Operation and Planning of Power Distribution Systems

Dr. Sanjib Ganguly
Department of Electrical and Electronics Engineering
Indian Institute of Technology, Guwahati

Lecture - 01
History of the Development of Electric Power System and Indian Power Systems- An Overview

In my first lecture, I will talk about the Historical Development of Electrical Power System ok. So, this is an overview of historical development of electrical power system and Indian power system. How it evolves since century ago and how it is in the present shape. So, personally I believe that history is an important issue everybody should know, particularly, if it is a history of the development of some complex system which was developed initially a century ago and it is still in the developing phase.

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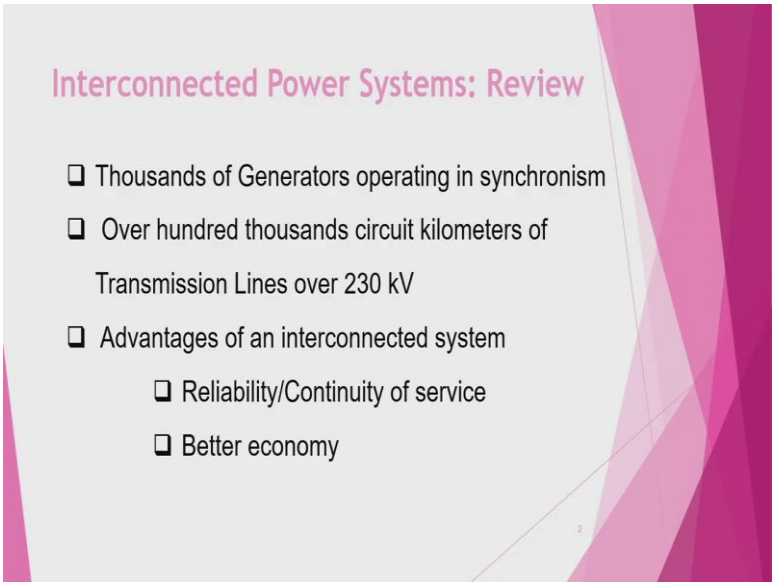

So, let's start. So, in this lecture, I will give you brief review on electrical power system and Indian power network. Now, first of all this, as you can see, that electrical power system is normally an interconnected system of thousands of generators, operating in synchronism. And in India also, we have a very big power network I will show you the statistics, latest statistics of having a very large capacity almost 400 gigawatt of capacity 380 gigawatt of capacity in reality.

And, this generation is transmitted to the individual loads areas or load centres through thousands circuit kilometers of transmission lines. And, this transmission lines are located very vast geographical area. And we also have in India almost 4 lakh or 400,000 circuit kilo meter of transmission line. Now, why we go for interconnected system? Because in interconnected system as you can see we have better reliability and also we have better economy.

So, this is the reason that, we, in fact not only in our country, but also in across the globe since the inception of power system slowly these different power networks are interconnected. I will show you here how Indian power networks which are basically spread in a very large geographical area are finally, integrated to one-nation-one-grid.

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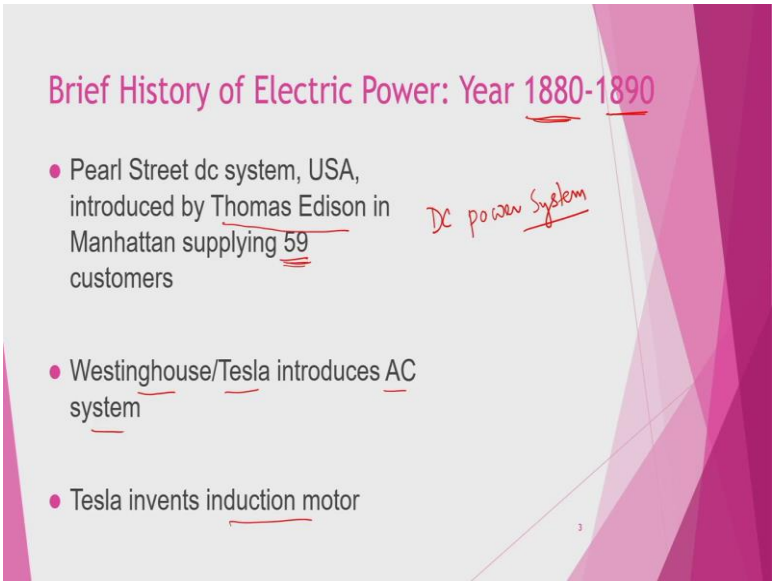

Now, before I go for this development of Indian power network, let us first review the brief historical development of electrical power system as a whole. It was started late 19th century, i.e., in between 1880 to 1890 specifically in Europe and USA. And as you know Thomas Edison initially developed a DC power system, which is the first such kind of system. And this system was very small system considering this present scenario. It was developed to supply only few number of customers, only 59 number of customers in Pearl street USA.

And during that time, other people are also in search of a better system and parallelly Westinghouse and Tesla joined hand together to develop an interconnected AC system.

And there was a series of this invention took place during this time 1880 to 1900 during these years. Tesla invents induction motor, which runs with AC system and which is one of the robust kinds of motor that even we use today.

There is no replacement of induction motor. May be its performance is upgraded, but as such the principle-wise almost everywhere you will find induction motor works.

