead of carrying the coal, we transmit the electrical energy. By means the transmission lines and distribution lines. So, power plants are geographically disposed a power plant, may house more than one generating unit. Most of the power plants have more than one generating units. That is super thermal power plant, which are generally 1000 mega watt or more capacity. They may have 4, 5 units in one plant. So, there are different number of units in different plants. Now, how do we classify the power generation generating plants. Well, most of the time being classify them based on the energy source, which is use for as a fuel.

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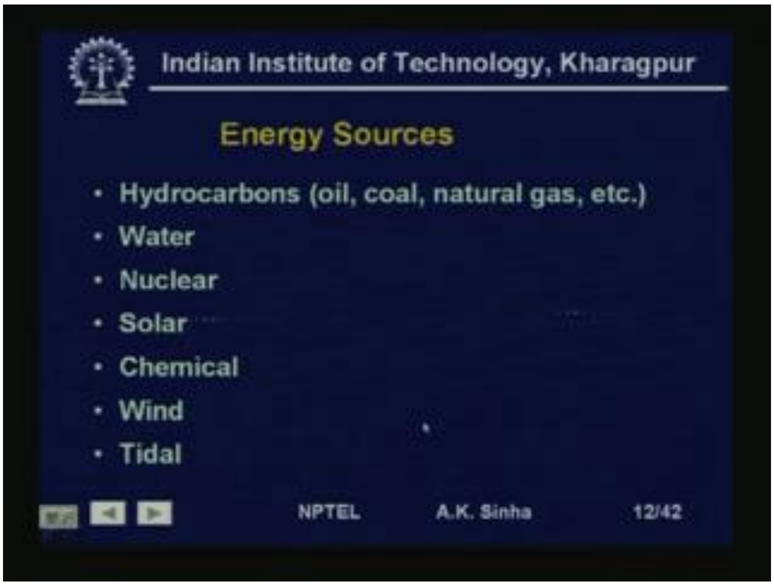

So, here if we see based on the energy sources, if we are using hydrocarbons. That is oil, coal, natural gas, etcetera. Then, oil and coal plants are generally called the thermal power plants. Because, oil and coal is used that is the thermal energy is burnt in a boiler. And this heat of this as used to makes steams which is use to run steam turbines. Similarly, natural gas is used to be burnt in gas turbines and produce electrical energy.

So, we have gas turbine units or even water is being used, we have hydropower stations. Where the we have built dams to store large amount of water, which can be used for generating power. That is the potential energy of water is converted into kinetic energy by the turbines. And which is used to run the generators. So, we have hydropower stations. Similarly, nuclear energy the vision of uranium is used in most of the places, for producing nuclear energy.

And once this nuclear energy is available, it is available in the form of heat. And rest of the process after this reactor from where this energy is taken away, by means of heat exchanger. The rest of the process is very similar to that of the thermal power plants. That is again you for a stem and stem is used in stem turbans to run the generators. Chemical energy we have all been using this in batteries and other sources. We also use this chemical energy in fuel cells, and other kinds of devices.

Solar energy, we all know we have seen the photo voltaic cells. Solar thermal energy is also sometimes used for generation of power. So, we have solar thermal power plants, or photovoltaic areas to generate power. Wind and tidal energy are other kinds of energy which are also been used. Solar, wind and tidal are generally termed as non-renewable energy sources.

So, solar energy, wind energy and tidal energy. Wind energy of course, has become a very, very important aspect in these days. And you might have seen many wind generators in coastal areas, where we are using. So, India is using quite substantial amount of it is energy from wind, we will see all these things as we go on. Tidal energy, that is the ocean tide is used for generating energy.

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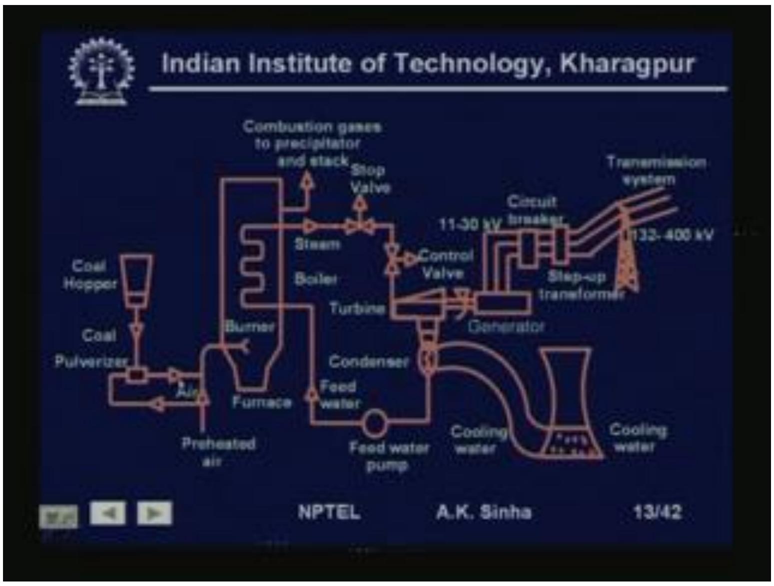

Here, I just give a brief description of how electrical energy is generated, in a thermal power plant. So, this is of a coal burning power plan. So, coal is brought into coal hoppers and it is pulverized in a ball mill or where it is mixed with air. So, this powered coal goes along with air into a burner were it is burnt. And the heat of the burning of this coal is creates the flue gases. And these flue gases are very hot and the heat up the water tubes in the boiler.

And the water in the water tubes will get heated and they become steam. Of course, there is very hot flue gases most of it is heat is taken away here. But, still this hot flue gases are to be removed. And this is removed by means of stack, the large chimneys that you see in some of the thermal power plants. Now, in order to reduce the pollution. Because, the flue gasses will also be carrying large amount of unburned coal, in very minute particles.

So, you will see the oldest stations, might be giving you some black smoke. But, the new stations where we have electrostatic precipitators. Which basically scrub out all this particles in the flue gas. And from the stat, you will find very thin white smoke coming out. So, this is to reduce the pollution, we many times use electrostatic precipitators. Or back filters and things like that to filter out the flue gasses coming out.

Of course, when this flue gasses go out, they are still hot. So, quite a lot of amount of energy is wasted in this, almost 10 percent of the energy goes through the flue gasses. Of course, this hot steam here is used to run the turbine. And the control of the flow of steam, is done by means of this control works. In case the turbine has to be suddenly stopped or something; we have a stop valve which opens if the pressure here becomes very large.

So, beyond a certain pressure, stop valve can be used to release the steam out. And to bring the pressure in the system up to tolerable levels. So, in the turbine, this steam goes in high pressure, high temperature steam which rotates this turbine. The shaft of this turbine is connected to the shaft of a generator. So, which is just synchronous generator, at three phase synchronous generator mostly, the generation voltage normally as in the range of 11 KV to 30 KV. This three phase voltage by means of circuit breakers. And this step of transformer is stepped up to the transmission voltage level, which is 132 KV to 400 KV line to line voltages. So, this is how it goes, the water which comes out from the turbine is send to condenser. Where it is cooled and this condense sets.

