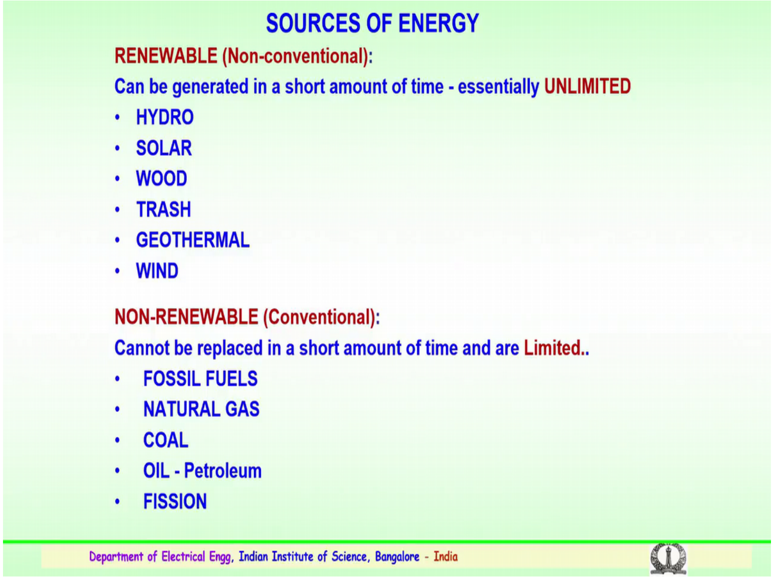
Advances in UHV Transmission and Distribution

Prof. B Subba Reddy
Department of High Voltage Engg (Electrical Engineering)
Indian Institute of Science, Bangalore

Lecture – 01
Advantages of HVAC/DC Transmission, Introduction to Grid Management

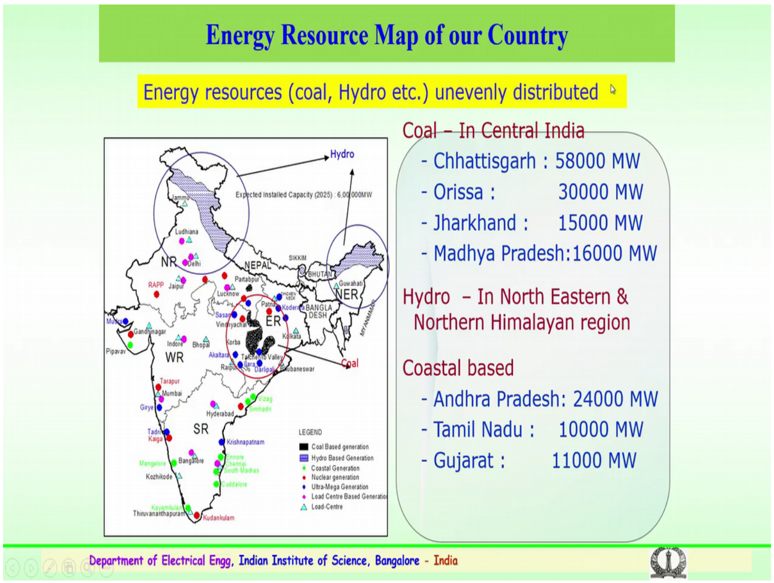
Welcome to the course. We were discussing about the syllabus and references to be looked in to the course.

(Refer Slide Time: 00:38)



So, I would I like to have a quick look at the various resources which are available for the energy conversion. So, we have categorized in to 2 divisions, renewable sources which are basically non-conventional. These can be generated in a short amount of time. And these are essentially unlimited; so abundantly available. So, the resources come under this category are hydro solar wood trash geothermal wind etcetera, all these come under the category of renewable energy sources. We have other category non-renewable or a conventional type of sources. These resources cannot be replaced in a short amount of time and they are basically available in unlimited way.

(Refer Slide Time: 01:39)

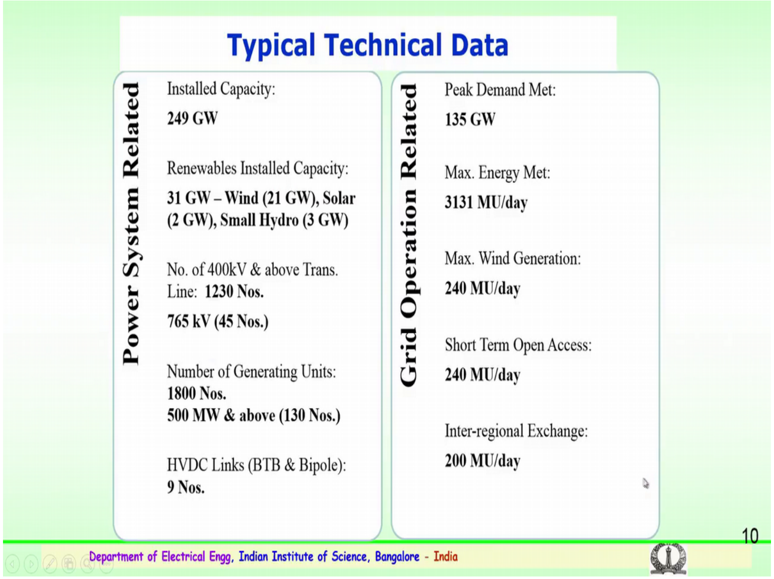


So, these are fossil fuels, natural gas coal oil petroleum and the sources because of the fission. So, these are some of the energy sources which are being used for the generation of hydro electricity. So, further the available resources which in the country referring to the major energy resources, this map show the entire sources resources are available in our country.

