Advances in UHV Transmission and Distribution
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Lecture - 23
Introduction to HV Substations

So good morning, we have discussed about various components and the importance of the transmission system by looking into the entire power grid.

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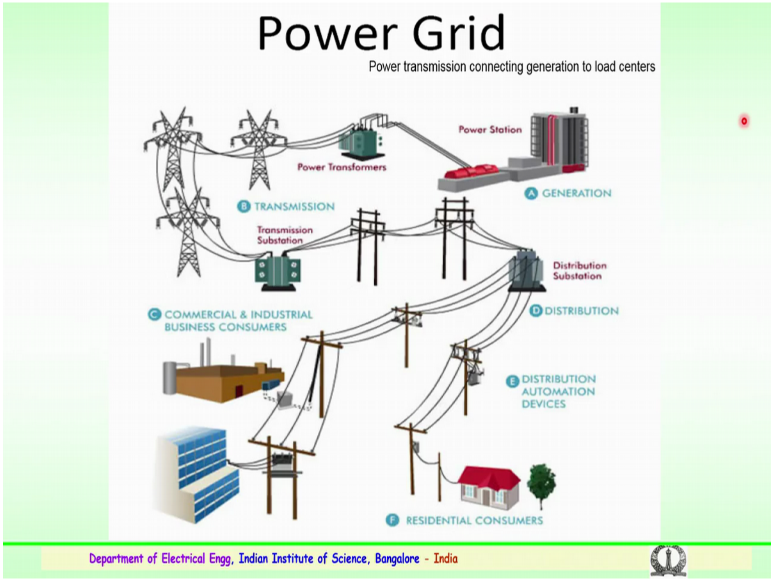

So, power grid consists of the generating the units, so the generating units again could be of thermal hydro nuclear or the renewables so on. So, here the generation of the voltages which are happened because of various resources, these voltages from the generating station are suitably stepped up using a step up transformer; that is a power transformers here. At desired voltage level, the transmission from the step up transformer is made through the towers consisting of the conductors, insulator, strings and which we have discussed.

So, this transmission could be from a lower medium voltage level to a very high voltage or ultra high voltage levels. Further, this power transmission depending upon the requirement it is (Refer Time: 01:25) a step down at various locations, it could be a transmission substation from a very high voltage to the next level of voltages or further it is again through the distribution substations, where the voltage level is step down to the requirement of the distribution networks. It could be of the industries or the commercial establishments or could be for the distribution of agriculture or domestic purposes.

So, this is how the power grid looks, so main intention is to see that the power which is generated at the transmission, at the generating station is economically transmitted to the load centers.

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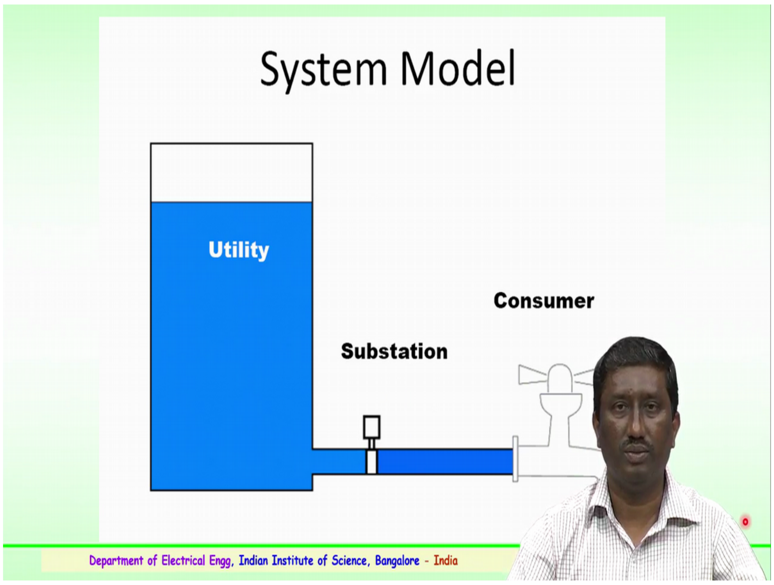

So, the system model when we look; we have utilities who are controlling the entire the network of operations. So, the main transmission utility from the generating to the transmission; you could think of a utility where is the main entity which is supplying the power.

So, from the transmission system as mentioned earlier we have a substation network. A substation where the voltage levels will be step down from the very high voltage levels and it will be effect to the customer as per the requirement; either industrial loads or the agriculture or the domestic loads, this is just a system model representation of the transmission, a distribution and reaching to the consumer levels.