And then, through a feed water pump, it is again re-circulated in these water tubes of the boiler. And this a close cycle, because here we need to use very pure water. Otherwise, the tubes which are being used will get clubbed with the residues, which will get stuck to this. So, this is now when we want to condense this steam, which is coming out from the turbine. We do it by means of providing a circulating water in the tubes of the condenser which takes away the heat.

And this circulating water is again reused by cooling it in a cooling tower. Basically in cooling tower what we do is we evaporate the hot water and in the process of evaporation. It gives a it is energy and it cools down. So, this is process of thermal power generation.

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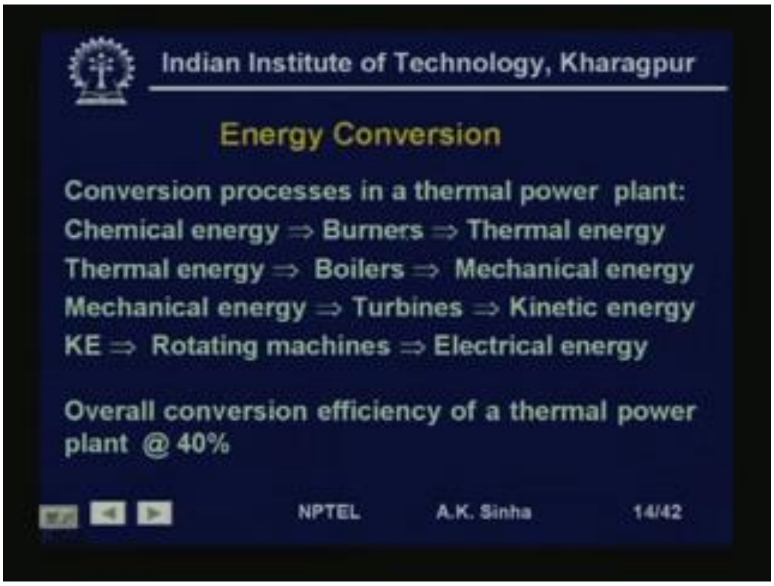

Here if we see, initially the chemical energy in a coal, is in the burner is converted converts it to thermal energy. Then, thermal energy is converted to mechanical energy in the boilers. And that is the steam at high temperature in pressure. The mechanical energy of this steam is converted by turbines into kinetic energy. The kinetic energy of the rotation is converted into electrical energy in the rotating machines, which is mostly a three phase synchronize machine.

And overall conversion efficiency of the thermal power plant is about 40 percents only. If we see here 10 percent goes out here, and almost 50 percent goes out here. So, what we get out here is only around 40 percent.

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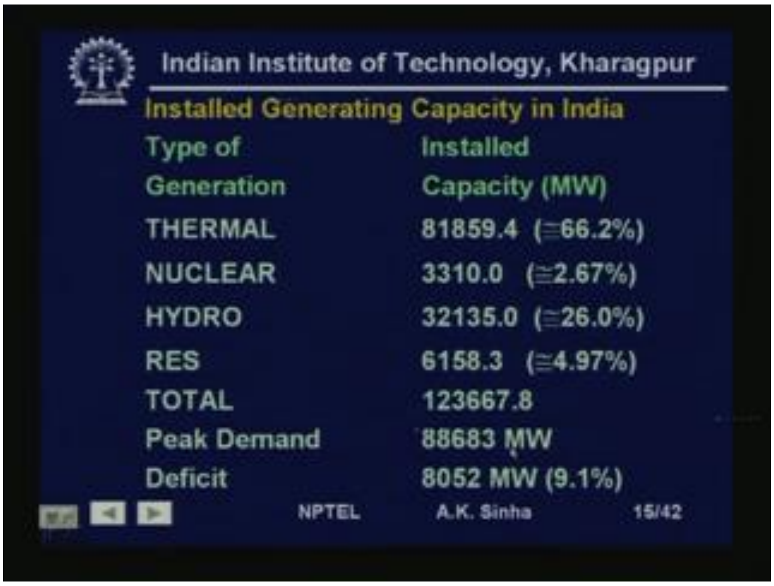

Now, if we look at India the total generating capacity available till 2005 was around 123668 megawatt. So, install capacity was of that order. Out of which 81000 or nearly 82000 was built up of thermal power plants. Around 3310 nuclear power plants and around 32135 in the hydro plants. Renewable energy sources provide about 6158. That is renewable energy sources are providing more capacity than the nuclear power plants.

So, we most of it is built up in terms of in terms of wind power. So, we have large amount of wind power plants in the system. Though the total capacity may be this much. The amount of power that we can supply at any time is not certainly this much, because many plants are very old plants. They cannot work at their full capacity, also some plants have to be taken out for maintenance another purposes. So, the peak demand is of the order of 88683 megawatt.

That is the maximum demand on the system in year 2005 was of this order. And the maximum which could be met was of the order of 8052 megawatt. That is we still have a peak demand deficit of almost 9 percent. So, we need to install more generating capacity. So, that we can provide power to all people when it is needed.

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Next part we will talk about power transmission. Now, as we know once the power is generated at the power plant. It has to be transmitted from these power plants up to the consumers. And generally as we have said earlier, that these power plants specially the large once or built near the mines or what we call pithead power plants. So, that they save the cost of transporting the coal up to a power plant. If it is build near to large cities where most of the loads are. Then this power has to be transmitted by means of power transmission system.

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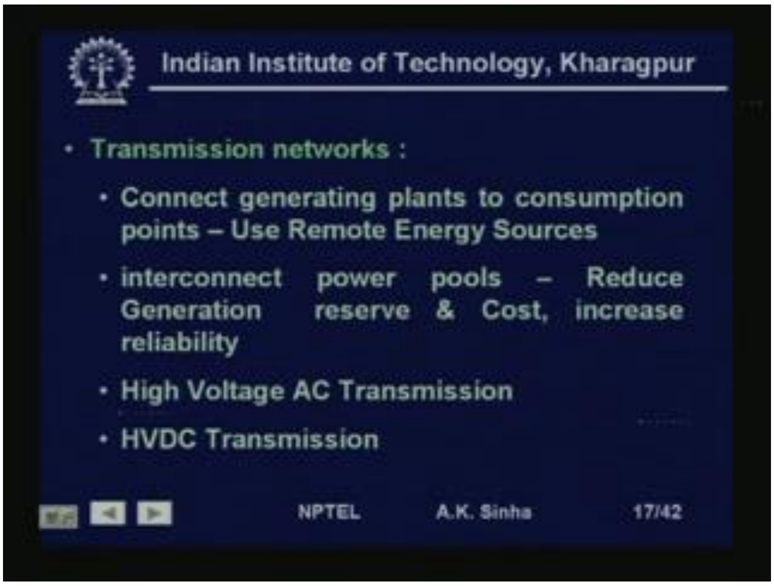

Now, transmission systems basic job is to connect generating plants to consumption points. That is to use remote energy sources, since the energy sources are not very near to the loads. So, we need to transmit this energy. Same is the situation with hydel plants. They are built near the dams where these resources are available. And we will have to transmit all this power, to places where it needs. So, a transmission system does this job.

