Advances in UHV Transmission and Distribution
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Lecture – 03
Insulation coordination, over voltage in power systems

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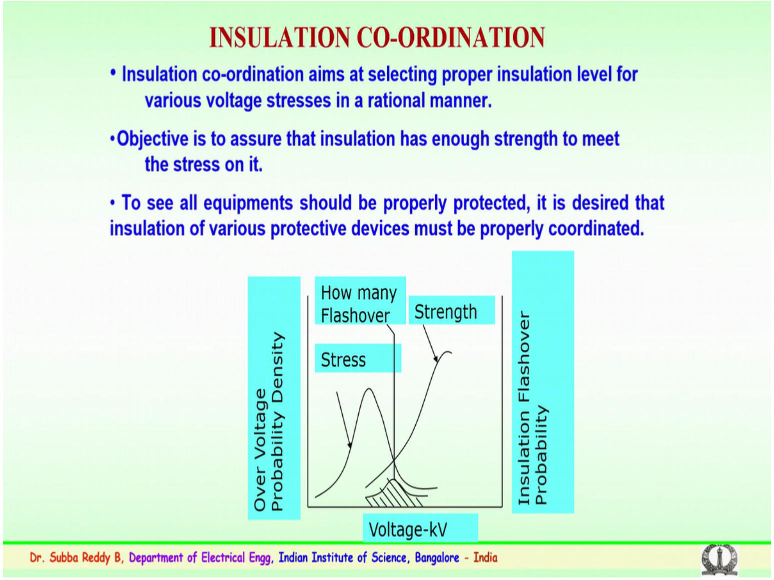

So we see about the day design and criteria which is being used for the transmission insulators; very important is a insulation coordination which the high voltage engineering have to be careful while designing the insulation particularly for EHV and UHV transmission levels. So, insulation coordination mainly aims at selecting proper insulation level, for various voltage stresses in a particular a rational manner. So, that is it is main objective is to assure that insulation has enough strength to meet the stress on it. In case of the stress which we discussed, may be mechanical may be electrical may be environmental insulation has to with stand doing emergencies conditions.

So, to see all equipments which are to properly protected. So, it is desired that insulation of various protective devices must be properly coordinated. This is the main aim of insulation coordination. The graph which is shown here it gives the voltage verses the probability density your voltages and insulation flashover. Simple looking into the insulation aspects of any particular equipment, this is the insulation strength which is designed for the equipment or the component, about this shows the stress which is being continuously on it. So, the level of the coordination or the insulation coordination will definitely be seen that it has more strength compare to the stress which has to undergoing the field because of several stress which is likely to face.

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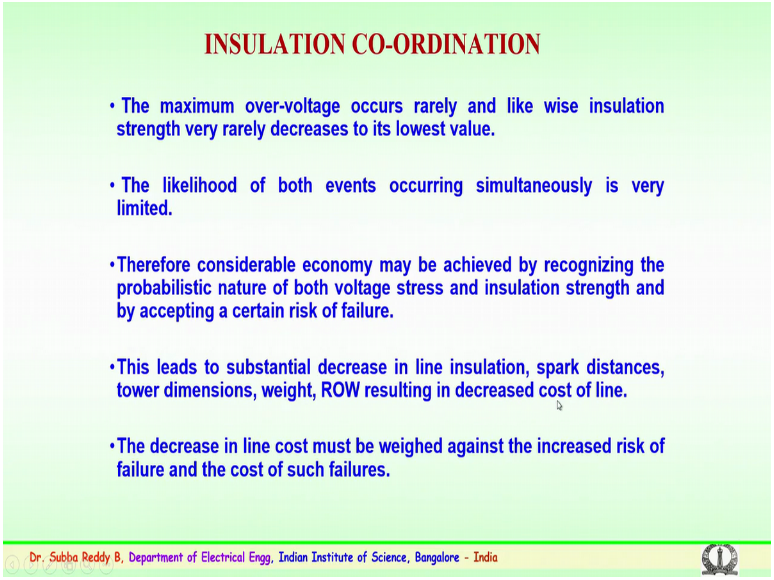

So, the maximum over voltages as we know occur rarely, and like wises insulation strength occurs very rarely. Because very insulation strength rarely decreases to it is lowest value. This has been in practice which has been seen. So, the likelihood of both the events that is the over voltages occurrence and also the insulation and decreasing simultaneously is very limited and very rare event.