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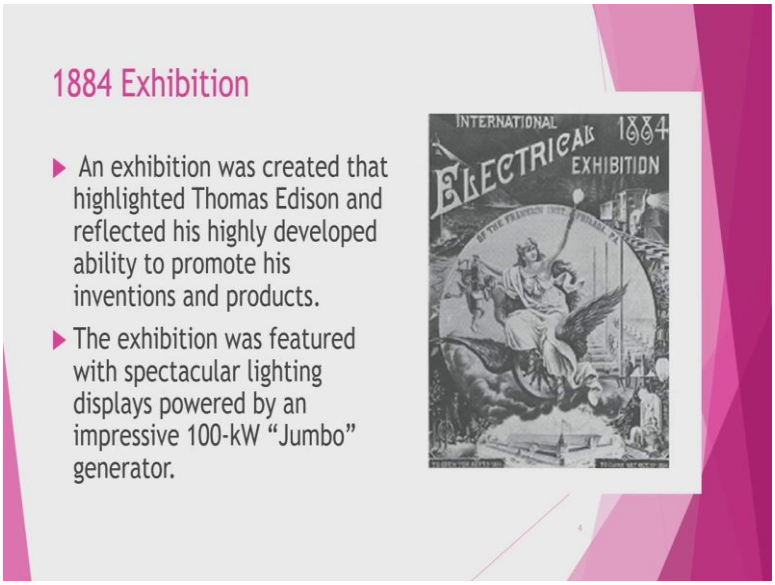

Now, during that time there was an exhibition and we call it the first kind of power conference/technical conference, which was organized by American Institute of Electrical Engineers. You can see the figure which is shown in the right hand side of the slide. In that figure you can see, that there was a big exhibition which was organized in 1884 so that the people who are working on this particular field, i.e., electrical power system they come and exchange the ideas they can show their invention.

And, thereby, this first kind of technical information exchange can take place. So, there many people have shown their own inventions which include 100 kilowatt of jumbo generator. And, you might be knowing that later the American Institute of Electrical Engineers are renamed to IEEE that is the well known body which is having enough contributions throughout the world.

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In fact, the first IEEE conference technical conference took place in 1884 and that time it was named as American Institute of Electrical Engineers.

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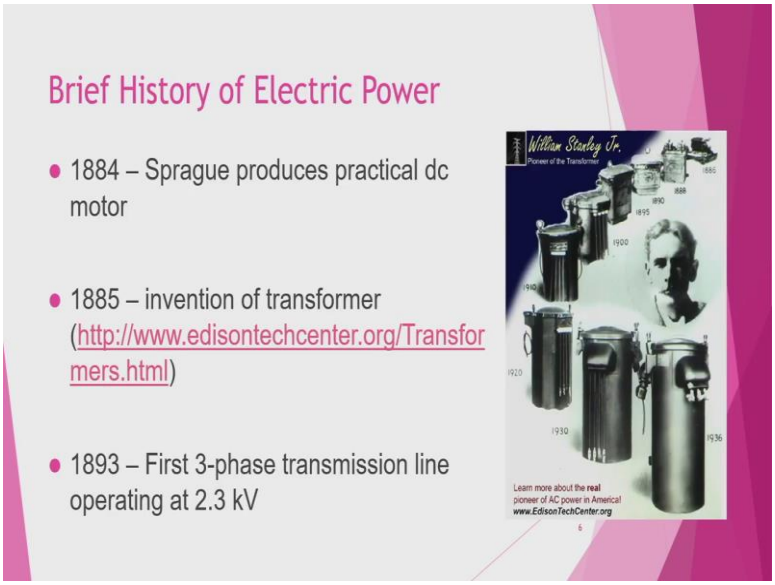

Then, there was a series of invention took place, in 1884, Sprague produced practical DC motor. Because, since the beginning of this, you know that development of electrical power system we need particularly two types of machine. One which can convert other form of energy to electrical energy that we call as electrical generator. Another is those

types of machines which will convert electrical energy to the mechanical energy to do various types of works that we need in day to day life which is called as electrical motor.

So, when Tesla developed AC electrical machine or AC electrical motor which is called as induction motor, during that time only Sprague produced practical DC motor. And, there was a development of transformer. Transformer is developed by a group of people and one of the pioneer in this field is William Stanley Junior, as you can see. Now what is the need of this transformer that one should know. This transformer is basically required to transform the one voltage level to another voltage level.

Now why we need for voltage transformation from one voltage level to another voltage level? Because I will show you in my next lecture, because there are several reasons that we cannot provide this electricity or energy at the generation voltage. So, there is a series of transformation required before you get the electrical energy from your local utility. Then what are those transformations? We need sometimes to upgrade the voltage level. We need sometimes to downgrade the voltage level and those things are done by the transformer.

And that time this development of this transformer give a push to the AC system because as I said I will show you in detail in my next lecture, that we cannot provide power to huge number of customers as a whole in a comparatively lower voltage. So, we need to upgrade the voltage level sometimes and we need to downgrade the voltage level to utilization voltage level. So, those things can be done by using transformer and that transformer was developed in 1885 by a number of person and as I have shown you William Stanley is one of the pioneers on it.

And after this development of this transformer there was a huge push towards this AC system and first three phase transmission line was developed in 1893 which was operated at 2.3 kV in USA. And there was a development of similar type of AC system in other parts of the world particularly in Europe, as well.

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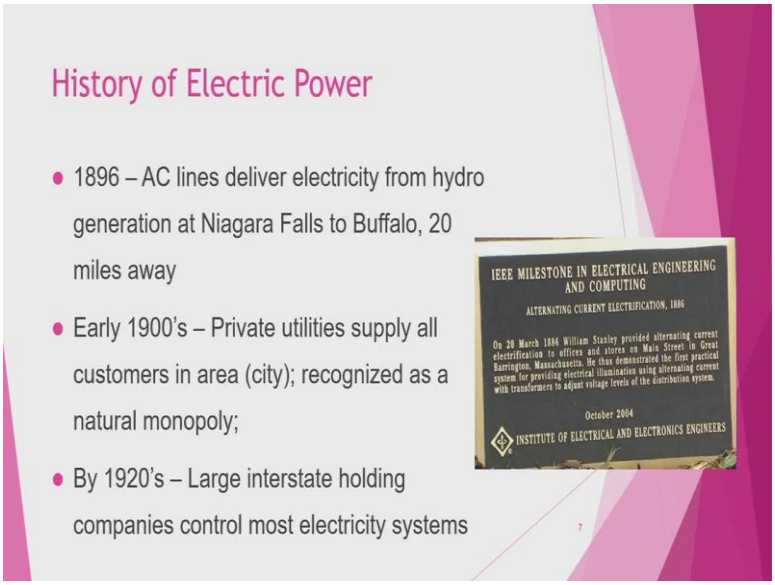

So, as you can see in 1896, AC lines deliver electricity from hydro generation station Niagara falls, which was 20 miles away from the city where people are living. Now that time 20 mile was a huge distance or it is a high value of this length as far as the length of the transmission network is concerned and that was possible with the development of transformer.