It interconnects power pools, again if we have different systems which we need to connect. Like earlier we have state electricity boards. And these state electricity boards were basically entities in each state. And it may be possible that some state has extra energy available. Whereas, some state may be needing that energy sometimes. So, we had connected various states. So, interstate transmission was used and this we call as interconnecting of power pools.

Two power pools are interconnected. When one is in deficit, another one has some power to share. It can share it through the transmission system. This is generally done to reduce generation reserve, as well as cost and increase the reliability of this system. We will talk some of these later. Another aspect of transmission is we generally use high voltage AC transmission. We will see why we need high voltage AC transmission. The another kind of transmission which has been used in our country is high voltage DC transmission.

Now, high voltage AC transmission connecting to synchronize machines. Will provide a synchronous link between the two systems, but if we convert the AC into a DC and then, transmitted in terms of DC power. And then again inverted at the other hand into AC power, then the link that is there is no longer a synchronous link. And this we call as asynchronous link or asynchronous type between two systems, which run at synchronous streets.

This kind of a transmission is what we call asynchronous types. And this has been used, in our country mostly to interconnect the different regions from each other. Eastern region getting connected to western region or northern region or to southern region. These interconnections have in general, been in terms of high voltage DC transmission, because it has certain advantages over AC transmission.

One of the major advantage is that you have complete control on the power flow, on the transmission HVDC transmission system. Whereas, in AC transmission system the power control is not so simple of course. Now, a days we have other kinds devices using power electronic devices, which we call facts devices, flexible AC transmission system devices which are used to control power on AC transmission system as well.

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Now, what are the advantages of using high voltage transmission system. First is we have lower transmission losses per megawatt of power being transferred. We have lower line to voltage drop per kilometer. Because, we are working at high voltage the i square r losses. Since the voltage is high, the current will be low for the same amount of power. So, i square r losses are going to be low. So, transmission losses are going to be low, if we work at high voltage.

Similarly, the i r drop or i z drop, in case of AC system is also going to be less, because the current is smaller in case higher voltage systems. We will also see that if we go for high voltage systems. We can transmit more power through this transmission lines, then at low voltage. Another aspect is reduced right of way requirement, that is if we are using high voltage systems.

Then, we can use less number circuits. That is less number of transmission lines are required to transmit the same amount of power. Like say a 400 KV transmission line can roughly carry about 550 megawatt of power, whereas a 220 KV transmission line can carry only of the order of around 200 megawatt. 1, 32 KV will be able to carry only around 85, 200 megawatt.

So, if we need to transmit say 1000 megawatt from one place to another, we may need 2, 400 KV lines, whereas we need around 5, 220 KV lines an around 10 or 12, 132 KV lines. Therefore, since the number of lines means you require much more space for putting your transmission towers another things. So, with this we call as the right of way has to be bought by these transmission companies. From the people whose land, on whose land they are going to build this transmission towers and other things.

So, if we use high voltages, we reduce also the right of way requirement per megawatt transfer. And also it will reduce our operating cost, as well as capital cost. And these are the reasons why, we use high voltage transmission for transmitting large amount of power. In fact, as we will see later with lower voltages, it may not be possible to carry, so much power. As we have seen, 132 KV transmission line you can carry only around 82, 100 megawatt, whereas if we are using a 400 KV line, you may be able to carry more than 550 megawatt.

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Now, what are the various equipments used in transmission systems. We have step up transformers, as we have already seen. The power is generated at somewhat lower voltage between 11 to 30 KV. We need to step it up to a much higher voltage for transmitting this power. So, we need step up transformers, again at a load end we need to reduce this voltage, because the consumption will be at much lower voltage.

So, we need step down transformers. We need voltage regulators to try and maintain the voltage at the various points in the system. We sometimes use fresh shifters to try and control the real power flow, through the transmission lines.

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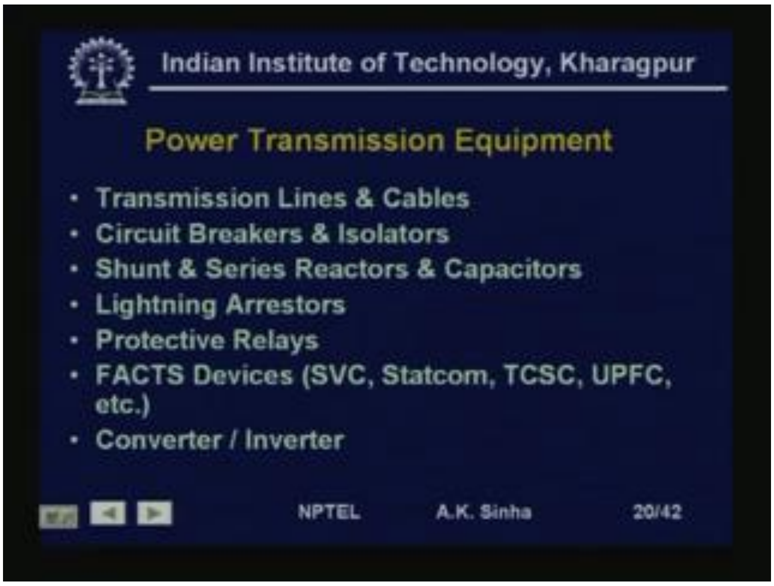

The other equipment that we use are of course, lines and cables to carry the power, circuit breakers and isolators. Circuit breakers are used to disconnect the line when case of falters. Some other reason, isolators are also same kind of switches. That main difference between circuit breakers and isolators are that circuit breakers can break a circuit in which current is flowing. Whereas, isolators are used only to isolate circuit, when it is not carrying any current.

We have other devices like shunt and series, reactors and capacitors. These are basically the reactive power consuming devices, reactors. Whereas, capacitors generate reactive power. So, in order to maintain the voltage profile in the system. And we put these capacitors and reactors at various places in the system. Lightening arrestor is one device, which is used in substations. As soon as the line enters the substation, the first device it encounters is lightening arrest.

These devices the basic idea is, if lightening transmission line, a surge voltage which is a very high voltage. And current surges propagate on the transmission line. And these need to be grounded or isolated. And not allowed to go up to the equipment where it can damage the isolation of equipment. So, we use these lightening arrestors to ground these surges. Then, we have protective relays, which disconnect a transmission system, when there is fault in any part of the system.