Therefore, considerable economy may be achieved by recognizing the probabilistic nature of both voltage stress and insulation strength by accepting a certain risk of a failure. So, this is where the design aspects looking in to the economic point of you have to be taken care so this leads to substantial decrease in the line insulation, if you properly design properly take care of the parameters. Particularly spark distances the dimensions of the tower the weight of the entire insulator saying consisting of the conductors' accessories corona control ring so on so forth. Then write of a clearance of a write of a resulting decreased cost of line. So, this proper coordination proper planning proper insulation design will help in the decrees of cost of the line. And this decrees in line cost must be seen again is the increase risk of failure and the cost of such failures.

So, the design engineers have to bare in mind while designing proper insulation either it is not require to over designed insulator under designed the insulator insulation. So that cost must vivid against the risk of failure and the cost of failure which may happen in the system.

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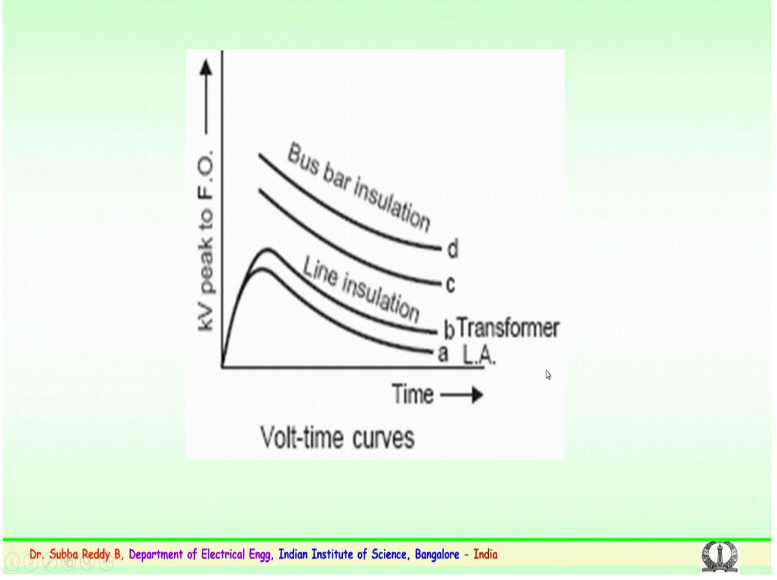

This is an important insulation coordination curves which shows of the peak kV peak of flashover voltage, with the volt time curves is verses the time. You can see that various curves are there. These are the level of protections which are being done for the insulation level. The initial you see the a b c d are different curve here the insulation level example for the transformer the line insulation will be somewhere here to protect the transformer we have LA that is lightening arrester, which has lower insulation level then the transformer in case of over voltages in case of failure in case of abnormal conditions the initial sacrificing should be lightening arrester were the lightening arrester should conduct in the transmission system and protect the transformer. So, this is how line insulation is designed.

Further, the transformer there may be some other insulation which has been designed like the bus bar and so on and so forth. So, the insulation coordination proper planning proper insulation coordination is to be done to protect the major equipment, particularly the transformer circuit breakers and controls in the substation and for the generating in the transmission network.

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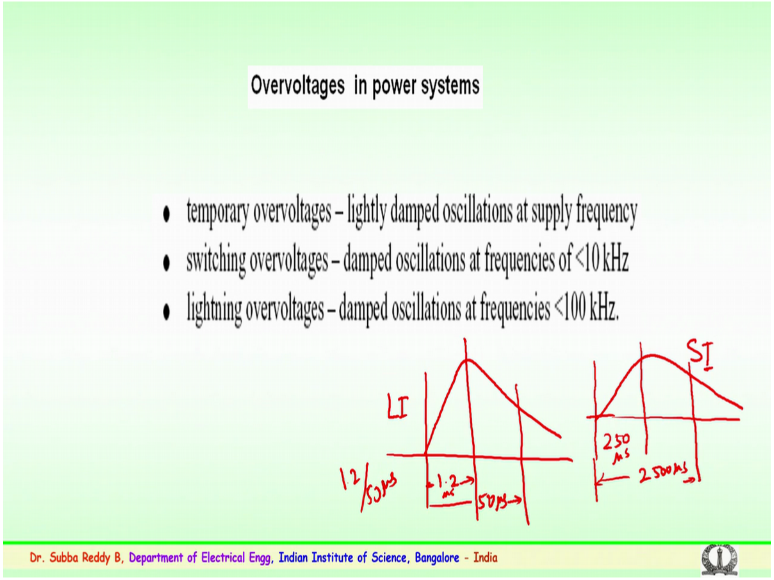