So, basically like coal hydro etcetera. These resources you can see over map of the country. So, we have abundant resources particularly in the Northern part of the country like Punjab- Northeastern areas. So, where we have hydro potential we have resources which are in the places like Jharkhand Orissa Chhattisgarh and parts of Madhya Pradesh where abundantly coals is available that is in some parts of central India. So, hydroelectric generation can be done in Northeastern and North Himalayan. Region coastal based generation is also available in the parts of Andhra Pradesh Tamil nadu and Gujarat. So, this is the spread of the energy resource resources.

We can look in to the map and see that all the resources are unevenly distributed across the country. So, the generation is limited to an area may be thermal may be hydroelectric may be nuclear. So, these generations of the voltages which is being taken is to be transmitted to a far of distances from one region or one place to the longer with to a longer distances places which are of very further away.

(Refer Slide Time: 03:23)

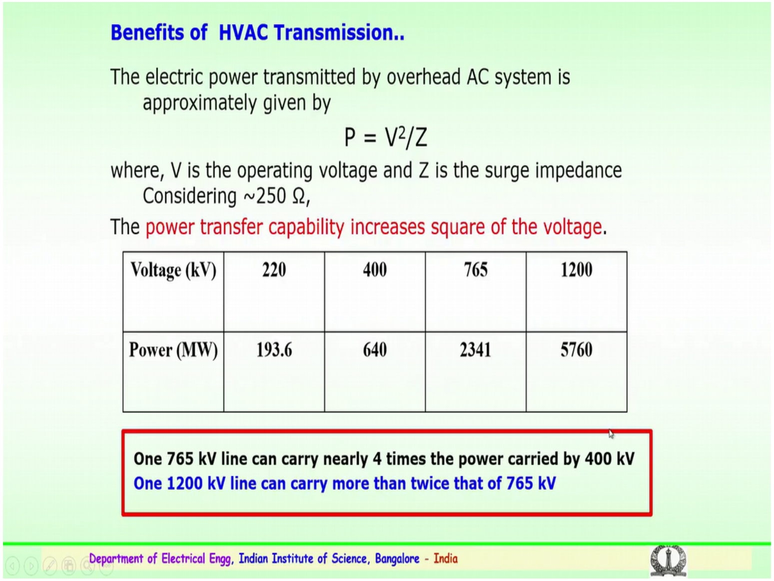


So, for this we require the transmission which is a very important component after the generation. So, for long distance a transmission it is advantages to going for the high voltage AC or high voltage DC transmission. So, before going in to the advantages or benefits of high voltage AC or DC transmission, let us look in to the typical technical data which is available. So, these data is of current which is being available which is being lo which is being available in the country.

So, installed capacity is being somewhere around 250 giga watts, the peak demand met is 135 giga watts. We have a re renewable installed capacity which consist of solar wind small hydro which is of 31 giga watts in case of wind solar being 2 giga watts, small hydro being around 3 giga watts. So, presently we have around more than 1230 transmission lines at 400 kb operative and more than 45 transmission lines which are operating it 765 kilo volts.

So, we have number of generating units more than 1800 and which are of 500 mega watts and above are of 130 numbers. So, apart from this AC we also have a high voltage DC links which are both type that is back to back and bipole in nature these are of 9 numbers. So, this is the data and the demand which is met from the grid operation related is the peak demand is met is around 135 giga watts. We have maximum energy which is met per day is around 3131 million units per day. So, maximum wind generation is above 240 million units per day the short term open access which is available is around 240 million units per day. So, the integrated regional exchange is around 200 million units for that is the typical data which has been obtained from the central electricity authority or the power grid government of India.

(Refer Slide Time: 05:45)



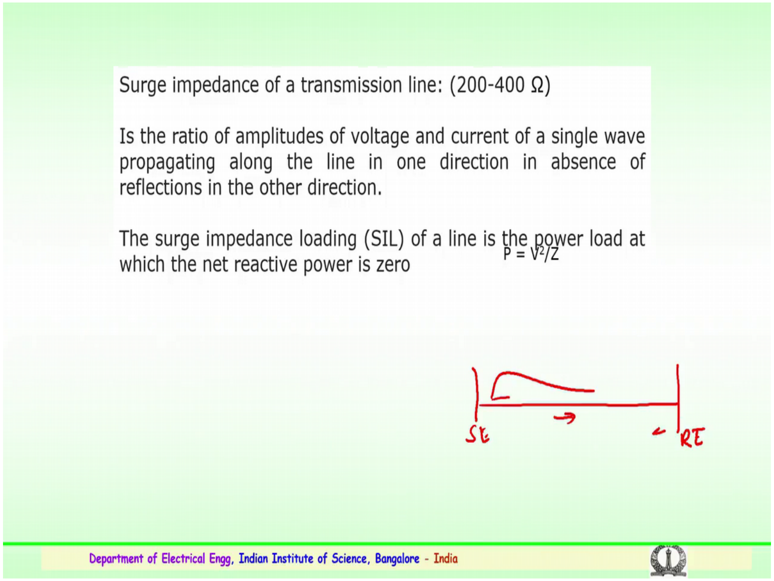
So, we were looking into the benefits for long distance and we have a generation may be hydro nuclear thermal at particular location the power has to be transmitted to a far of distances. This is being done because you where looking in to the resources available the resources are at a particular place, the transmission has to be carried out over a large long distances.