So, they identify which part of the system is faulted. And then, isolate the fault as quickly as possible. These devices were very fast of the order of milliseconds. That is in less than 20 to 50 milliseconds, they are able to isolate the transmission systems. FACTS devices just now I told you. Using power electronic devices, we have different kinds of FACTS devices, which can control power flow on the transmission system. And maintain the voltage at various points in the system.

Some of the devices which we use are SVC. The Static War Compensator or Static War Controller systems, Statcom, Static Compensator Systems, TCSC that is Thyristor Control Series Capacitors, UPSC - Unified Power Flow Controllers etcetera. For HVDC transmission system, we need converters and invertors at the tube sides. In fact, these are used, they use basically the get firing devices. That is controlled rectifier and invert devices.

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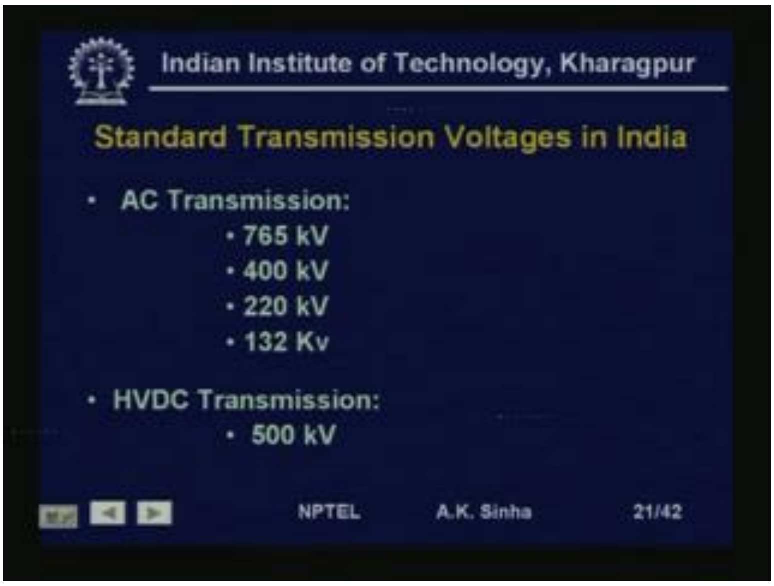

The standard transmission voltages in India are basically 132, 220 and 400 KV. Now, 765 KV transmission is also being built in India. And we are going to have a number of 765 KV transmission system to carry large amount of power, that we need to transmit. HVDC transmission the normal voltage that we are using. Or of the order of the 500 KV though 600 KV is also being. Thought of in certain HVDC transmission systems.

Somewhere, where we have a small transmission line we have worked it at somewhat lower voltages also.

That is when we collect 2 system, which are near to each other. The transmission line is very, very small, we call these system as back to back HVDC systems. And here we have worked at lower voltages as well. ((Refer Time: 41:32)) Next is power distribution systems. Once we have transmitted the power near the load center. Now, it is the distribution system which distributes it to individual consumers.

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Now, the distribution system receives electrical energy from high voltage and medium voltage levels. From the transmission system and sub-transmission system. In fact, below the transmission we also have, what we call as sub transmission system. But, generally all this is clubbed into one part, which we call the transmission system. Then it is supplies this energy to the consumers, at medium level and low voltage levels.

So, medium voltage levels and low voltage levels, that is around 33 KV, 66 KV, may be 11 KV. Or lower voltages of the order of 3.3 KV or 415 volt or so on. The distribution is in terms of three phase, as well as in terms of single phase. Whereas, the generation and transmission is always in three phase, if a three phase system. That distribution specially for small consumers like a residential building, is generally a single phase distribution, whereas, for large consumers it is normally a three face distribution system.

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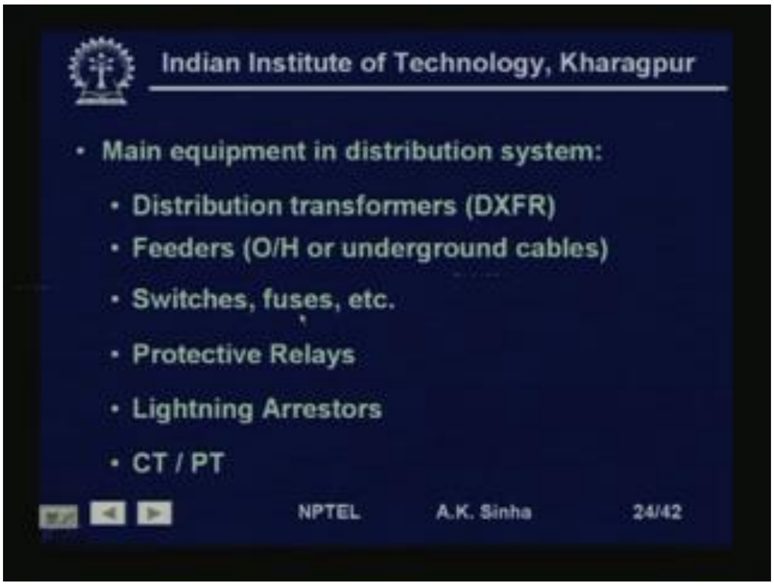

The main equipment of a distribution systems are again you have in the distribution system. Once you have got the power at higher medium voltage, you step it down by means of distribution transforms. Which then we have feeders or which are basically overhead or underground cables to provide the transmission. Or to carry this electrical energy up to the consumer premises, we have again switches, fuses etcetera.

These are again the protective devices, which are used protective release are there, in case of a fault. They operate to isolate the part of the system. So, as to maintain the system in a proper way. As well as not to in danger the system operation or fire etcetera. Lightening arrestors as I have already said are used. We have CT’s and PT’s, that is the current transformers and potentially transformers. These are generally used for providing power to the relays. As well as for measurement purposes, for energy meters another things. So, we have all these kind of devices which we use.

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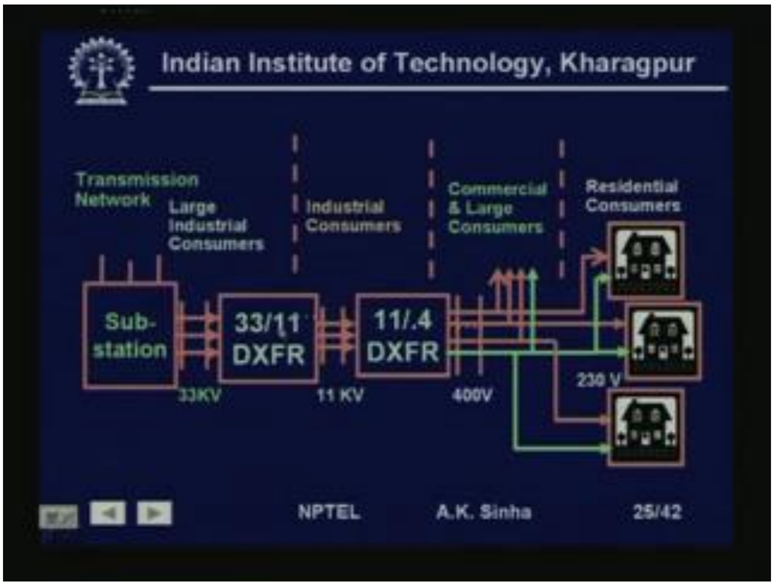

This is very simple representation of a distribution system, from the transmitter network. We come to a substation at the high voltage or medium voltage level. There we have, once we have got this power at 33 KV level, by means of transformer here. This goes up to some large industrial consumers at 33 KV level or may be at 11 KV level. So, we have a 33 to 11 KV level transformer, which we call distribution transformer are used for this purpose.