And then from early 1900 to 1920 there was various developments took place in developing AC power system. And when we develop something you need to create some standards and there was some distribution companies/some power utilities, which are come to picture and they were starting business in electrical power system.

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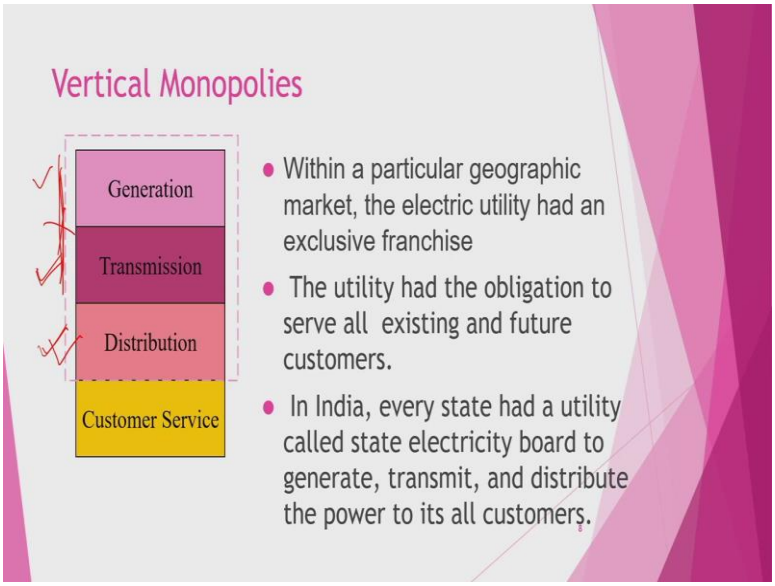

Now, as I said that we need three different building blocks, one is generation of electricity and other is transmission, another is distribution. These are three important building blocks for a power network. Generation means, where power is being generated. And where is it generated? It is normally generated for a conventional type of power plant like a thermal power plant. It is generated in a typical thermal power station.

And this thermal power station is usually located far away from the load centres. So, in order to bring power from this generating station we need to build transmission network and the basic idea of transmission network is to evacuate power from the generating station and to bring it to the customer's sites. And then finally, those powers need to be appropriately delivered to the customers, who require the power and that is the main thing that is done by distribution systems.

Now, in this course, I will not discuss this generation and transmission. I will not discuss these. But this course is essentially focused on how the power is being efficiently delivered to the customers, i.e., how it works for a practical distribution network. Now you know that up to 20 years back mostly these generation, transmission, distribution were done by a single utility, i.e., single company who was supervising this generation, transmission and distribution. And that is why there was a monopoly in the business. There was a monopoly in the business.

And, you might be knowing that, in India, we had State Electricity Board in different states who were supposed to provide power to the customers of their own state. So, they generate with their generating station. They had this transmission line to transmit this power and they had this distribution network to distribute the power. And therefore, there was a monopoly in the business. So, this monopoly was there till early of this century in India.

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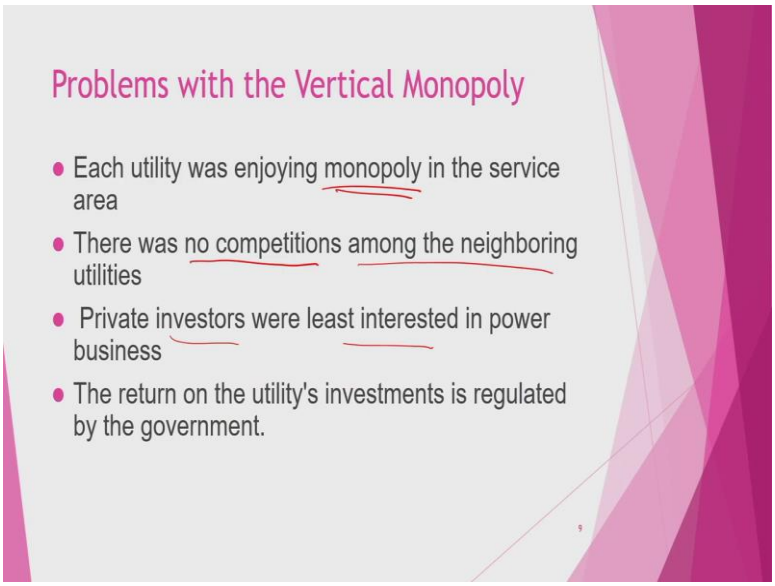

And, because of this monopoly there was no competition among these utilities. Because as you know that the state of Assam they had Assam Electricity Board and they are supposed to generate the power and to distribute to the people of Assam only. And similarly, in West Bengal, you know that they had West Bengal State Electricity Board. So, they generate the power to distribute among the people of West Bengal.

So, there was a monopoly and these utilities were enjoying their monopoly in service. And private investors were least interested in power business. If you look at this overall generation capacity of India in early in 2000, then you will see that mostly the generations were owned by the Government or either central government or state government owned utilities. There was a very few private companies who were generating power. So, mostly private investors were least interested.

And as a whole this system was, in fact, working since its inception. Now this concept you know was the major barrier for further accelerating the growth of this power market and that is why people all around the world felt restructuring of power industry.