So, the benefits for going in high voltage AC transmission is here we can see that the electric power transmitted by over head AC system is approximately given by formulae P is equal to V square by Z where P is the power V is the operating voltage at particular voltage level and Z being the surge impedance of the transmission line the Z the surge impedance. We will be discussing in the next slide- what is exactly the surge impedance of a transmission line.

So, just consider typically normally in the transmission lines the surge impedance is taken anywhere between 250 to 400 ohms. So, considering for the present case for a long distance transmission for surge impedance of 250 ohms; the above formulae in case of a voltage level for 220 KV. We get a power of 193 point approximately 194 mega watts in case for a voltage level of 400 KV, we get 640 mega watts for voltage level of 765 KV transmission, we get the power of 2341 mega watts. So, for 1200 KV 5760 is the power which is being transmitted by the high voltage lines.

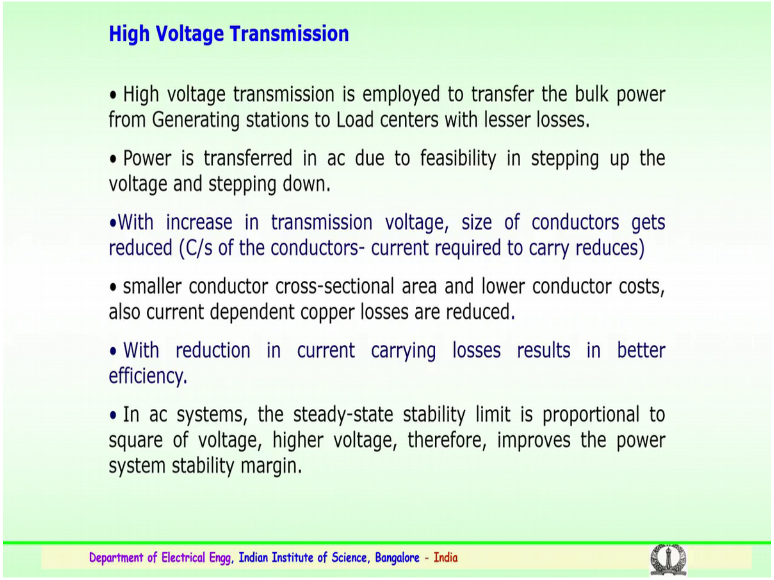
So, by looking in to the table we can very clearly see 1 765 KV transmission line can nearly carry transmit 4 times the power which is being carried by a 400 KV transmission system and 1200 KV line can carry more than twice that of 765 KV transmission line. So, it is very clear from these data that going in for a very high voltage AC transmission is much more economical.

(Refer Slide Time: 08:24)



So, surge impedance of a transmission line as I was mentioning, normally it is taken between 250 to 400 ohms 250 to 400 ohms. Basically the surge impedance is the ratio of amplitudes of voltage and current of a single wave propagating along the line in one direction. In the absence of reflections in the other direction, it is simple that if there is a sending in we have a receiving end. So, the amplitude of voltage and current of a single wave which is propagating towards one direction, and reaching the receiving end without any reflections from the receiving end the absence of reflection. So, this surge impedance is known as surge impedance the surge impedance loading are the SIL of a line is the power which is load having a load at which the net the reactive power is 0.

(Refer Slide Time: 09:54)

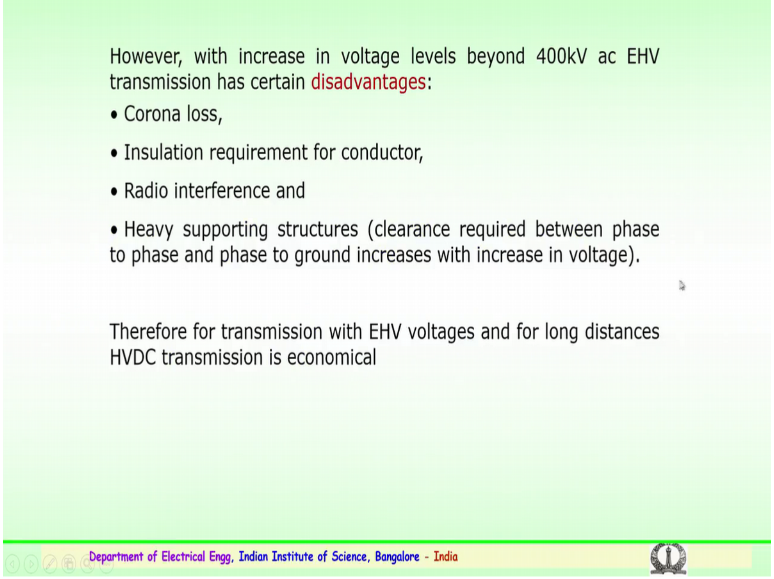


So, with this importance of high voltage transmission we have this is being high voltage transmission, we have this is being high voltage transmission is being employed to transfer the bulk power from the generating station the generating stations may be as mentioned earlier may be nuclear thermal hydroelectric renewables etcetera. From the generating station to the load centers again the load centers may be industry may be domestic use or may be agricultural purpose.