So, some industrial consumers will take power at 11 KV. Then from 11 KV to 450 volt. Basically we have another transformation which we do by means distribution transform. And this in general is supplied as three phase, 415 volt to commercial establishments may be large consumers, whereas it goes as single phase at 230 volts or 240 volts to variance residences. So, this green line is showing the fourth line, which is the neutral wire.

So, we have a one line and the neutral supplying to one consumer, another line and a neutral to another consumer. Similarly, the third line and the neutral to another consumer and so on. That is what we do as, in order to balance the three phase system. The loads are distributed specially the single phase loads are distributed on the three lines. So, that this three phase system we come somewhat balanced. So, this is about the distribution system.

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Next we will talk about power system operation and control.

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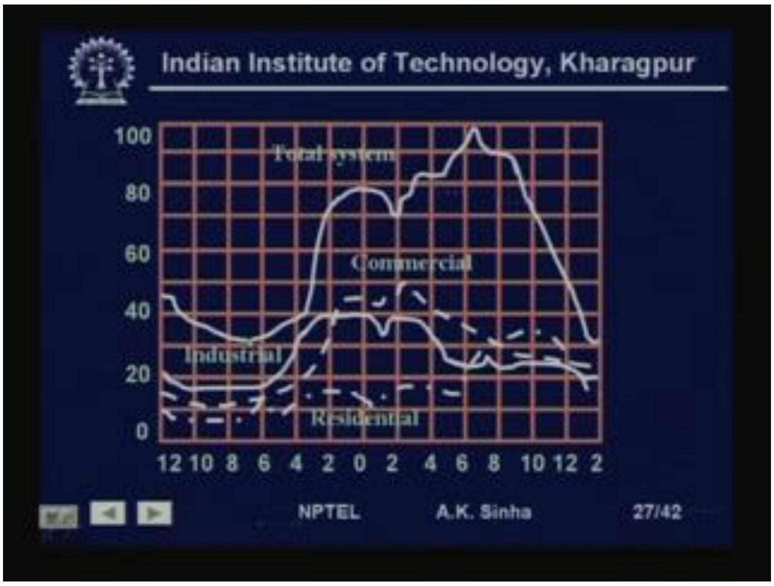

Now, as we see from this diagram which is a typical system load profile. That here what we have seen is, the system load is never constant, it keeps on changing at different times. We have a very low loading at early morning time, may be around say around, this is showing. So, late in the night we have very low loading, this should not be 10 this should be 2, 4, 6, 8, 10, 12 and so on, anyway this is.

So, here at late in the night we have very low loads. And then, as the morning goes up this our working starts, then the loads goes up. And we will see that during the evening time we have a very large load. This generally happens mostly with the residential loading. this is what you are seeing as residential load. That this loading becomes much larger, during the evening when people have switched on their TV's. They are doing, they are cooking and all that. So, all light are on and so on, whereas if you see industrial load, it will be very high during the day time. So, industrial loads are high during the day time. Commercial loads again are high starting around 10 o clock this will go up and late in the night they go down. So, around the evening they have a high peak may be. But, mostly these loads will be high during the day period. So, if we see we are finding that the load is changing all the time.

Now, whenever we switch on our supply we get the power. Now, this load that is when we switch on the load has increased. If we switch off the load has decreased. And we get this power as soon as we switch on. How does this power system work, how does this provide this power immediately to us. Well, if you can see in a power system what happens is, you have that turbine and generator set these are rotating at high speed. So, the inertia of this rotating mass, stores large amount of kinetic energy.

So, when you switch on a supply, immediately this power comes by getting extracted from this kinetic energy of the rotating mass. And what happens, because of this extraction is that, the speed of rotation will slow down. That is the rotating mass will experience some retardation. So, this is what we see in terms of change in frequency or reduction in frequency. So, whenever load increases, there is a reduction in frequency. Whenever the load decreases there is increase in frequency. And the job of power system operation and control is to try to maintain this frequency, as much constant as possible, which is done by means of various types of control devices.

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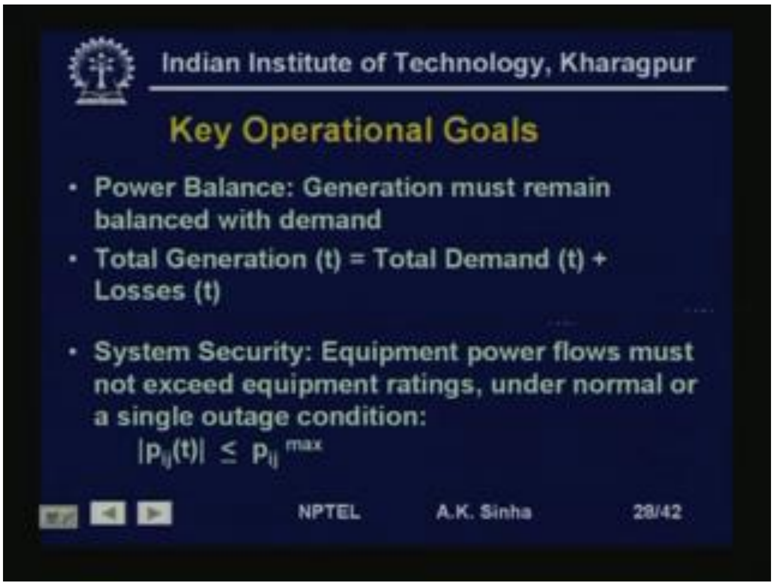

So, one of the key operational goals as we said is power balance. Because, when you generation must balance with the demand. That is when I switch on the generation must go up. But, how does a generator see that you have switched on your device, it does not know. So, this kind of indication comes to it by means up a drop in frequency. So, when a operator sees, that the frequency is dropping what he does is, he increases the input of this stem to the turbine, and because this input has increased.

Now, the generation has increase. And when the two get balance, the speed remain constant. That is the frequency will we maintain. So, total generation at all time t must be equal to total demand at time t plus the total loss losses are the time t. Of course, when the power is transmitted through the transmission line and distributed to you. There are losses in the transmission and distribution system.