So, earlier I mentioned about the over voltages which are likely to be seen in our system network. So, temporary over voltages again these temporary voltages are lightly damped oscillatory type of voltages at supply frequency. I was telling at normal 50 hertz frequency the over voltages are likely to happen and these are known as temporary power frequency voltages. So, switching over voltages or switching surges, these are damped oscillation at frequencies of less than 10 kilohertz.

Again switching over voltages are likely to occurs because of the opening or closing of the circuit breakers in the system. The switching over voltages typically has a wave shape of 250 microseconds 2500 microseconds. So, switching over voltages as I was mentioned are damped double exponential oscillations, which may at frequencies less than 10 kilohertz. So, switching over voltages are of in these nature where the front time will be somewhere on 250 microseconds on the tale time is at 2500 microseconds the time front to time tale is 250 2500 microseconds. This are normally happening because of the closing and opening circuit breakers in a transmission system.

Then coming to lighting over voltages these are again damped oscillation at frequencies which are less than 100 kilohertz. These lighting over voltages may occur due to the national lighting which may strike the tower which may strike the tower which may strike the equipment. So, this national lightening will be of the front 1.2 microseconds and a tale time that is 50 percent of the magnitude is the tale time. This is the 50 microseconds. So, lightening impulse is 1.2 by 50 microseconds whereas switching is 250 by 2500 microseconds.

So, these over voltages are occurred in the power system and proper protections for these over voltages have to be taken in to consideration.

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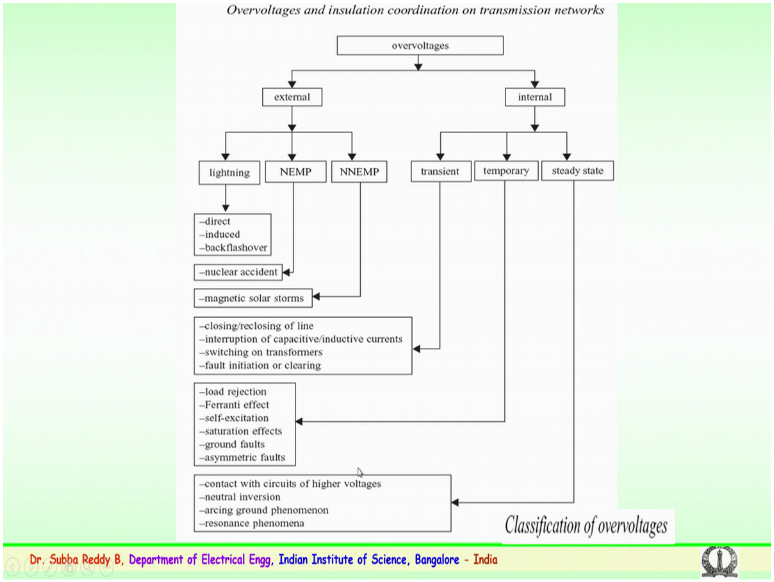

So, this table shows various over voltages which what be discuss which may occur because of the external or the internal application, internal service condition.

So, the external is because of the lighting as we are mention. So the natural lightening will create a direct induced or back flashover. These aspect will create a various type of impulse is various type of over voltages on the transmission network. Then the second externals being the NEMP that is nuclear electrum magnetic pulse, this is because of the nuclear accident which may happen which creates resharpe pulse and may create problem to the transmission network.