So, with lesser losses is the intension for going for high voltage transmission. Here the power is transferred in AC due to feasibility in stepping up the voltage and also stepping down. So, we have the advantage particularly when we going for AC transmission. Then with increasing in transmission voltage also the size of conductor that is a diameter of the conductor gets reduced that is the cross section of the conductors gets reduced and the current required to carry also reduces, because of the voltage is being transmitted in very high voltages.

So, this implies that the smaller conductor that conductor dia when it becomes smaller the cross sectional area and also the lower cost for the conductor and the current dependent which the copper losses are also reduced because of the size of the conductor. So, with reduction in current carrying the losses results, which are lesser, will result in a better efficiency for going in for high voltage transmission. So, in AC systems we all know that the steady state stability limit is proportional to the square of voltage. So, as the higher the voltage therefore, this improves the power system stability margin by going in for high higher voltage transmission systems.

(Refer Slide Time: 11:54)



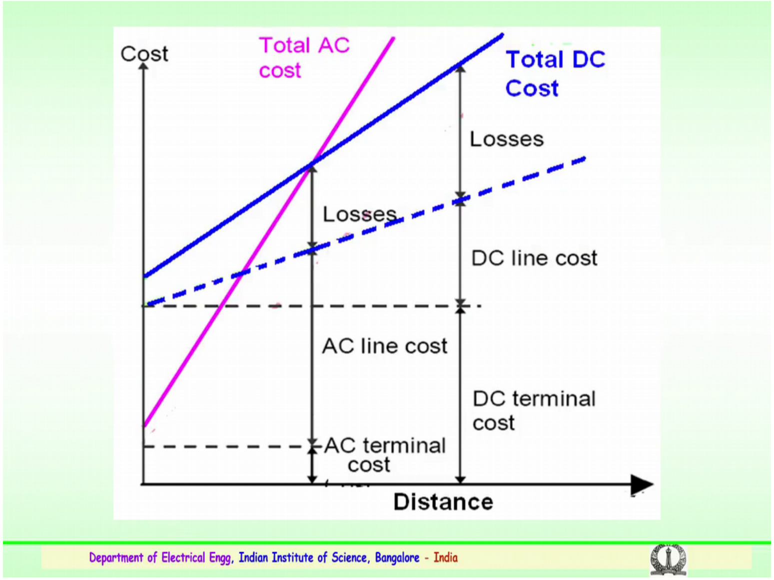
However, with increase in voltage levels beyond 400 KV of the transmission that is particularly for AC extra high voltage EHV extra high voltage transmission has certain limitations or disadvantages.

So, they are basically the corona losses, we will be discussing about the corona losses. This corona loss happens because of the conductors or a transmission hardware insulator hardware connecting clamps many of these, things the insulation requirement for the conductor has to be properly designed then the radio interference, because of the conductors which are operating in the environment. This radio interference is the discharges which are seem at 0.5 to 2.5 megahertz range. The discharges which are emitted from the conductor at the voltage levels above 400 KV can disturb radio sets which are operated near by the transmission lines.

So, these have to be content to a level. So, we will be discussing about the radio interference and corona losses. Apart from that going in for 400 KV AC above we have to have a heavy supporting structures, where the clearances are required between phase to phase conductor phase to ground conductor depending upon the increase in voltage. Therefore, for transmission with EHV that is extra high voltages and for long distances

HVDC line is becoming more economical high voltage this a lines are becoming more economical and or being adopted across the globe.

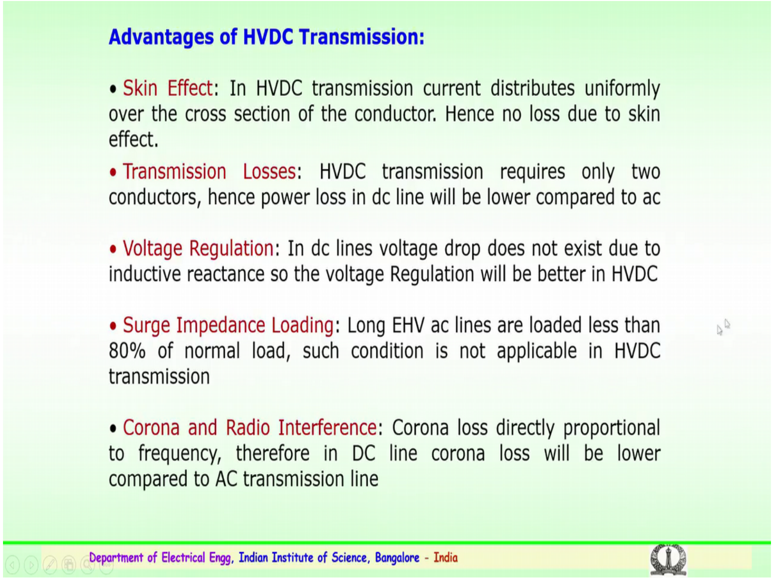
(Refer Slide Time: 13:45)



Just before going to the slide I would like to mention the high voltage when we talk about the high voltages. So, where exactly is the high voltage defined? So, when we see the international standard 6 0 0 6 0, it very clearly mentions any voltage above 1000 volts 1 0 0 volts is stated as high voltage in case of AC, and 1400 volts and above is stated as high voltage DC. So, this we have to bear in mind. The graph which is being displayed here gives the cost verses the distance is a very important graph, where it gives an indication of which when we are going in for HVDC transmission or HVAC transmission which is more economical. This is very clear in that we can see that the pink line displays the total cost for the AC transmission lines the blue line gives you the total cost for the DC transmission lines. So, you can very clearly see the distance at a typical joint this point is at a distance of 400 kilo meters.