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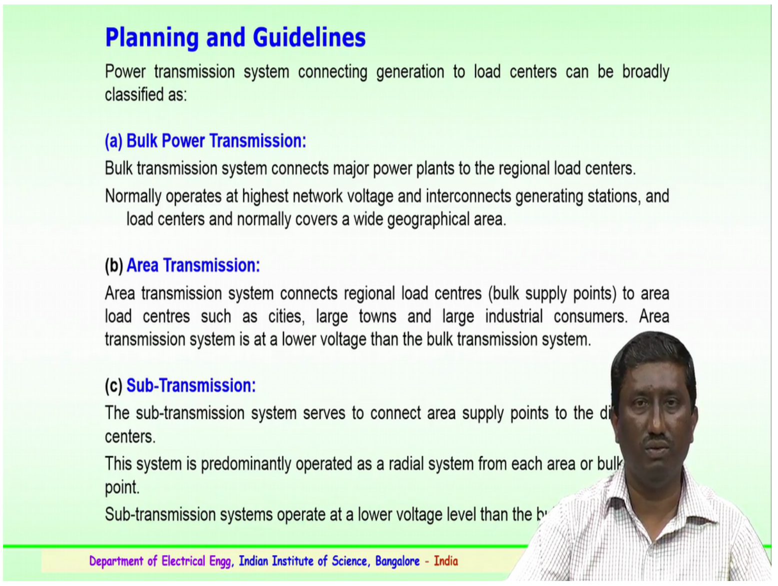

So, the planning and guidelines are very important in case of power transmission system because this have to be suitably planned and the load, generating; from this generating station to the load centers has to be properly and economically transmitted. So, the planning and guidelines for the transmission consists of the mainly three categories; that is the bulk power transmission, where the bulk transmission normally consists the major power plants could of thermal and nuclear or a hydro electric plants and the loads are supplied to the regional level and these bulk power transmission normally operates at a very highest network voltage, could be of extra high or the ultra high voltage levels.

And these bulk power transmission connects or inter connects the generating stations and the load centers and normally cover a wide geographical area; wherever wide area pertaining to some few states or it could be arranged in a very wide area. So, the next is the area transmission; area transmission system again consists of a regional level load centers that is both bulk supply points to the area load centers. This could be for the respective cities or large towns or large industrial consumers.

So, area transmission is slightly at a lower voltage than the bulk transmission system. So, in case the bulk transmission happens to be 400 or a 765 kV, the area transmission could be anywhere between 11 kV or 66 kV or 132 kV; depending upon the loads.

So, further is a sub transmission system where the sub transmission serves mainly to connect the area, which supplies the point to the distribution centers. The system is a predominantly operated either as a radial or in some of the cases as a ring system for each of the bulk supply points. So, the sub transmission systems usually operate at a lower voltages level than the bulk; so, the bulk and the area transmission. So, here it could be of 11 kV or lesser than; in case of domestic, it could be 440 volts where the 11 kV step down to 440 volts and so on.

So, these are the various power transmission levels which are been classified as per the planning.

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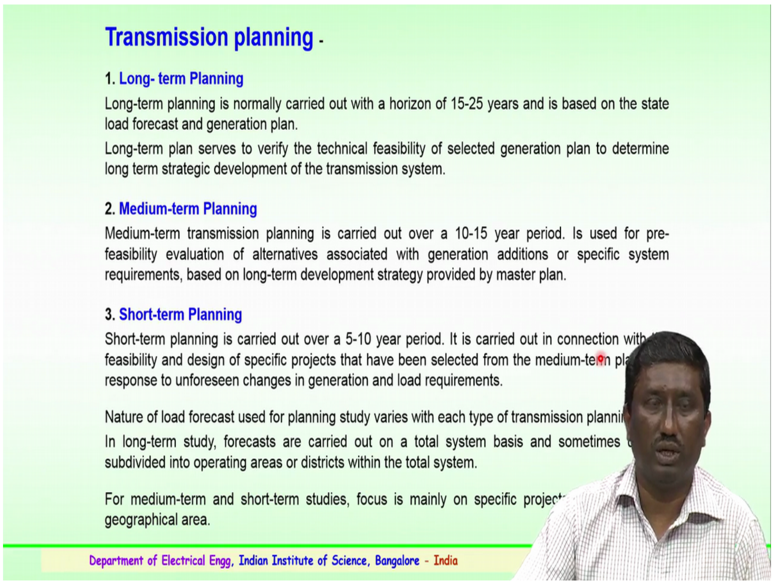

So, there for transmission planning; we have a three important aspects which are to be planned in case of a long term planning is essentially carried out with a horizon targeting for a 15 to 25 years and is based on the state load forecast and the generation plan for that area or that particular the region. So, long term plan service serves to verify the technical feasibility very important aspect of selected generation plan and this determines the long term strategic development of a transmission system.