So, non nuclear electrum magnetic third external over voltages being the non nuclear electrum magnetic pulse this may be because of the magnetic solar storms are so on so forth. So, second being the internal operations of the power systems can cause the transient over voltages. This transient what we were talking about is a surge or the switching over voltages which may happen because of the closing and reclosing, that is a opening and closing of the lines or interruption of capacitive or inductive currents or switching on transformers or fault initiation or clearing of the fault. So, these aspects may create transient or switching surge voltages in a transmission network.

An internal again a temporary over voltages this temporary voltages over voltages may occur because of the load rejection because of the Ferranti effect which the sending and receiving voltages defer. So, the Ferranti effect also will cause a temporary over voltages, then self excitation because of the saturation effect because of the ground faults and some asymmetric faults. So, all these are likely to cause the temporary over voltages in the system.

The third internal over voltages may be because of the steady state operations also. So, this steady state internal over voltages may occur because of the contact with circuits at particularly of higher voltages may because of the neutral inversion the arcing which is happening in the ground side that is a arcing ground phenomena and the resonance phenomena. So, these are various classification of over voltages in the power network or power systems have to be content to see the proper functional of the equipment which are used in the transmission or the distribution network.

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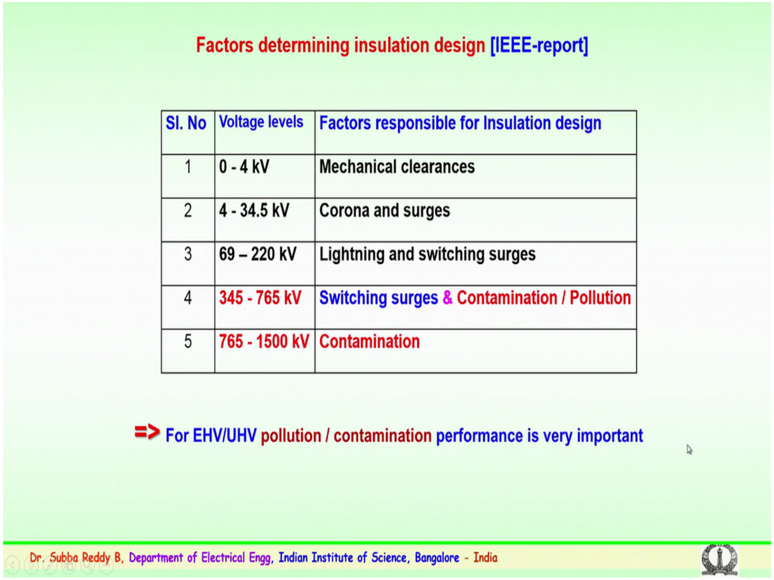

So, we have looked in to the slides. So, very important this gives us the idea what are the factors which determine the designs for insulation so the voltage levels particularly lesser than 4 kilo volt we have to look in to the mechanical clearances from the ground the tower which are being used have to be looked at the mechanical clearances bellow 4 kilo volt not much of the lightening switching surges play a role.

So, above 4 kV to 33 kV 33.5 kV the corona and lightening surges player role if the design of insulation; so the corona discharges which can create insulation has break down particularly at that voltage levels which may generate because of the transmission conducted a hardware a insulated accessories, and also the lightening surges which may dominate during this voltage insulation design engineer has to keep in mind are the various factors which are responsible for the design at particular voltage levels.

Coming up above 66 kV to 220 kilo volt's we have to look in to the consideration of lightening and switching surges which we previously look. So, lightening is again a natural phenomena. Switching surge may be happening because of the transmission network closing and opening of the circuit breakers so on so forth. So, the design has to be a taken care for lightening and switching over voltages up to 220 kilo volt above. 220 that is extra high voltage 400 kV to 7400 kV level, which we are normally call at extra high voltage levels and ultra high voltage levels above up to 765 kV or 800 kV apart from lightening the switching surges and contamination or a pollution dominates on the insulations design.

So, the insulation engineer has to take care of the switching surges contamination or the pollution above up to 765 or 800 kV. Further ultra high voltage insulation design mainly depends on the contamination aspects. The contamination or the pollution is a very important aspect to be considered for the design above ultra high voltage insulation.

So, for EHV UHV that is extra high voltage or ultra high voltage pollution or a contamination performance is a very important aspect for the design of line insulation. And we will be looking in to this contamination how serious how it happens the physics behind the contamination.