So, comparing at a distance 400 kilo meters for both AC and DC, we see that the AC terminal cost are very less in case comparison to the DC level which as much higher. The losses component you can see the DC losses comparison of DC and AC losses, but ones after the 400 KV transmission 400 kilo meters distance increases the DC line becomes much more economical you can see the AC line going in a very leaner fashion. So, before 400 kilo meters AC is much cheaper, after 400 kilo meters DC becomes much economical. So, it is advisable to go in for DC long distance lines in case the (Refer Time: 16:19) of power is to be done over a long distances.

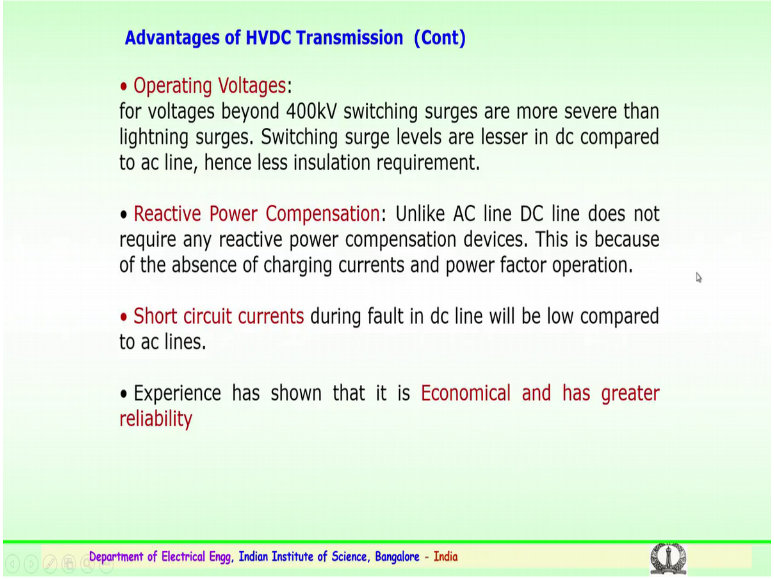
(Refer Slide Time: 16:17)



So, DC HVDC is advisable the main advantages of high voltage DC transmission. The first one is the skin effect we know that in HVDC transmission current distributes uniformly over the cross section the conductor. So, hence there are no losses and there is no skin effect which is present in case of AC transmission. And in HVDC transmission requires only to conductors the power loss; hence will be lower in case of DC line compare to the AC transmission losses which are seen for AC lines. In case of voltage regulation for DC lines the voltage drop does not exist due to the inductive reactance.

So, the voltage regulation will be much better in case of high voltage DC. Then surge impedance loading for long EHV AC lines you know that extra high voltage and ultra voltage AC lines are loaded less than 80 percent of the normal load because of the surge impedance loading. So, this condition will not be applicable in case of long distance or EHV and UHV HVDC transmission system, the corona and radio interference as mentioned corona losses which are directly proportional to the frequency. Therefore, in DC corona losses are much lower compare to AC line this has been studied a lot and lot of literature has been available pertain in to this view.

(Refer Slide Time: 18:05)

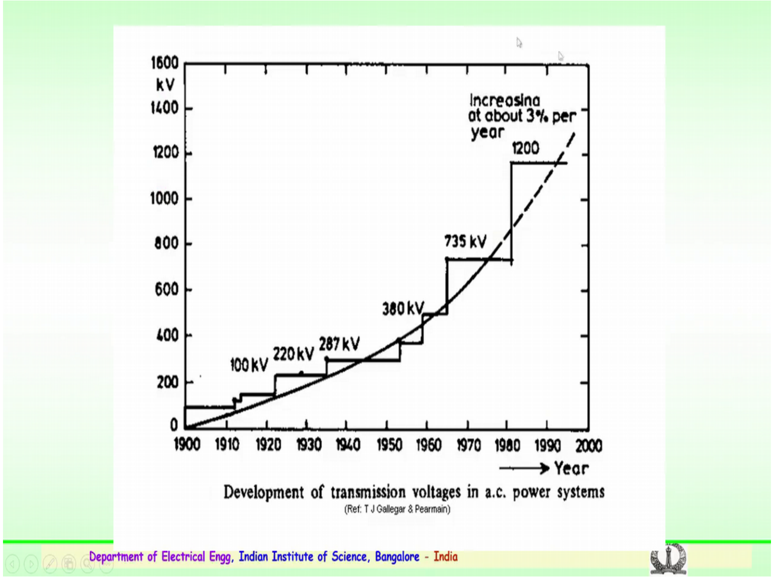


So, the operating voltage is particularly for 400 kilo volts and above, we all know that apart from lightning and normal power frequency voltages switching surges or switching impulse voltages are more severe than the lightning surges.