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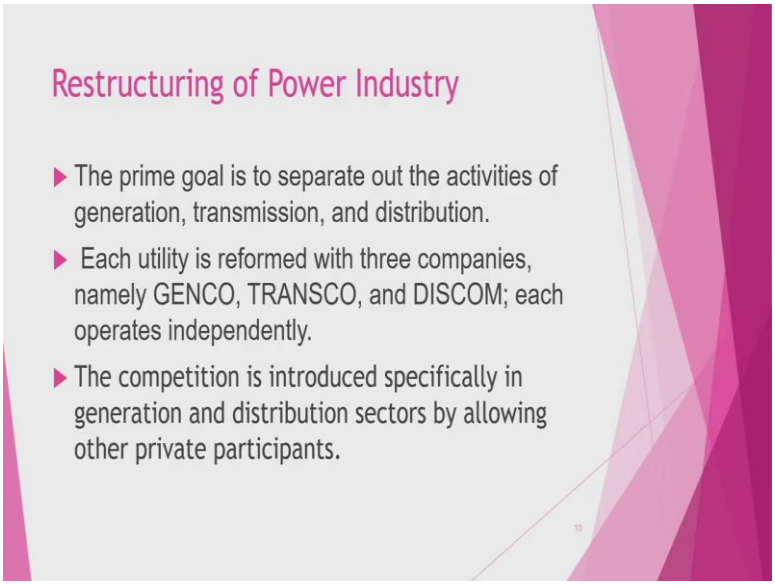

And primarily, in India, also this restructuring took place, after the implementation of Electricity Act 2003. I will come to that. So, what sort of restructuring they are suggesting? They are firstly, divided all these three different tasks of power business, i.e., generation, transmission and distribution with three different companies. One is called GENCO that is the company which is responsible for power generation.

Another is for TRANSCO that is the company which is responsible for power transmission. And the DISCOM, they are the power companies which are responsible for power distribution. And with this reformation, with some changes of these rules and regulations and this brought some sort of competition in particularly generation and distribution sectors, by allowing other private participants.

So, that is why if you look at this power generation at 2003 or early in 2000, you will see that whatever generation was there mostly limited to or mostly owned by this government companies. And then after the implementation of this sort of restructuring now if I show you statistics you will see there is a huge change particularly in terms of new power generation companies. Private companies are now coming into this power business and they generate and they are ready for power distribution.

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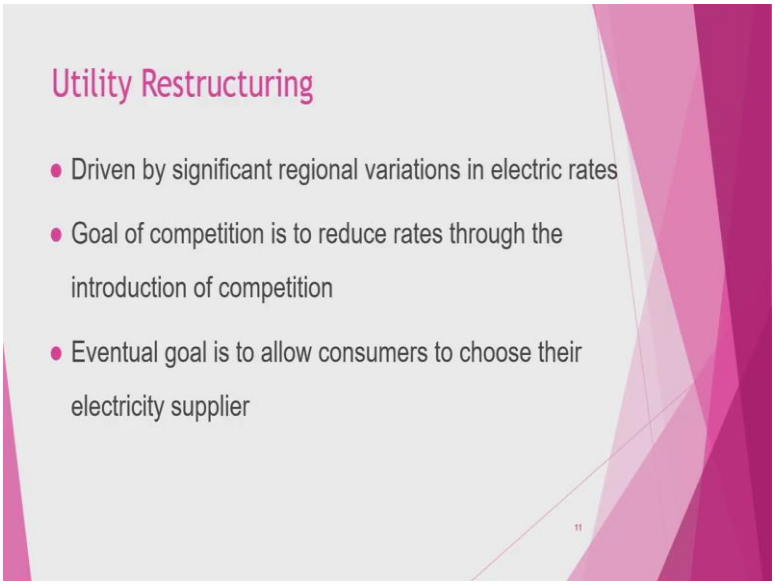

Now, driven by this utility restructuring, the main objective is to regulate several things like electricity rates or pricing. Also the main goal was to bring competition among these utilities to the power market. And it is used to allow the consumer to choose their electricity supplier, which is not in large case till today in India. It did not take place, but in future this will come.

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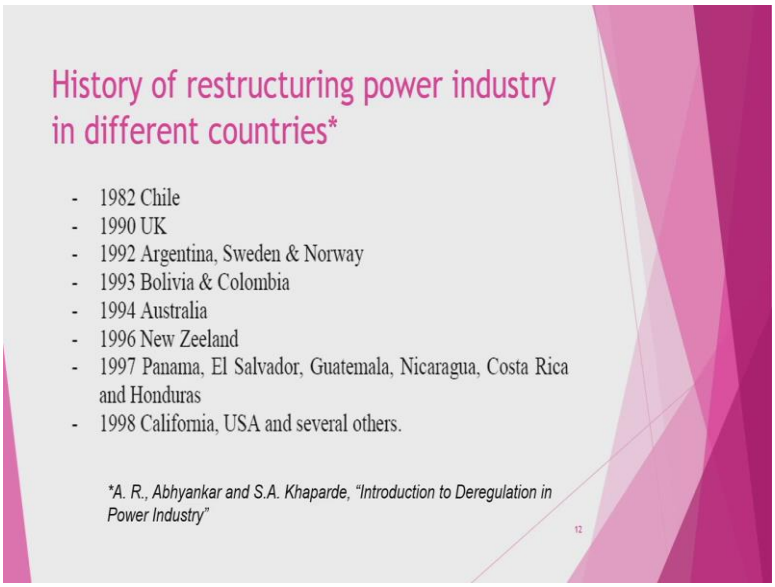

So, history of this restructuring of power industry in different countries happened starting from 1980s to early in 2000. You can see that it was introduced in Chile that is in Latin America, then UK and finally, in 1998 the restructuring took place in USA, as well.