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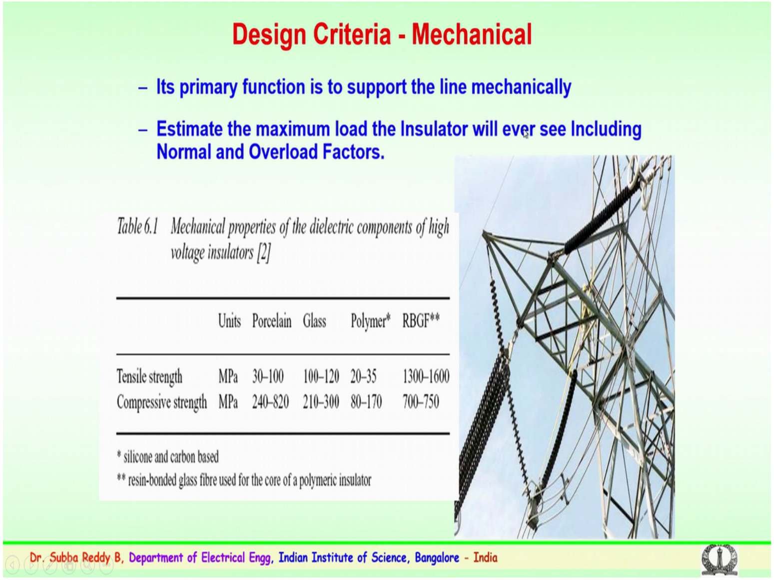

So, we were looking in to the electrical aspects now the design criteria which are followed for the mechanical aspects. So, it is primary function is to support the line insulator string is to support the line mechanically. One of the important factors apart from the electrical isolation mechanical it has to support the power. So, we have to estimate the maximum load which an insulator string consists including the insulator the line conductor the accessories, the hardware and the design has to be done how the load the maximum load including the insulator string will see under normal and also overload factors overload again depending upon the dynamic overloads of because of the compression because of the tensile aspect or because of the heavy winds and so on. So this has to be kept in mind before designing the requirement for mechanical criteria.

So, the mechanical properties of electric component of high voltage insulator typically when we look in to that mechanical strength of porcelain is somewhere around 30 to 100 and for glass it is 100 to 120 and polymer it is 20 to 35 and resin bonded material is 1300 to 1600, resin bonded glass fiber rbgf used for core of the polymeric insulator which we were talking about the (Refer Time: 15:48) which is employed for the polymer insulator core. So, resin bonded glass fiber with stands tensile strength of 1300 to 1600. And in case of compression the mechanical strength requirement for porcelain 240 to 820, the glass being 210 to 300 polymer is 80 to 170 and 700 to 750 in case of the polymer or resin bonded glass fiber.

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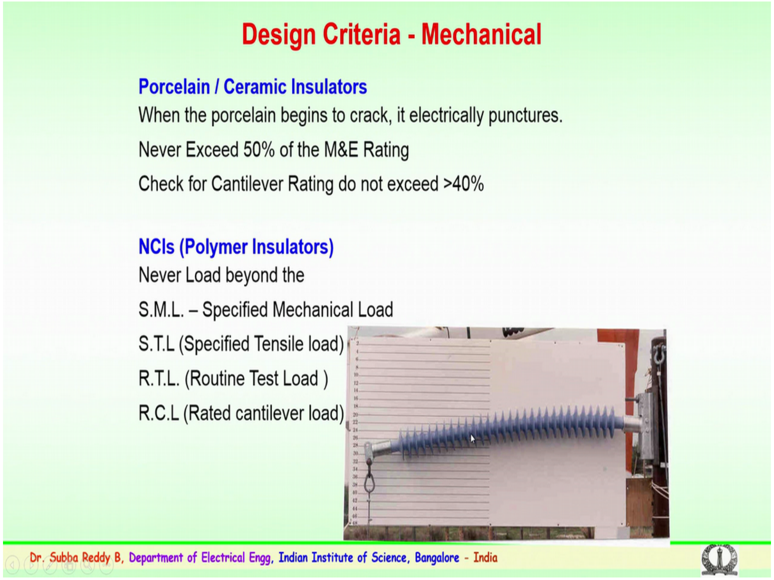