The next is the medium term planning, the medium term planning is carried out anywhere between 10 to 15 years. The long term is 15 to 25; here it is a medium is for 15 years period and is used for the feasibility evaluation of any alternatives which are associated with generation in case of additions or a specific system requirements based on long term development strategy provided by the first master plan that is for the long term planning.

Then there is a short term planning; short term planning is usually carried out over the period of 5 to 10 years, over a short period of time. So, it is carried out in connection with the feasibility and design of a specific projects which have been selected from the medium term plan or it could be in response to the unforeseen changes where in the generation or the load requirements being changed or drastically going in for a change. So, the nature of load forecast used for planning study varies with each type of transmission planning. So, in long term study the forecasts are generally carried out on a total system basis and sometimes can be subdivided into operating areas or districts or within some total other system.

In case of medium term and short term studies, the focus is mainly on a specific projects; with a smaller geographical area. So, the short term planning is normally carried out for a very specific low or a smaller area and the medium is for the period of higher than 10 to 15 years. So, this is how the transmission planning is normally done.

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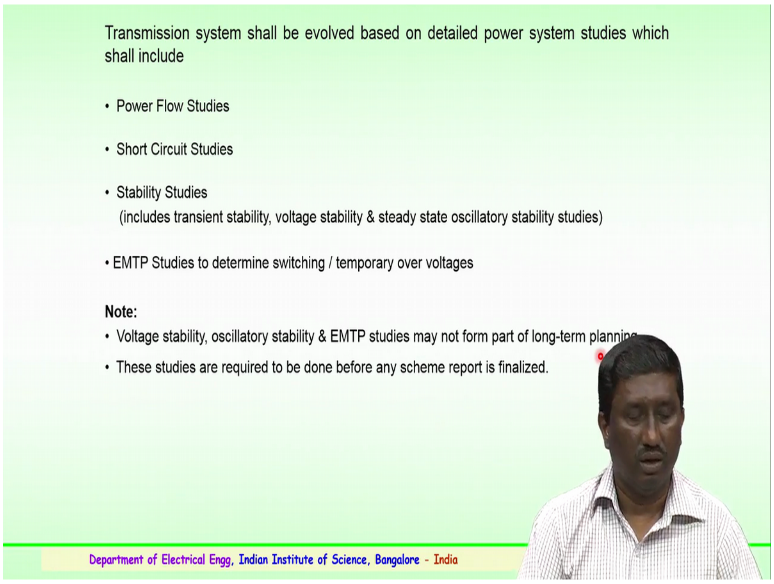

And this transmission system is normally evolved based on the detailed power system studies which include; so, any planning of the transmission or for the distribution, this pertinent studies have to be conducted. The studies like the power flow; study the short circuit, studies the stability studies. Again the stability studies include transient stability or voltage stability and the steady state oscillatory pertaining to stability studies.

Then software's like electromagnetic, transient, program studies to determine the switching or a temporary voltages will help to estimate or to forecast the planning of the transmission system. We should note that the voltage stability or oscillatory stability with the help of EMTP studies that the Electro Magnetic Transient Program studies which are normally used for the planning, may not form the part of the long term. So, these studies are required are essential to be done before any scheme report is to be finalized, which will give an idea for the proper establishment of the power transmission network.

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So, that was about the transmission activity and the transmission planning to be carried out. So, we will be focusing on the high voltage substations; we have looked into the transmission aspect of various types of the insulation requirement; the conductors, towers different type of towers which is used for the various voltage levels. Also the generating station to the load centers or through the towers, conductors, insulators several of components play an important role.

So, from the transmission to the distribution substation; the transmission is done and from the distribution locally the high voltage substations perform the next important role of the stepping up or stepping down the voltage levels from the transmission to the distribution and this forms an important part of the network; distribution network. So, we will look into the various issues and various importance components of the substations, the performance of various components in the substations and the necessary safety and necessary precautions to be adopted for the operating personnel in substations.