So, the total generation must be able to balance this total demand plus losses. Then only the frequency of the system, that is the speed of the generators will remain constant. So, this is done by means of power system control. Of course, instead of each operator, trying to maintain the frequency which was done earlier manual control. Now, we have automatic devices to do this. Next part is system security. Now, equipment may go out, there may be faults in the system.

And therefore, what we have to see is that even under conditions of fault. The system that we are running should be able to provide power to all the consumers, without any drop in the quality. That is frequency and voltage after supply. And in order to see that this happens, we have to see that all equipment are running within their limits. That is they working under normal conditions without violating any limits. So, it is we have to see that all equipments are within limits. As well as we have, whenever an outage takes place then also the limits are not violated.

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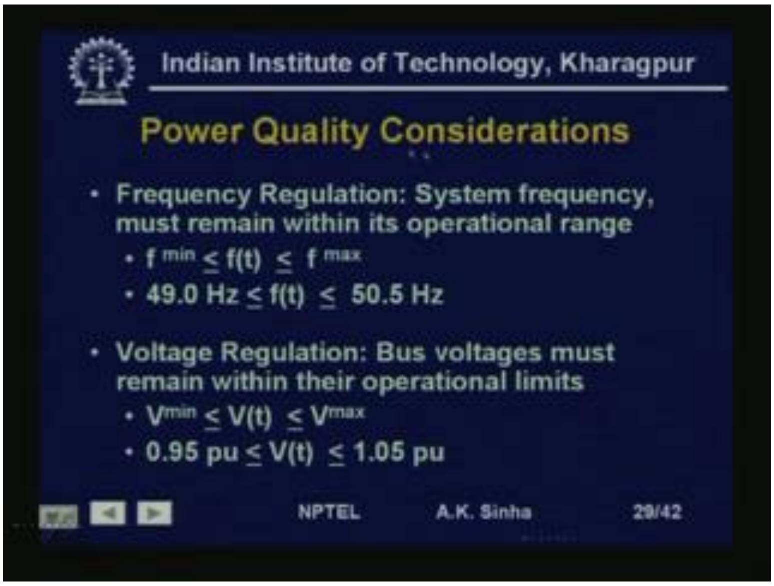

Another aspect is the quality of power as we have talked earlier, is in terms of frequency. That is frequency as a very important parameter. In India we are trying to maintain the frequency, within a range of 49 Hertz to 50.5 Hertz. Another aspect for quality is the voltage. And we generally try to maintain the voltage up to, that is the within the range of 0.95 per unit to 1.05 per unit.

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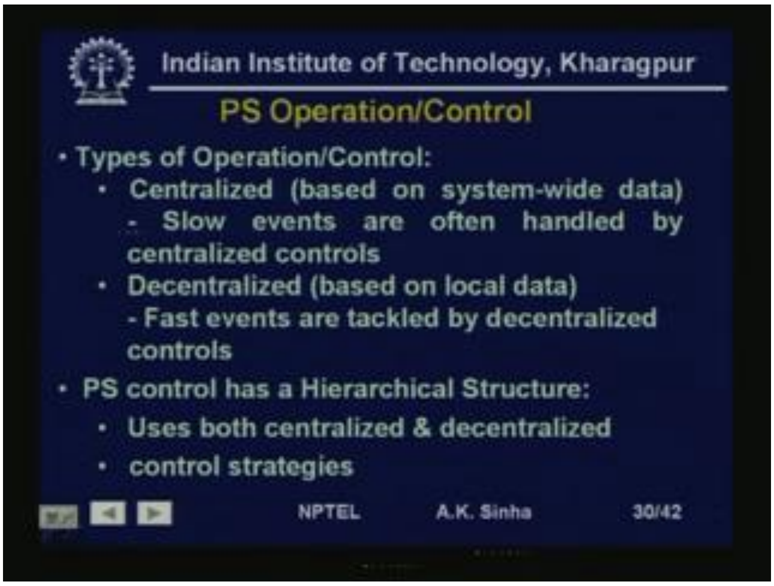

So, this is what is the goal of the operation and control of power system. Of course, this is achieved by means of what we call, a hierarchical control system, where the larger controls and the slow acting controls are done by means of a centralized controls, whereas the first acting controls, like protection another systems. They are done by means of decentralized control, that is local controls.

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Centralized controls some of the example has SCADA system, EMS systems. Decentralized controls as I said protection systems. Some controls like your speed governing system for turbines, for generators all these are also decentralized control.

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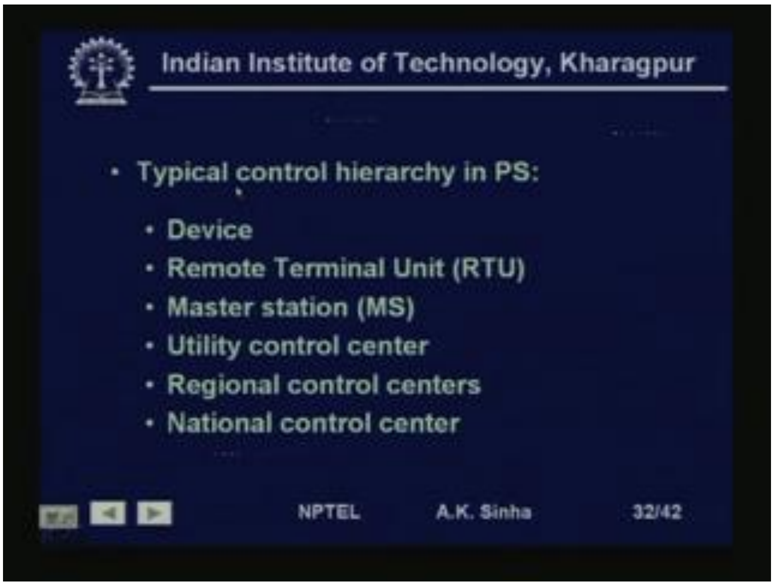

Typical control hierarchy is device. Then we have remote terminal units, master stations, utility control centers, regional control centers and national control centers. So, from the device the information goes after the national control center. They are concentrated at these levels and then, they are send further.

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Of course, the centralized controls we generally use frequency control. Interchange control, generation dispatch, security assessment, unit commitment.