So, switching surge level is lesser when compare to DC with comparison to AC line. Hence the requirement of insulation for the DC line gets reduced. So, the next is the reactive power composition compensation unlike AC transmission line, DC line does not require any reactive power compensating devices. So, this is because of the absence of the charging currents particularly in DC and the power factor operation so much more economical or much more advantages than HVAC system. Then short circuit currents particularly during fault in DC line are seem to be lower compare to the AC line with the experience.

So, for the last many years even in the country and many other places where HVDC lines have been adopted have been commissioned have been having the experience have shown that, it is much more economical and we also has a greater reliability in comparison to the HVAC particularly for long distance and bulk power and more power transmission.

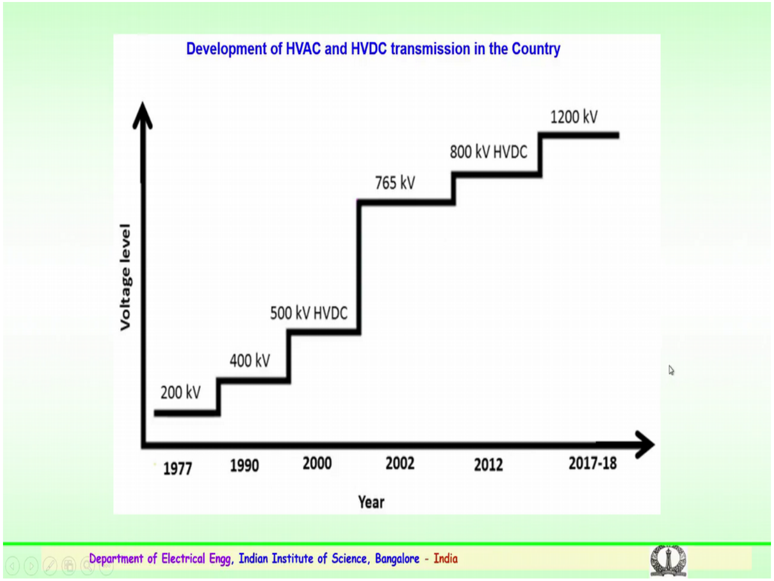
(Refer Slide Time: 19:43)



The graph shows the development how the transmission voltages particularly in case of AC power systems have happened since 1900.

We can very clearly see over a century a 120 years the growth of power has started from very low voltage and across the globe reached 1200 KV and increase of about 3 percent per year approximately has been witness across the globe. So, this is across the globe. So, we would like to see that how the growth of the transmission voltages particularly from both AC and DC as seen the rise in our country.

(Refer Slide Time: 20:29)

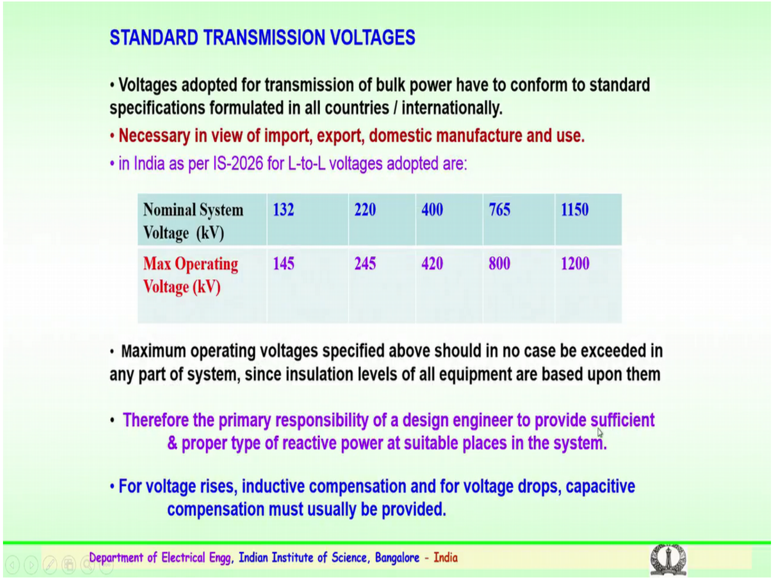


This graph shows the development of high voltage AC and high voltage DC transmission in our country. So, we are not lacking in terms of a transmission of at the higher voltages when comparison to the international internationally. So, this graph very clearly indicates we shows the voltage level verses the year, which has been the development has taken place we can very clearly see somewhere in 1970s we had the first 200 KV transmission the ninety we had in 80s or mid 80s 400 KV transmission which has come latter HVDC has been adopted in nineties or late 90s.

Then further in end of the 95 to 98 a lot of experimental work have been carried out for 800 KV that is the 760 65 KV operating voltages. So, the line first line in the country from Kishanpur to Moga was commissioned somewhere in 1998 where 765 KV transmission network was established the country further 800 KV high voltage DC. So, earlier 500 KV HVDC was in operational from 1980 1995 onwards. So, the country graduated somewhere around 205 to 206, 2006 800 KV HVDC further recently we are having 1200 KV AC experimental line that is being presently experimentation in a large scale is being conducted at the power station which has been established by the government, and also with the help of the private and public sector companies. So, the experimental line is stay is been established at bina in Madhya Pradesh.

So, where experimentation for 1200 KV transmission system including the transformer circuit breaker transmission components insulators many of these things are being carried out. We hope at the very early 1200 KV transmission system or lines will be established in the country and we will be seeing the 1200 KV of transmission towers being erected across for the long distance at transmission soon.