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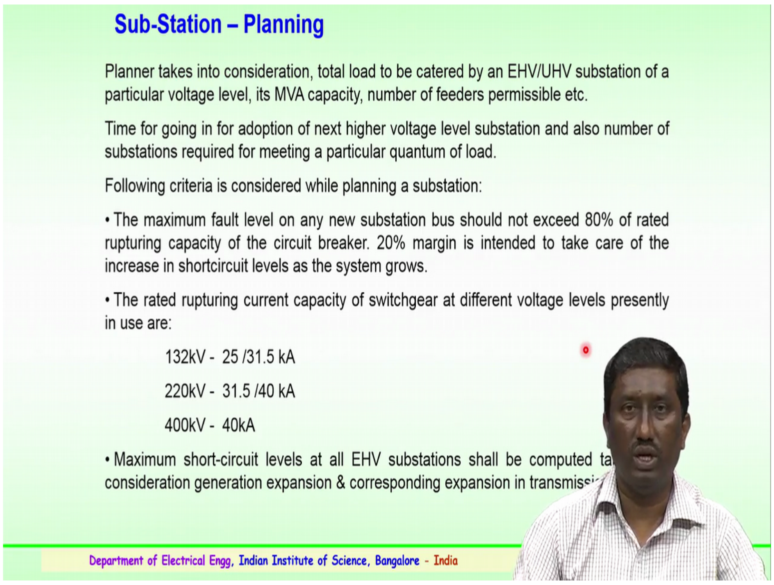

So, again substation planning is a very important tasks; similar to your transmission planning. Here the planning engineers have to take into consideration, the total load which is to be catered by an extra high voltage or ultra high voltage substation of a particular voltage level which is its operating. Then its MVA capacity and number of feeders which are permissible in that particular planned substation, so the time of particularly for going in for adoption of next higher voltage level, the substation and also number of substations required for meeting a specific quantum of load could also be estimated and planned for the future use.

So, all the criteria or the following criteria which is considered while planning for substation, which are the important is the maximum fault level on any new substation, bus should not exceed more than 80 percent of the rated rupturing capacity of the circuit breaker; very important point to be noted, which are to be considered while proper planning for the substation.

Then 20 percent margin is intended, 80 percent is for the rated rupturing capacity of the circuit breaker, 20 percent is intended to take care of the increase in short circuit levels; in case there is a future growth of the network. So, that is the reason this 20 percent margin is intentionally made available for the future scope. So, the rated rupturing current capacity of a switchgear at different voltage levels; which are presently being adopted for various voltage levels are as follows. For a 132kV system, the rupturing current capability will be 25 bar 31.5 kilo amperes and for a 220kV our substation, the rupturing capacity will be 31.5 or 40 kilo Amps capacity of the switchgear and in case of 400 kV, it would be 40 kilo Amps and further 800 and 765kV levels, it will be 40 kilo Amps or higher than the 40 kilo Amps level.

So, maximum short circuit levels at all the extra high voltage and ultra high voltage substation shall be computed taking into consideration, particularly the generation, the expansion in future and the corresponding expansion in the transmission network in the future years to come. So, this is how the planning has to be coordinated and planning has to be done.

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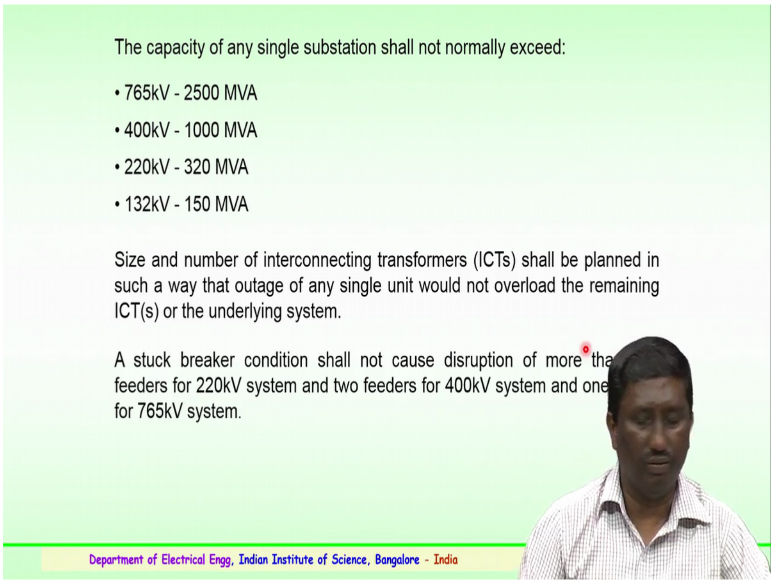

The capacity of any substation is normally prescribed as per the international and the national regulations, which should not normally exceed the prescribed limits of the megawatt level or MVA level of the substations. So, you can see here for a 765 kilo volt or 800kV transmission network, the substation capability is 2500 MVA of any single substation, should not exceed this value. For 400 kilo volts, it is 1000 MVA; in case of 220kV, it is 320 MVA is a peak, which is prescribed and 132kV substation it is 150 MVA.