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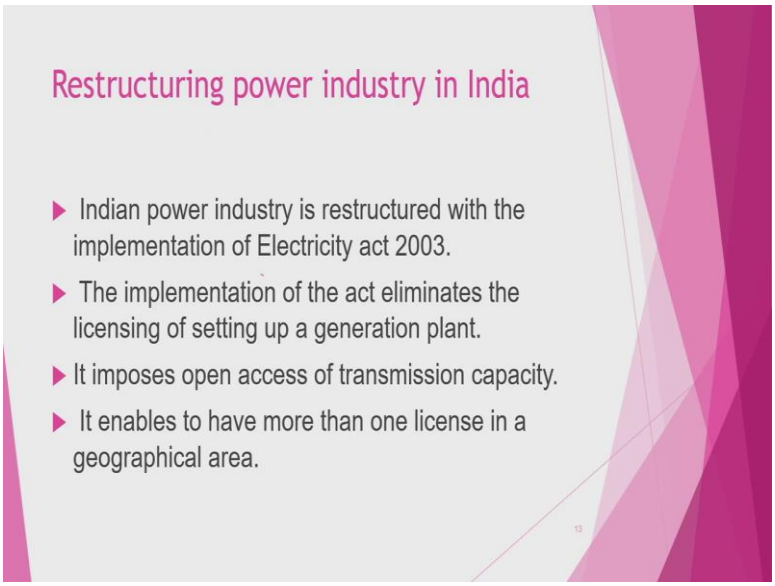

And in India, as I said, this sort of restructuring first took place after implementation of Electricity Act 2003. Now, what is that act? I will not go in detail, but due to the imposition of Electricity Act there was elimination of licensing of setting up generating plants. And it imposes open access to the transmission capacity. It also enables to have more than one license in a geographical area. So, this all are basically imposed in order to bring competition in the power market.

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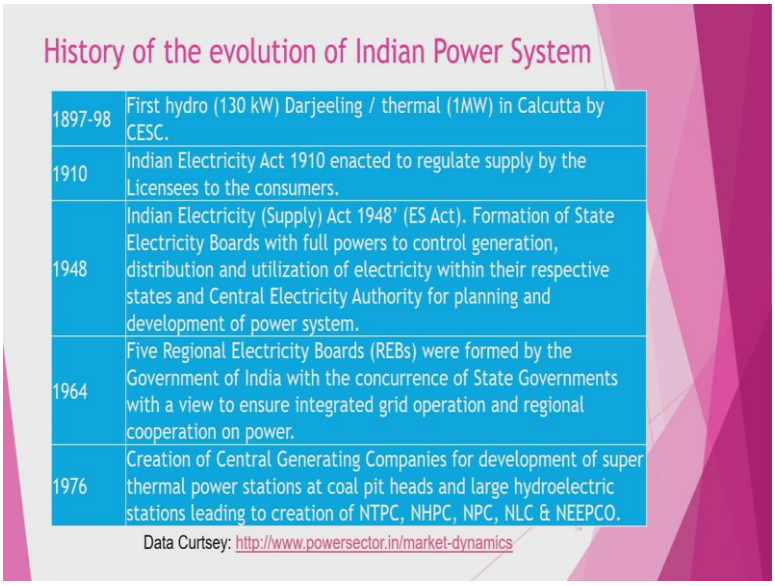

Now, this is how the Indian power system is historically evolved. As you can see in 1897 to 1898 first hydro power plant was set up in Darjeeling. That was 1 megawatt of power plant and that was owned by CESC that is Calcutta Electricity Supply Corporation. In 1910, i.e., in British India, the first Indian Electricity Act was enacted. Then, after the independence, in 1948, the first Indian Electricity Act was enacted that was the first Electricity Act in the after independence.

And after this enactment of this first Electricity Act in 1948, there was some changes took place. One is that formation of State Electricity Boards, where the formation of the State Electricity Board was done. And also there are some other changes took place. For example, the respective State and Central Electricity Authority are basically created for planning and development of electrical power system. Then that law or act further was amended and time to time some significant changes took place, for example in 1964 Regional Electricity Board was formed.

And after that, in 1976, again there was a major change to create the central government owned electrical power generation company, for example, NTPC, NHPC etc. NTPC stands for National Thermal Power Corporation, that is one of the biggest central government regulated power company, i.e., public sector unit of India and they have a very big generation capacity. Similarly, NHPC is for hydro power generation and so on. So, all these data, I took from this the link given below.

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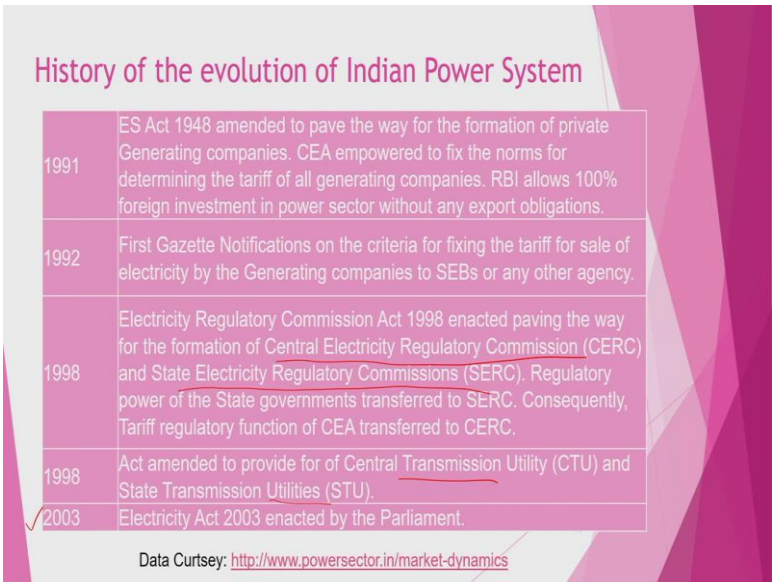

Then in 1991, again the Electricity Act was amended which will create provision for foreign investment in power sector. Now, in 1992 gazette notification for sale of electricity by the generation company to State Electricity Board to the other agency. In 1998, first electricity regulatory commission was formed in India and we have a central electricity regulatory commission that is CERC and we have also state level electricity regulatory commissions. They basically supervise the power business of this country.