(Refer Slide Time: 23:05)

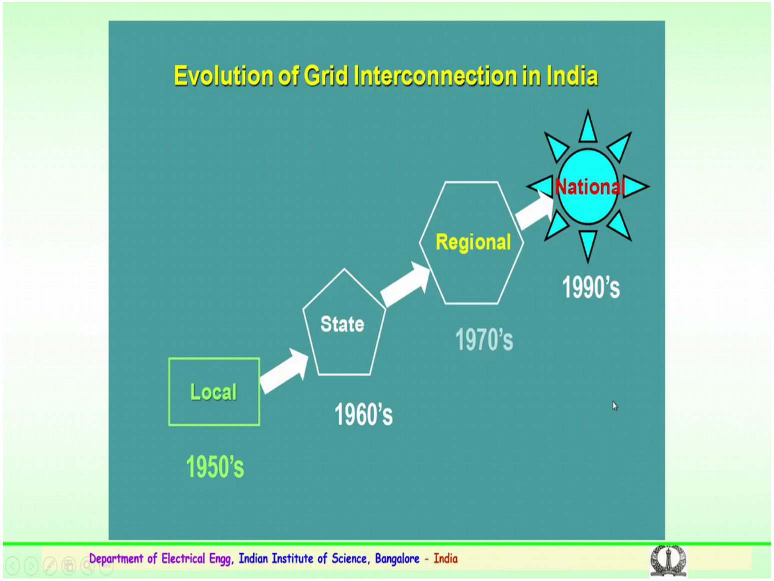


So, these show the standard transmission voltages. So, when the transmission voltages which have inception have started somewhere from a very low voltages and we have raised up to 1200 KV in case of AC and plus minus 800 KV in case of HVDC. So, there should be some standard which has to be followed, both nationally and internationally. So, that it is beneficial to the utilities beneficial to the manufactures and the design engineers. So, keeping this in mind the voltages which are adopted for transmission particularly for bulk power transform how to confirm to the specifications formulated by many international standard groups in countries. So, that it is beneficial to every utility and manufacturer.

So, necessary this is also necessary in view of the import export and domestic manufactures design and use. So, in India we as per is that is international standard 2026 these are the following line to line voltages, which are adopted for the high voltage transmission system. So, nominal system voltage for 132 KV the maximum operating voltage will be 145 they insulation lev level will be designed in case of 130 KV system the maximum insulation will be designed for 145 KV for the components which are being operated at that voltage. So, similarly for 200 and 20 KV 245 is the maximum operating voltage and for 400 a kilo volts 400 and 20 KV is the maximum operating likewise 765 KV nominal AC voltage the operating maximum operating voltage will be 800 KV and similarly for 1200 KV maximum operating voltage 1150 is the nominal operating or nominal system voltage which is being standardized.

So, the maximum operating voltages are specified as shown above in no case these should be exceeded in any part of the system because the insulation levels of any equipment the design of the equipment are based upon these voltage levels. So, therefore, the primary responsibility of any design engineer is to provide sufficient and proper type of reactive power at suitable places in the transmission system.

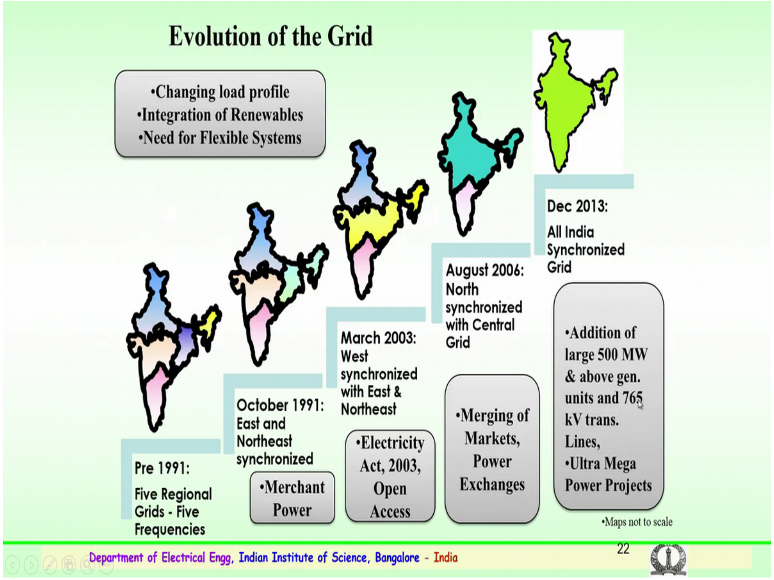
(Refer Slide Time: 25:51)



So, in case of voltage rise and inductive composition for voltage drops capacity compensation much suitably we used. So, that we have see in the voltage levels up to 1200 KV standardized. So, before going in for the country how it has been progress; how we have reach the 1200 KV transmission systems, how the evolution of grid can inter connection India happened. So, way back in 1950s there were local generations the local generation again it may be of ideal it may be of local or thermal plants or other resources. So, this local grid formations happened in 1950s further several of such things were thought that at a state level are the resources should be pulled and a grid should be maintained well the distribution could be made for the entire state this concept was thought in 1960s, then the concept of regional grid inter connections was thought.