So, the size and number of interconnecting transformers very important; this should be planned in such a way that outage in any single unit; even the number of transformers are in service, in case outage happens on in a single unit; this should not overload the remaining interconnected transformers or the underlying system that is the point to be considered and in case any of the breaker malfunctions or a stuck breaker condition in one of the breaker gets stuck or mall functions.

In such a condition this shall not cause disruption for more than four feeders particularly with respect to 220 kilo volt system or if the substation is 400kV, the breaker should not cause disruption to two figures in case of 400 and it should not cause disruption to even a single one feeder, if the operating is at 765kV or 800kV level. So, very important points to be noted for the planning and the capacity which any single substation is normally ah maintained has to be strictly followed.

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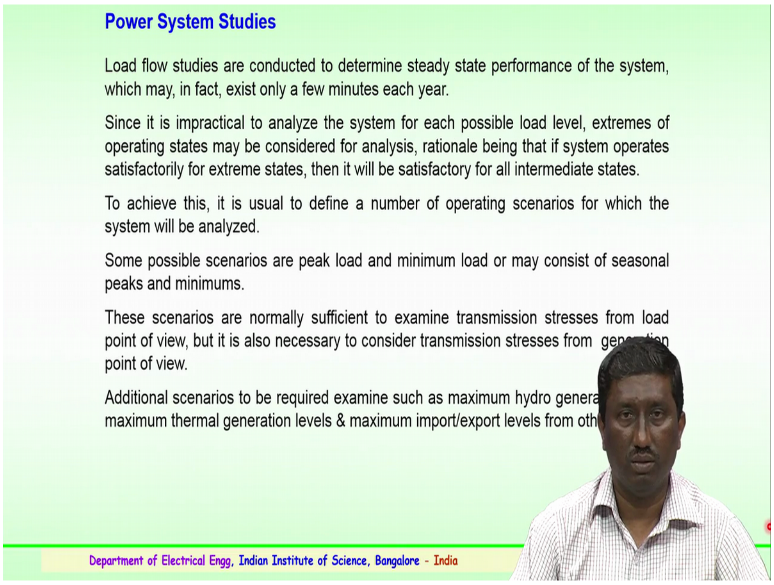

So, various studies are being done like a transmission related studies, here substation also you have to have a prior knowledge of the conditions, of that area; the voltage level where the substation is planned. So, like the power system studies; the important being the load flow studies are usually conducted to determine the steady state performance of a system which may in fact, exists only for a few minutes in a year. So, this is very important since it is impractical to analyze the system for each possible load level. So, extremes of operating states may be considered for analysis, so the rationale being that is if system operates satisfactorily for extreme states, then it will be satisfactory for all the intermediate states that is the assumption which the studies are aimed and which are the carried based on the assumption.

So, to achieve this it is normally used; it is usual to define a number of operating scenarios for which the system will be analyzed. So, some possible scenarios could be are the peak load and the minimum load or may consists of a seasonal peak and minimum. So, this has to be properly documented and it should be known for the proper planning this peak load minimum load of that substation, depending upon the seasons the data has to be available.

The scenarios are normally sufficient to examine transmission stresses from load point of view, but it is also necessary to consider the transmission stresses from the generation point of view also. So, all the stresses pertained to the transmission from the load and from the generating stations point of view or also to be considered during the power system studies. Apart from this additionally, scenarios to be required are to examine such as the maximum in case of hydro generation levels, it could be the maximum thermal generation levels or the maximum which are the import or the export level from the other systems could be a renewals or could be of any other generating units which are connected to the substation. So, all theses have to be incorporated in the power system related studies before the planning is being carried out.

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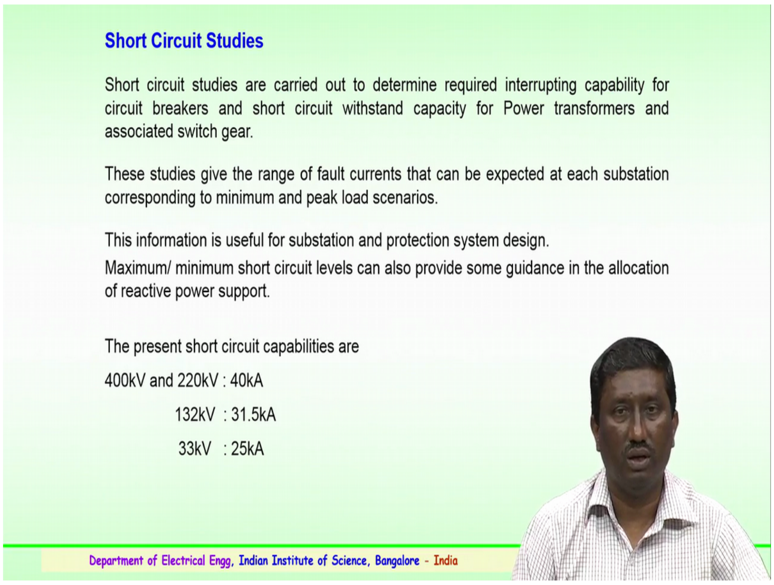