Then in 1998, the act was again amendment. The act was again amended to form Central Transmission Utility and State Transmission Utilities. And finally, Electricity Act was enacted. This was, in fact, the major. You know after that implementation of Electricity Act the major changes took place.

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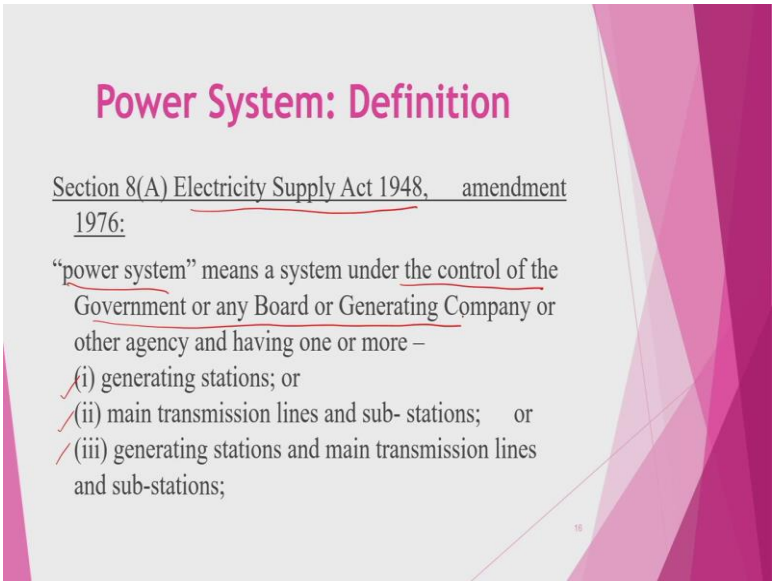

Now, what are those changes? You can see according to this Electricity Act 1948 the definition of power system if I go through the text is, power system means a system under the control of government or any board or central generating company or other agency and having one or more- generating station transmission lines or substations and generating station and main transmission lines and sub stations.

So, if you look at the main keywords for this particular act you will see that power system means, it is a system under control of the government or any board of the generating company.

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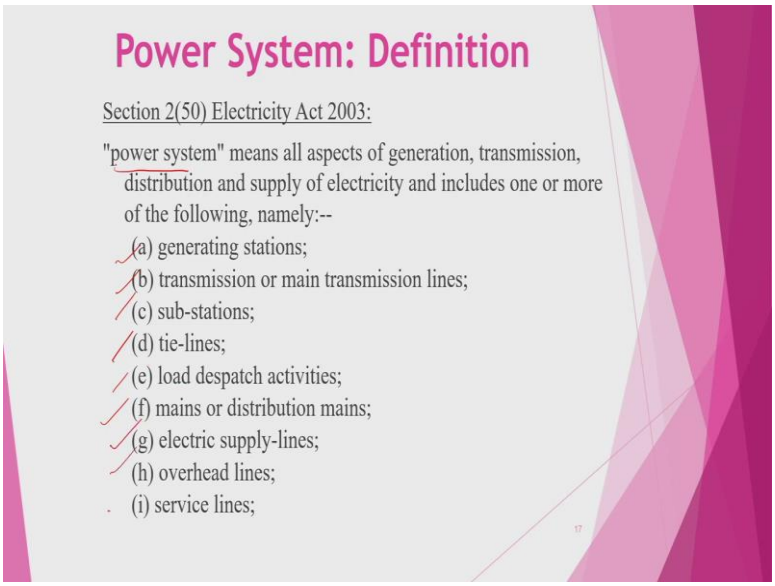

Now, if you look at the definition of power system which was changed in after implementation of Electricity Act 2003. Then you will see, if I go through the text again you will find that a power system means all aspects of generation, transmission, distribution and supply of electricity and it includes one or more of the following namely generating station, transmission, sub-station, tie lines, load dispatch, distribution system, electric supply lines, overhead lines, service lines.

So, there is, if you go through this text, you will get the idea of the major difference between these two Electricity Acts. And that will facilitate you what sort of major changes took place.

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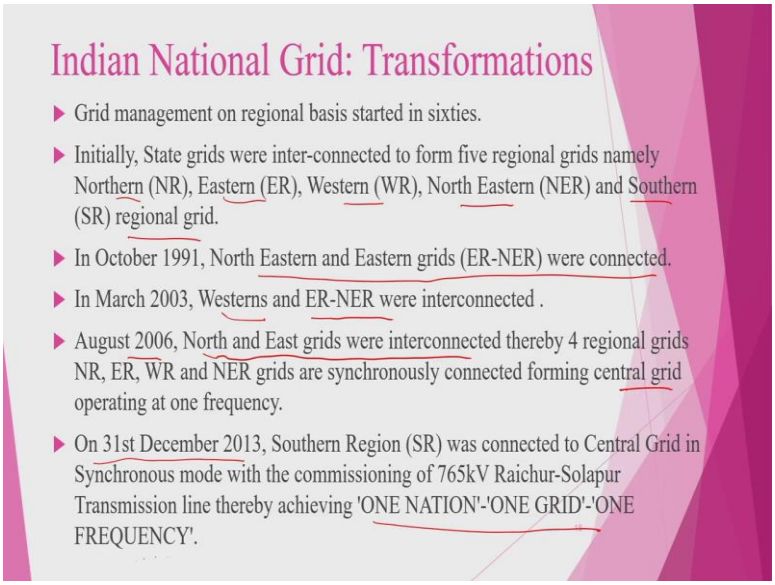

Next, I will show you how Indian National Grid was transformed. Firstly, as I said a state level electrical utility board was developed. Then, one state was started interconnected with the other state and there was a formation of 5 regional grids which include Northern grid. All these state electricity boards of northern part of the country were integrated, then Eastern grid, Eastern regional grid, Western regional grid, North Eastern regional grid and Southern regional grid.