So, what this mechanical criteria particularly porcelain or ceramic insulators when the porcelain begins crack it electrically punctures. So, that we have to keep in mind. So, the mechanical strength may deter ate the insulation, initially this will lead to the electrical punctures. So, we should not exceed electrically, should not exceed 50 percent of the mechanical and electrical ratting of the insulators. So, this has to be checked for cantilever rating which d not exceeds more than 40 percent of the actual load. In case of polymer insulator non ceramic insulator the load should not be beyond specified mechanical load for each type of voltage level the specified mechanical load is being mentioned. Similarly specified tensile load a routine test load and the rated cantilever load.

All these things which have been mention will be applicable for a particular voltage level particular insulator dimensions have to be strictly followed so that the failure does not occur and the insulation does not beat them in the system.

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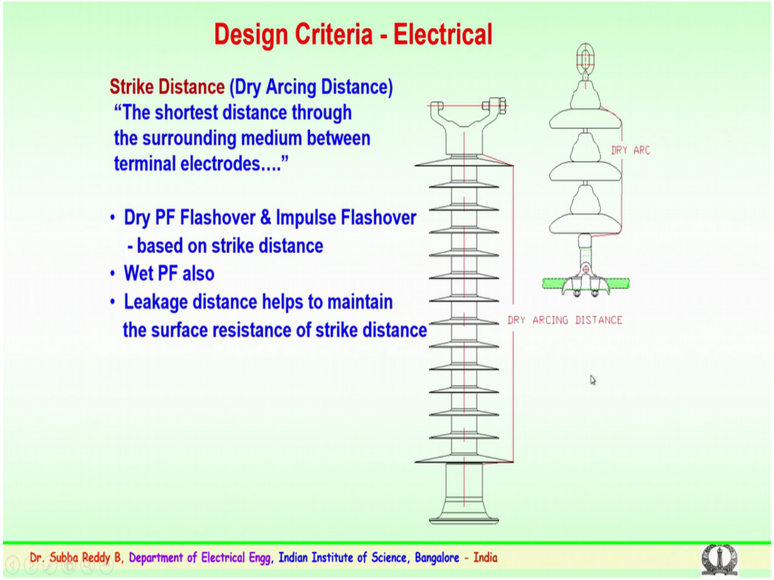

The important component while designing the electrical criteria is the strike distance. What is a strike distance or a dry arcing distance which is known with a high voltage terminology? The strike distance or the arching distance is the shortest distance through the surrounding medium, near the insulator between the terminal electrodes. You can see here this is the insulator the insulator can be of porcelain ceramic glass or hollow insulator. Representation here very clearly it is the both here the end fitting or metallic end fittings, the distance between end fitting from here to the end fitting in between the there is a complete insulation.

So this distance the direct distance clearance from the metal to the metal is known as the dry arcing distance. So, in case when one of that disconnected to the high voltage other disconnected to the ground. Because of the voltage stress increases the likely to flashover, and the nearest flash over will happen during this metal to metal a junction. So that shortest distance through the surrounding media that is air surrounding media in here, should be from the terminal electrodes. So, this known as a strike distance for a follow a porcelain bushing.

Similarly, in case of a insulator string a representation of 3 insulator is given. You can very clearly see from the top cap the metal cap to the bottom most metal thin. This is the arcing or dry arc distance strike distance which being refer. So, the dry power frequency PF is the power frequency flashover and the impulse flashover based are designed on the importance of the strike distance by the insulation or designing engineer. So, the power frequency voltages and impulse flash over voltages are likely to see depending upon the dry arc distance which is being provided and wet flash over also. See in case of insulate there airing because of the wetness of the wetting of insulator surface the flashover voltages is likely to come down. So, this flashover voltage also kept in mind while designing the arcing or a strike distance.

So, the leakage distance mainly helps to maintain the surface resistance of the strike distance. So, this is important design criteria for the electrical. So, a very clear distension has to be made between the strike distance and why it is important in the design of insulation.