So, after the power system studies the short circuit studies again this play a very important role and these are normally conducted to determine the required interrupting capability for a circuit break especially and the short circuit withstand capability for the power transformers and also with the associated switchgear which are used in the substation. The switchgear again could be of s e t p t circuit break (Refer Time: 18:54) several of this switchgear.

So, these studies short circuit studies give us the range of fault currents that could be expected at each substation and this corresponds to the minimum and also the peak load scenarios. It is very important information which we could get from the short circuit studies and this information will be useful for the substation and also for the protection system which could be planned for the design.

So, the system production can be designed based on this available information; so, the maximum or a minimum short circuit levels will also provide some guidance in the allocation of reactive power support. So, we also need to get with the estimation for the reactive power support. The present short circuit capability for various voltage levels as we mentioned earlier also; 400kV and 220kV substation represent short circuit capability should be 40 kilo Amps and in case of 132 kV, it is 31.5 Amps and for other degree kV substation it should be 25 kilo amp short circuit capability level.

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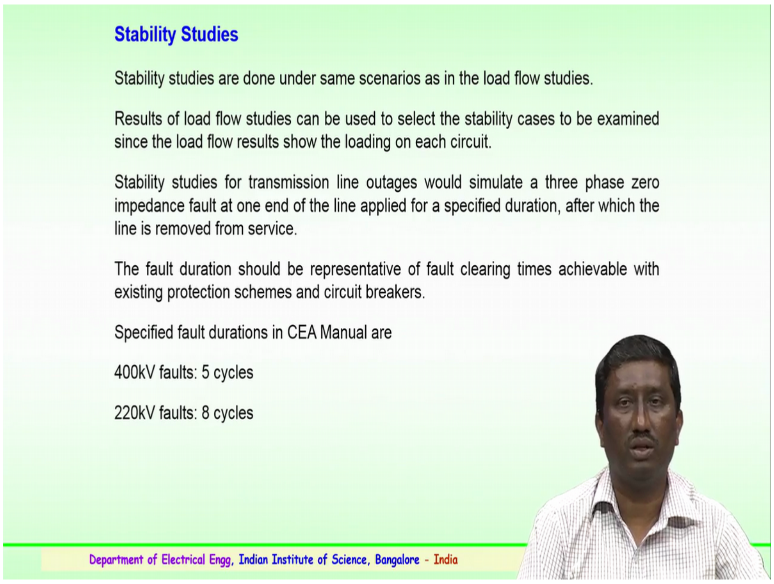

So, further is stability studies these are done under a similar scenarios as in the previous load flow studies. So, the results of again load flow could be used to select the stability cases which are to be examined. Because this load flow results show that a loading or given indication of the load on each of the circuit. The stability studies which are carried out for transmission line, outages would also simulate a three phase a zero impedance fault at a particular end of the line, which is applied for a specific duration; after which the line is removed from service.

So, all these could be helpful in finding out the performance of the substation during the fault occurrences. So, the fault duration should be representative of the fault clearing times which could be achieved with the existing protection scheme and with the available circuit breaker isolators and many of this devises or equipments which are installed in the substation. The specified fault duration as per the central electricity authority manual in the country for a 400kV faults, it should not exceed more than 5 cycles, in case of a 200 and 20kV faults; it should exceed more than 8 cycles.

So, these are the prescribed limits or prescribed values as per the guidelines of the central electricity authority in the country.