In October 1991, North Eastern and Eastern grids were interconnected. So, this starts the interconnection of these regional grids. First, North Eastern grid was interconnected with Eastern grid. Then in 2003 March, Western grid was interconnected with now Eastern grid and North Eastern grid. In 2006 North and East grids were interconnected and there were 4 regional grids, i.e., Northern grid, Eastern grid, Western grid and North Eastern grids were interconnected; they were synchronously connected. And, they formed a Central grid.

Then, afterwards in 31st December 2013, the Southern grid was interconnected to the Central grid and thereby this forms an interconnected Indian power grid “One Nation One Grid One Frequency”.

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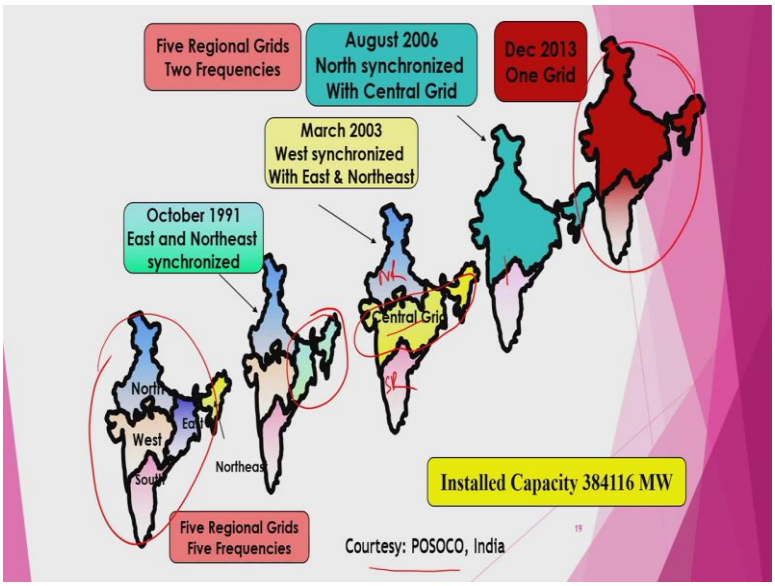

This figure will pictorially show you how this grid interconnection took place. So, I sincerely acknowledge that this figures I took from POSOCO website that is Power System Operation Corporation of India. So, you can see whatever I mentioned in my last slide this was pictorially shown in this particular slide. So, initially there were 5 regional grids. They were operated differently. Then you know in Eastern and North Eastern were integrated. Then you know Western grid was integrated to form a Central grid.

That time 3 grids were operating one is Northern grid; another is Central grid; another is Southern grid. And then finally, Northern grid also joined with this Central grid and then on December 31st 2003 this Central grid was connected with the Southern grid and this forms a one grid, one frequency of the country.

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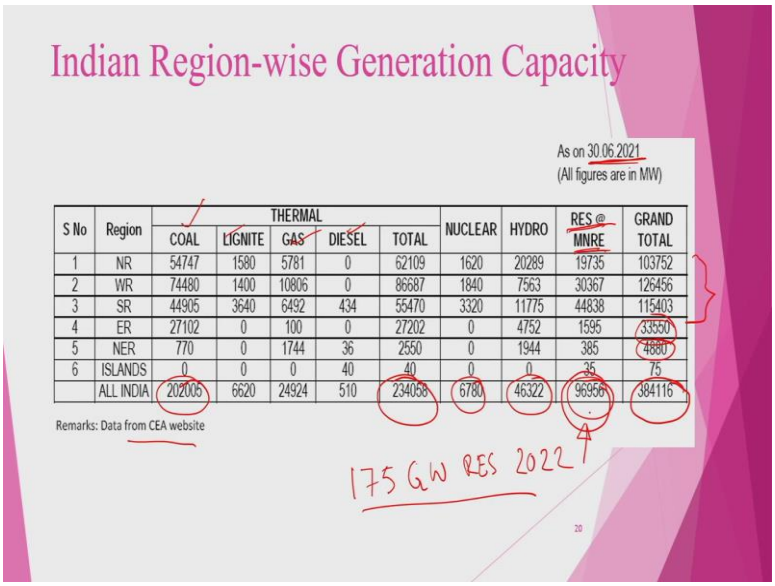

S No	Region	THERMAL					NUCLEAR	HYDRO	RES @ MNRE	GRAND TOTAL
		COAL	LIGNITE	GAS	DIESEL	TOTAL				
1	NR	54747	1580	5781	0	62109	1620	20289	19735	103752
2	WR	74480	1400	10806	0	86687	1840	7563	30367	126456
3	SR	44905	3640	6492	434	55470	3320	11775	44838	115403
4	ER	27102	0	100	0	27202	0	4752	1595	33550
5	NER	770	0	1744	36	2550	0	1944	385	4880
6	ISLANDS	0	0	0	40	40	0	0	35	75
	ALL INDIA	202005	6620	24924	510	234058	6780	46322	96956	384116

Now, this figure again I took it from Central Electricity Authority website CEA website. These figures give you some statistics. This data will give you some statistics of the overall generation capacity of India. So, it is around 384 gigawatt, i.e., 384000 megawatt in total and this data is very very up to date, i.e., on 30th June 2021. But, as you can see the individual generation capacity of different regional grids you will see, they are not symmetrical.