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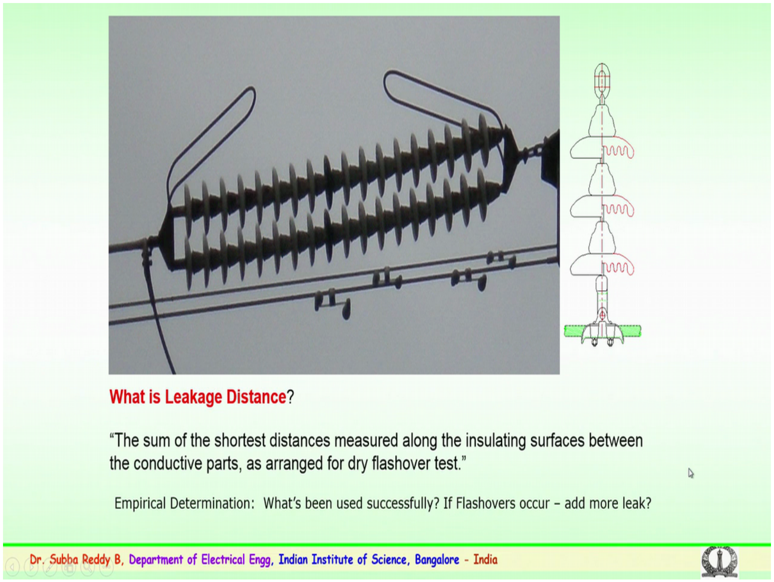

Next is the leakage distance what is the importance of a leakage distance. So, this is an example of insulator string which consist of several insulators double attention insulators several insulators are there. And here you can see the metallic ring type of arrangement are known as arcing hones. So, this distance between this is known as the strike distance what we discussed earlier, that tip of this metallic to the tip is a strike or the arcing distance which is being maintained for this insulator string. In case of over voltages the discharge should happen from metal to metal it should go to the ground; so where the protection for the insulators string is done.

So, similarly what is leakage distance, the leakage distance is the sum of shortest distances measured across along the insulating surface between the conductive parts as arranged in here. So, this shortest distance each insulator each ceramic portion minus the metal part that is the cap and the pin will constitute a leakage distance. The actual insulation provided for entire string minus the metal parts will give you the leakage or distance for the insulator string. Here we have to take from the first petticoat of the insulator on the surface here and again from here. So, this addition of this porcelain insulation will give you the leakage distance of in a insulator string.

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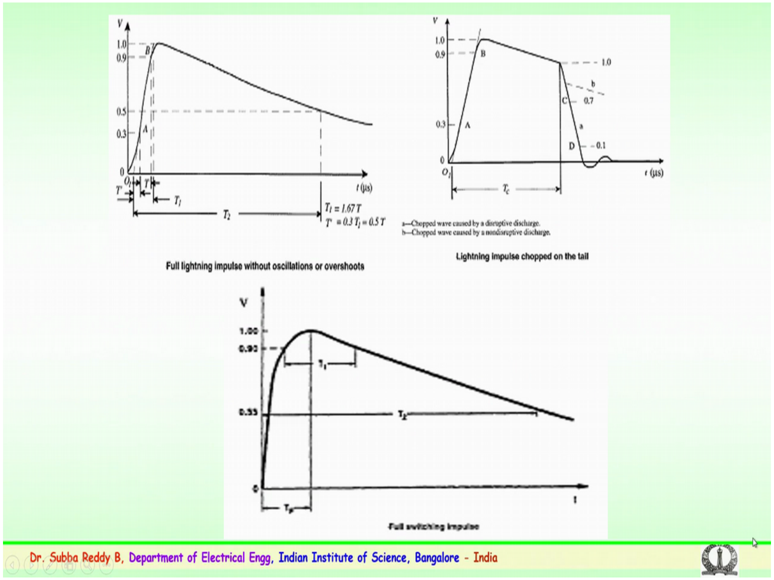

So, as discussed we were looking in to we are talking about the over voltages which happened in the transmission. So here are few examples which have been given the first is the lightening impulse or a lightening surge which occur in the transmission, how it looks. The second is the lightening impulse chopped wave and third is the switching impulse. So, we will look one by one. The first is the full lightening impulse voltage which is being shown without oscillation are overshoot.