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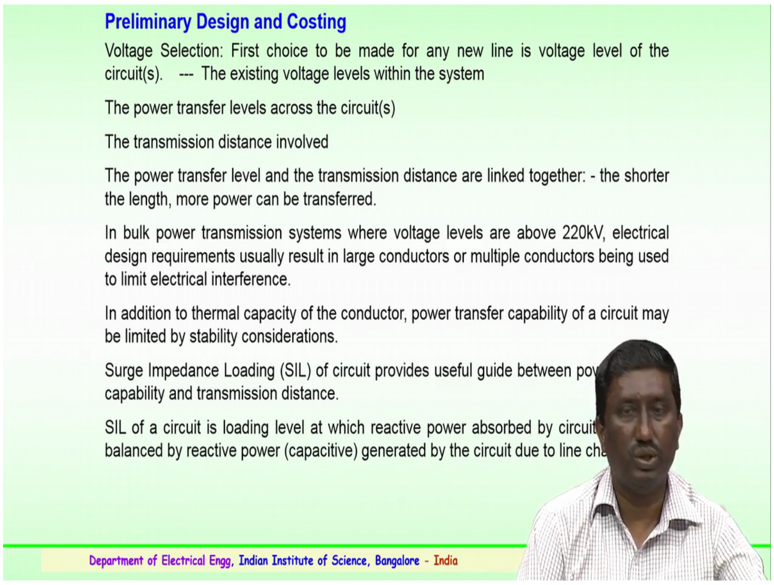

So, now how the preliminary design and the costing evaluation for the substation is generally considered or how it is estimated. So, we will have a very quick look at the preliminary design aspects, the first being the voltage selection. So, this first choice is to be made in case of any new line or the voltage level of that circuit or already the existing voltage levels within the system has to be modified. The power transfer levels across the circuits have to be identified, the transmission distance which is involved is of importance, the power plants, the power transfer level and the transmission distance are also linked together and the shorter, the length the more power could be transferred; this is also a very important.

In bulk power transmission systems, where voltage levels are above 220kV, electrical design requirements usually result in large size of the conductors or multiple conductors or a bundled type of conductors being used; this is to limit the electrical interferences particularly the (Refer Time: 23:00) interference, the corona and the audible noise. In addition to the thermal capacity of the conductor, the power transfer capability of a circuit should be limited by the stability considerations which are plan.

Then important component being the surge impedance loading; the surge impedance loading of a circuit provides useful information between the power transfer capability and the transmission distance, this is a very important line. With the surge impedance loading of a circuit loading level at which; what is the surge impedance loading is a loading level at which the reactive power which is absorbed by the circuit, particularly in inductive in nature should be balanced by the reactive power that is the capacity power generated by the circuit due to line charging.

So, this surge impedance loading is a very critical parameter which has to be provided or which acts as a useful information between the power transfer capability and the distance of which the transmission or the distribution is to be made.

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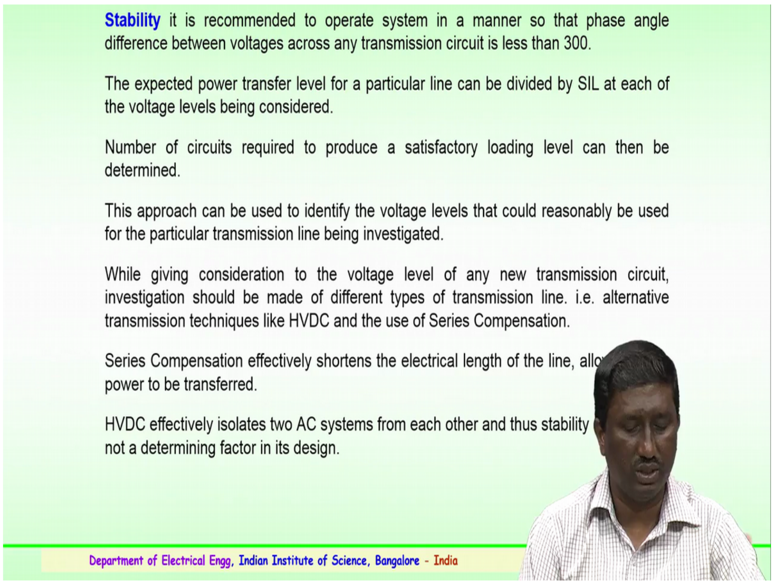

The stability is very important for any power studies, so stability is usually recommended to operate system in a manner so that the phase angle between voltage across any transmission circuit should be less than 300; that is very important point to be noted. The expected power transfer level for a particular line can be divided by the surge impedance loading at each of the voltage levels which are been considered in that particular station.

So, the number of circuits required to produce a satisfactory loading level can then be determined. This approach can be used to identify the voltage levels that could reasonable be used for a particular transmission line which is being investigated. So, the consideration to the level in case of any new transmission circuit; an investigation should be made of different types of transmission line; that is any alternate transmission techniques like the high voltage DC and the use of series compensation. So, all these things have to be considered for the stability aspects in case of the interferences.