So, particularly this northern region, western region, and southern region they are having a bit higher capacity more than 100000 megawatt and eastern region is having a capacity of 33000 megawatt and north eastern region is only having a capacity of 5000 megawatt. And, this also gives you the statistics of different types of power generators we have in our country, one is you know coal based power generating system which is dominating the major share. Out of this 384 gigawatt, 202 gigawatt comes from this thermal power.

And also we have more than 202 gigawatt, if you consider other small thermal power generating unit like, gas, diesel, and lignite. So, it is around 234 gigawatt of capacity as a whole in India coming from thermal power generation. Then, we have a small power generation capacity in nuclear as well that is 6780, we have around 46322 megawatt of hydro capacity, around 46 gigawatt. And the renewable energy RES stands for renewable energy source which is supervised by ministry of renewable energy government of India.

They are having almost 100000 megawatt of generation capacity and they are growing fast. Because as you know, that government of India took an aggressive plan to increase the renewable capacity and they have a target of integration of 175 gigawatts of renewable energy source by the year of 2022. So, till now we achieved almost 100 gigawatts and another 75 needs to be integrated ok, at least to fulfil that particular goal.

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This is the plot of typical power demand. In fact, this is the load characteristics of all over India on 30th June 2021. You can see that vertical axis is basically representing this power demand in terms of gigawatt and this horizontal axis is representing time. As you know load in fact, in my first module I will talk about this load modelling. You will see that, load is a parameter which changes time to time and this time varying nature of this load of all over the country is shown over this particular characteristic. We call it is a load curve. I will discuss in detail.

You will see only one thing that on June 30th 2021 the peak power demand of this country was around 190 gigawatt and this is one of the largest power grid of all over the world.

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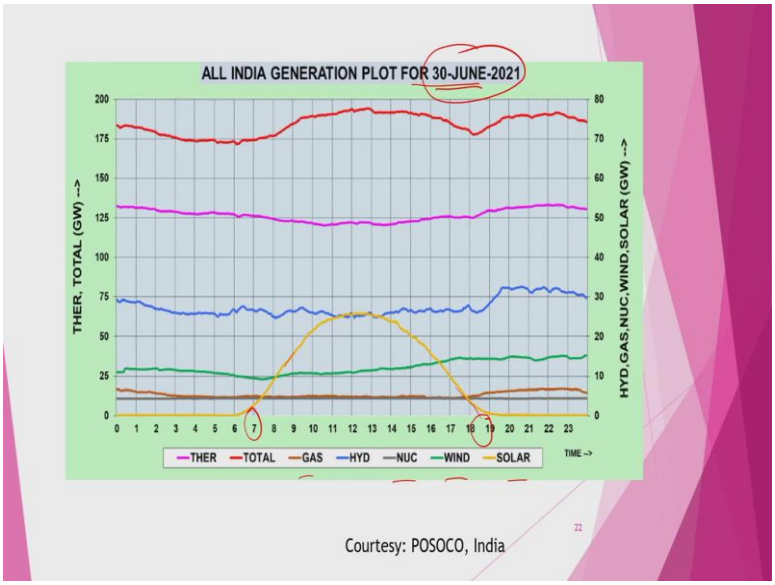

So, this is the figure and it provides you the data of the generation of power on 30th June 2021. As we know that we have different types of generation which includes thermal, which includes gas, which includes nuclear, which includes wind and solar. So, they have their individual generation characteristics; for example, the solar generation only can take place from the 7'o clock in the morning to maybe, since it is you know taken in 30th June that is during summer of this country, So, this will generate up to 6'o clock in the evening.

So, this generation is completely based upon the solar irradiance or solar insolation level. So, they are variable of course. I will discuss this in detail in my later lecture. And other types of generations are also provided. This thermal power generation which is controllable or which is dispatchable, so, how it needs to vary? And similarly the wind also how it is varying? All these things you can get from these particular characteristics.

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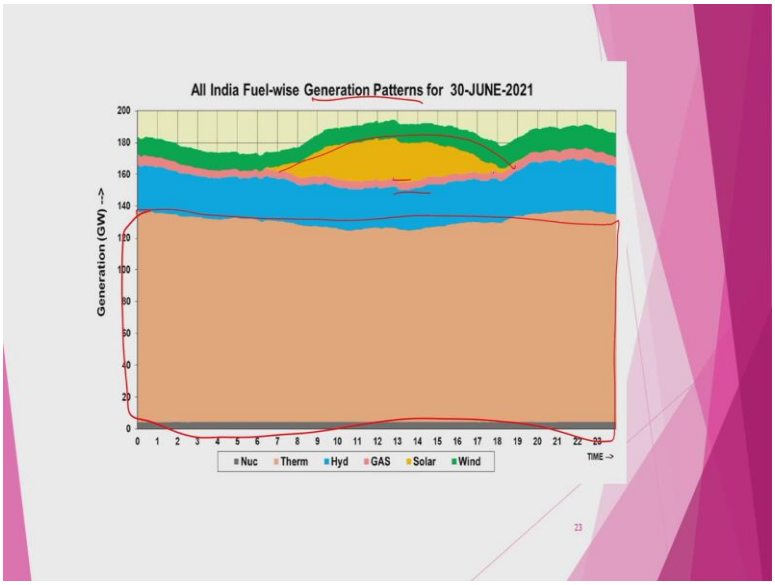

So, this gives you again a better view of the generation pattern of this country. So, mostly it is you know thermal power based. So, this is what amount of thermal power generation; then we have hydro; then we have small gas based power plant and solar. Again its characteristic is varying from 0 to 0 during daytime only. And also we have a time varying nature of wind generation of the country.

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So, finally, I will end this lecture with showing you this references or data sources because lot many statistics I gave in this lecture. So, I sincerely acknowledge this data from the Central Electricity Authority website, Government of India and Power System Operation Corporation Limited, i.e., POSOCO.

Thank you for your attention.