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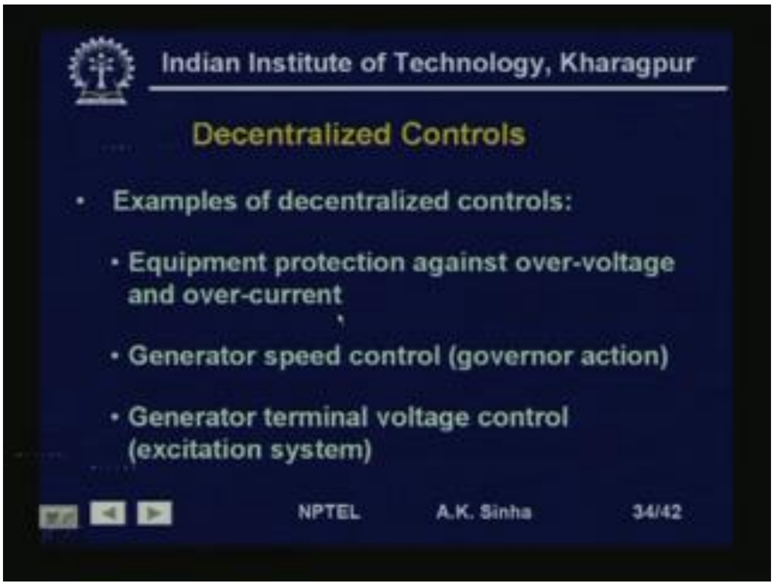

All these are generally done on for centralized control purposes. Whereas, decentralized control as we said speed governing system, protection system, voltage control system. Automatic voltage regulators or the excitation control of each generator, these are decentralized control options.

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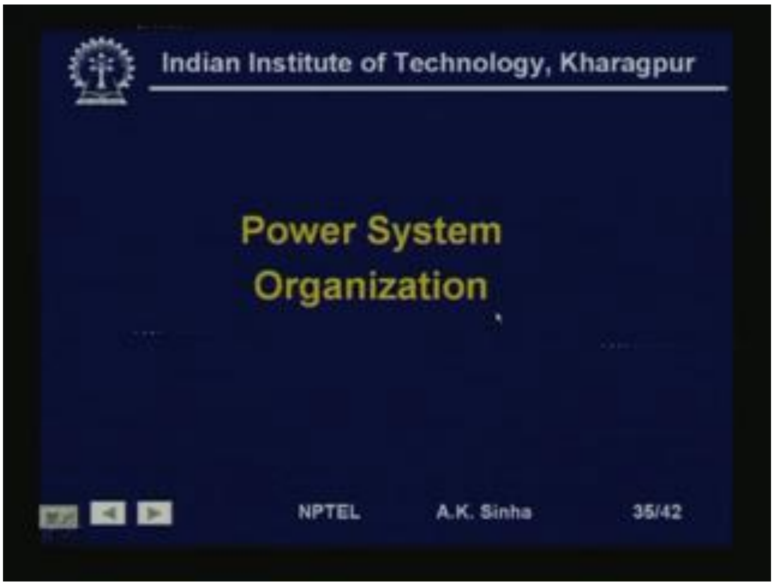

Now, power system operation and it is organization. Earlier power systems that we have which we call the traditional power system.

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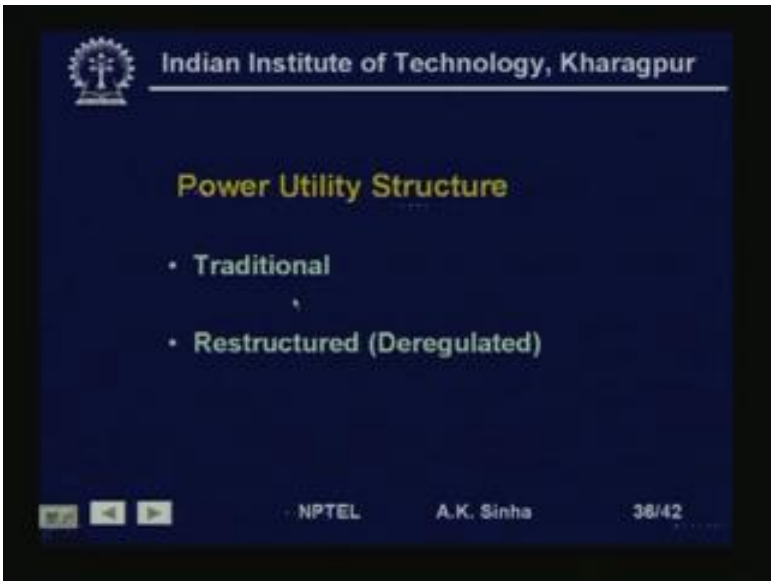

Was what we termed as vertically integrated system, where both the generation, transmission distribution, all these parts are controlled by a single entity. Whereas, the new structure that is emerging, which we call the restructured or deregulated power system structures. These entities are unbundled. That is they are made into separate entities, which are controlled separately manage separately. So, this is change a which is occurring in the power system structure.

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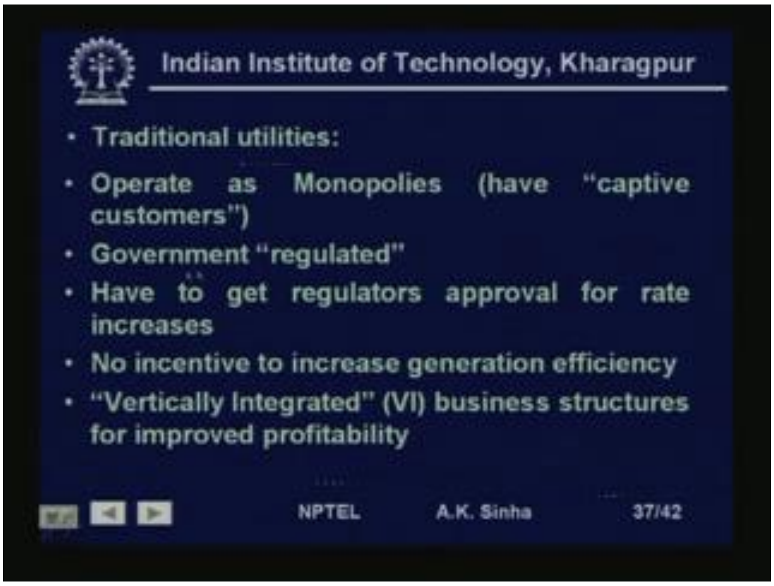

Traditional utilities were operated as monopolies. There are mostly government regulated. We had state electricity boards, have to get regulators approval for the rate increase, that is they were not running as a business. They were running more as a government department. And therefore, there was no incentive to increase, efficiency. And therefore, there was because there was no more motive for profitability of the system.