So, series compensation effectively shortens the electrical length of the line and allows more power to be transferred that is very very important with the help of the series compensation which is being done. Then in case of high voltage DC; is effectively isolates to AC systems from each other and thus here the stability of the link is not determining factor in the design, so this is to be noted in case of HVDC; it isolates to AC systems.

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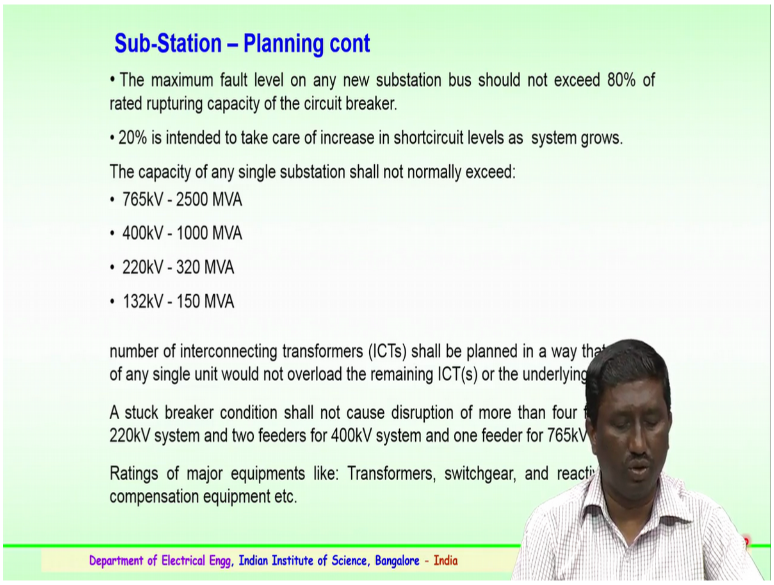

Continuing the substations planning, the maximum fault level on any new substation which is being thought or which is to be planned should not exceed 80 percent of the rated rupturing capability of the circuit breaker, this point we have already discussed. This is mainly is to see that 20 percent of the intended is to take care of the increase in short circuit levels, in case of the future growth of the transmission.

The capacity of any single substation should not exceed this point also has been stressed 765 kV should not increase more than 2500 MVA; for 400kV, it is 1000, 220 it is 320 and 132kV, it is 150 MVA.

So, the number of interconnecting transformer should be planned in such a way that outage of any single unit would not overload the remaining inter connecting transformers or the underlying system. So, the important component being the ratings of the equipments are to be carefully chosen and planned; particularly for transformers which (Refer Time: 27:06) compensation, equipment is used for reactive compensation so on and so forth.

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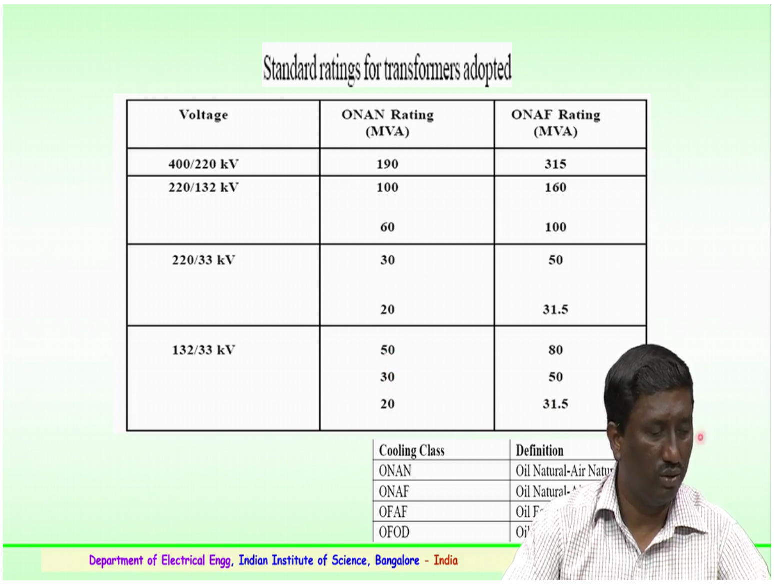

Some of the information that which are normally available for the standard ratings; for the transformer which has adopted for the substations are shown here. For a voltage level of 402 or 220kV; Oil Natural Air Natural rating of the transformer that is 190 MVA is typically adopted. In case of Oil Natural Air Forced rating, the megawatt ampere rating of the transformer could be around 350. Similarly, for various voltage levels these are the ratings of the transformers which are adopted for typical substations, from a distribution 33kV substation to a 400kV transmission type of substation. For various cooling class of the transformers the ratings have been chosen or adopted basically.