So, in 1970s a regional grid concept was consider and India were made in to 5 regional grids and many states which are coming in that particular region got were made to at particular region and these are 1970s the regional grid concept was thought. Further in 1990s thought was made that entire nation should have a single grid this will be much beneficial for the country in terms of operation and much to cater the needs for the entire country.

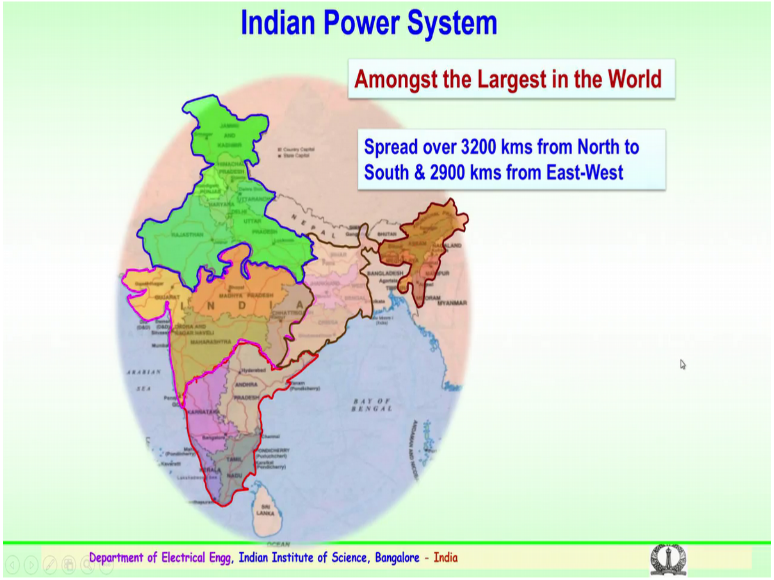
(Refer Slide Time: 27:31)



So, looking back at the evolution of the grid how it happens because this is required depen for the changing load profile and also the integration of renewables particularly with the other sources like hydro nuclear and thermal. So, there was need for more flexible in the system. So, as mentioned pre 1991 earlier 5 regional grids where form and these 5 regional grids where operating at particular frequencies and somewhere in October 1991, 1991 East and North grids where synchronized and where seen that the 4 grids were formed out of 5 the regions the 4 regions were made. Further in 2003 a thought was made and 2003 is an important year particularly for the electricity act it is a very important act.

Where this was very clearly mentions about the inclusion of the private partnership in the transmission and distribution system and many regulations and rules were formed in the electricity act and subsequently lot of amendments have also been done. So, further in august 2006 the other 2 grids were synchronized with the central grid and India became a 2 grid a well system. So, lot of advantages than it was designed it was thought that a single grid which we much economical and much beneficial to the country.

(Refer Slide Time: 29:44)



So, this happened in December 2013 the all India synchronized grid happened with the addition of 500 megawatts and above generating units of 760 KV transmission line from the Karnataka to Maharashtra where we had a single grid single operating grid with single one grid one nation concept was achieved. So, looking at the Indian power system presently we are amongst the largest in the world one among the largest in the world there are around 6 or 7 countries which have a large power network.

So, India also becomes one in the group of the largest operating power system network group. So, this here the spread over 3000 kilo meters from the North to the South of the country for Jammu to the Kerala and East from Gujarat to North-East Bihar around 2900 kilo meters; so this is the spread of the transmission network system in the Indian power system very large complicated network system consisting of 130 kilo volt lines 220 kilo volt lines 400 kilo volts 765 KV AC lines then 500 plus minus HVDC and 800 plus minus HVDC transmission systems.

So, this is the typical map which shows the spread. So, before going in for the details of the transmission system the important factors have to be considered before designing any insulation. So, the factors which are responsible particularly for the insulation design or the voltage levels up to 4 kilo volts the mechanical clearances are the important to be considered that is from the high voltage to the ground the design is made depending upon the mechanical clearances.

Further 4 kilo volts to 33 kilo volts or 34.5 kilo volts a corona is a factor because of the discharges the corona is basically ionization near the (Refer Time: 32:02) conductor this corona happens because of the hardware or a transmission conductors in case of the sharp edges so on. So, this has to be taken care before designing the insulation. Above 66 KV the lightning switching surges come in to the design criteria. So, where the transmission system above 66 KV to 200 and 20 KV lightning over voltages apart from the normal operating for frequency voltages, switching over voltages have to be considered.

Above 220 that is above 400 KV lightning switching apart from lightning switching we importance is the contamination or a pollution, which is a very important factor. So, lightning normal power frequency over voltages lightning over voltages because of the natural lightning switching surges this may happen because of the opening and closing of the circuit breakers, but contamination is a phenomena which is not because of over voltages it is because the phenomena of the flash over or the break down occurs at the normal working voltages.

So, this is a very serious implication to the transmission system. So, above 400 kilo volts of the contamination or a pollution criteria has to be taken in to consideration before design of the transmission line insulation. So, above 765 KV particularly for 100 or 1200 kilo volts' part from the major important insulating criteria is being the contamination. So, contamination is a very important criteria to be considered for the design aspect particularly, at EHV that is extra high voltage of a 400 KV and ultra high voltage is for 765 KV in case of AC or plus minus 800 KV in case of DC is a very important factor for the insulation design.

So, we will be looking in to importance of this contamination how the contamination or pollution affects the transmission system when we go further in the course.