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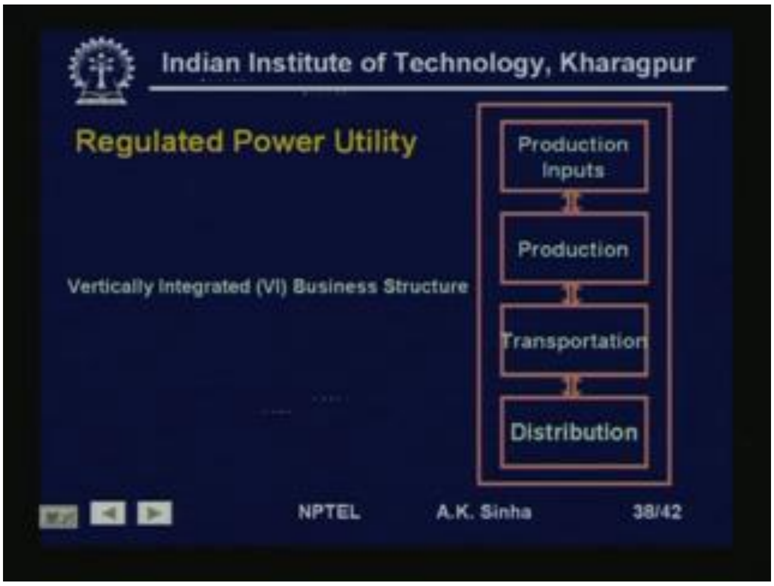

Whereas, that is this is the structures that we call vertically integrative system business structure. Production units, production, transportation, distribution everything is in the same hand.

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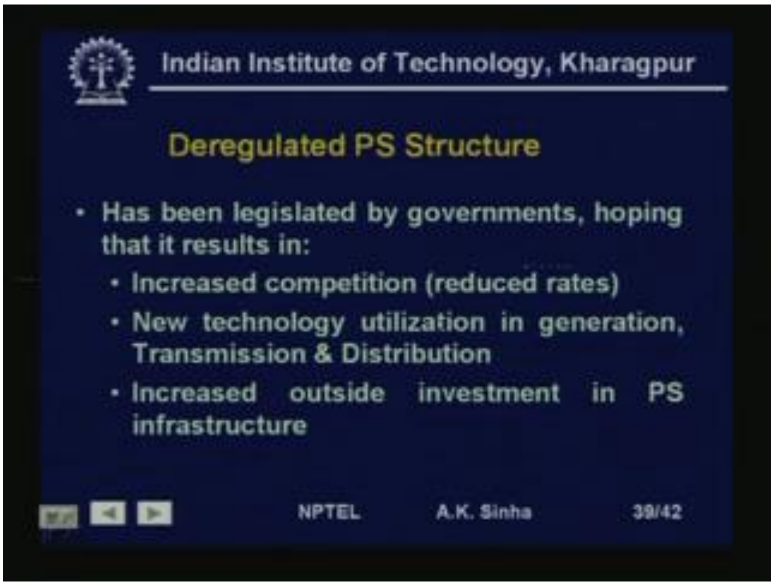

Whereas, in deregulated power system structure. What is being done is that the generation transmission and distribution parts are unbundled. This is being done to increase competition by making more players to come into this business. And thereby with competition it is expected that the tariff will reduce. It will introduce the new technology in generation transmission and distribution, has happened in case of telecom sector. It will also increase outside investment in structure. In power system infrastructure, because a power system requires huge amount of investment. In fact, it is expected that within the next 5 to 7 years, the country needs an expenditure of the order of more than 1 lakh crore in this sector.

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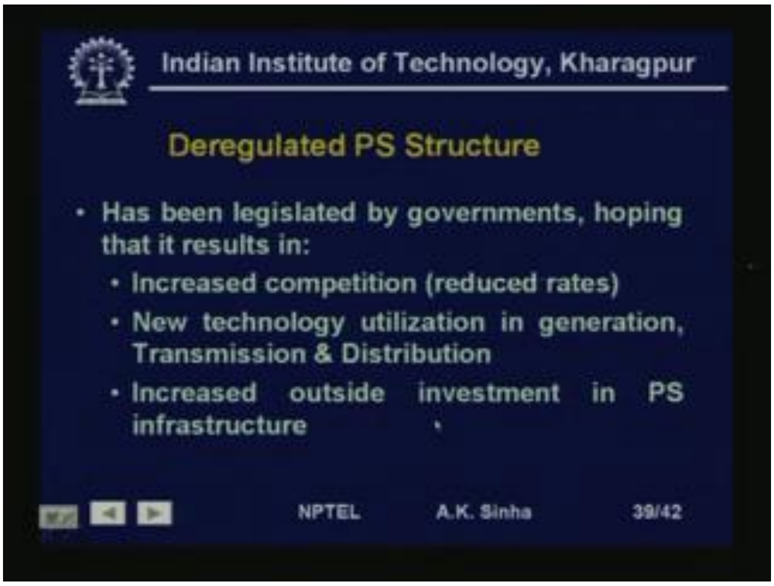

So, this is expected that since there is competition other players will come in.

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We in the deregulated power system, we will have more money coming in. This has happen that is as I said, it is being unbundled, in terms of we have Gencos, we have Transcos. And we have distribution companies or retail services or Discos. Whereas, other players like power marketers, we have independent system operators. These will come when this system starts functioning, because without a proper structure this system will not able to function.

So, many countries this is already coming up; and this has already started working.

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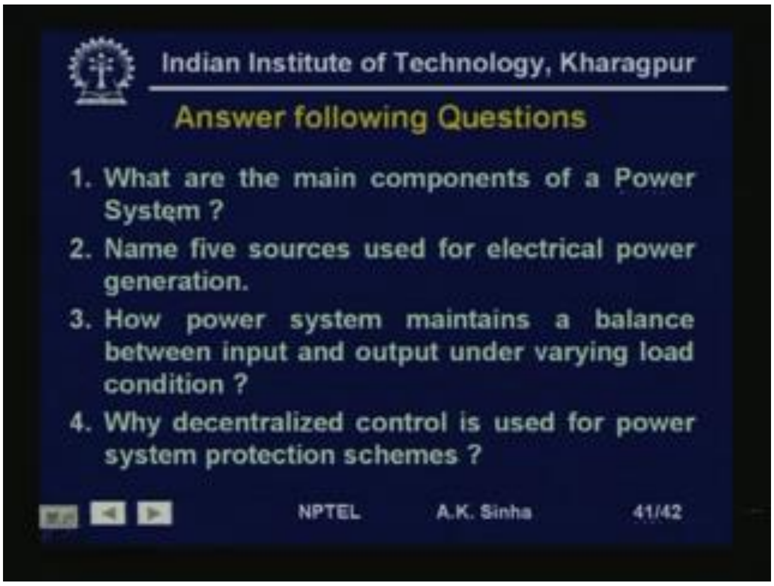

Now, once we have gone through this we will, I would like you to answer some of the questions. What are the main components of a power system, this question number 1. Question number 2, name 5 sources used for electrical power generation. Of course, you this is again a very simple question. How power system maintains, a balance between input and output under varying load conditions. Again we talked about this, so you should able to answer this question.

That is when we increase the load what happens and how power system tries to balance it. Why decentralized control is used for power system protection schemes. Because, this again you known that we are using for protection system very fast acting, devices are needed. So, this is again you should be able to answer this, why decentralized control is used for power system protection schemes. So, with this we finish this lesson.

Thank you very much.