Typically, this is a test book type of wave form which is been shown, but practically you may happen to see the oscillations here in this raising portion. So here it is not been shown, to see that how it is being consorted. So, the full lightening impulse without oscillations which is shown here is from the 0 to the 1, where shows the magnitude. And the time to front is calculated either from the 10 to 90 percent in some cases it is 30 to 90 percent depending upon the oscillations which are seen here. So, time to tale is taken as a total magnitude there is a 50 percent of that you see the time to tale.

So, this is the typical lightening impulse for a lightening surge wave from which is used for the application of the various component to check their performance in the laboratory before it is being used in the transmission system. Similarly, you have a lightening impulse chopped. This again a similar wave from the chopping is intestinally done either on the tale or on the front.

So, in the transmission network these type of surges a likely to see across the transformer are any other equipment were intention is to see simulate such condition in the laboratory and check the insulation could withstand in the laboratory. That is where chopped lightening impulse is being carried out again there are standard for this how many applications of lightening impulse voltages whether it is 10 positive 10 negative or 10 positive of this thing and 10 negative it depends for each component standards have been specified for this applications based on the standard performance is verified in the laboratory before it is being used the field. So, here again wave form shows a chopping in the tall section and similarly chopping could also we done in front portion. So varies type of a lightening impulses which will be interracially chopped at a required level will be tested for the insulation.

The third is the switching impulse a over voltages or a switching surge what we call. Here as I mention earlier the time to front will be 260 microsecond and the time to tale from here to the magnitude 50 percent magnitude will be 2500 microseconds. The switching surges are likely to happen because of the closing and opening of the circuit breaker and in that transmission network here the front time will be one point to microsecond and tale time will be 50 microseconds for lighting surges for switching it is 250 by 2500 microseconds.

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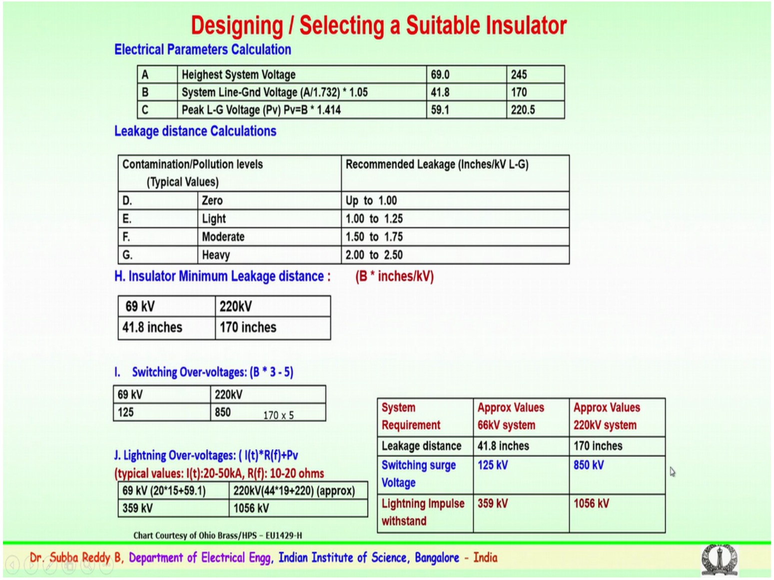

So, now we come in to the selection of a suitable insulator, how to design or select an insulator for electrical for various levels in the before it is being put in a transmission. A thumb rule has been given here design aspect consist of several design consist of several aspects for it is being put in the service. As a thumb rule just for understanding have given you here the selection of how suitable insulator is made for the transmission system.

A simple example here I have given for 2 voltage level that is 66 kV and 240 kV similarly the higher the voltages could be used with of factors which have been employed will be a slightly different. So, a simple example for 220 kV system voltages the 220 kV the highest system considered that second portion of the Colum values in second portion. The 220 kilo volt transmission system is a normal operating voltage will be 186 and the maximum operating or the design of insulation for a 220 kV will be done to 245 k v.

So, this is what I have shown here a system highest system voltage of a 220 kV to 245 kV and the system line to ground voltage that is whatever I indicate in the a the system line to ground voltage divide by rote that that is 1.73 into 1.05 is a 5 percent extra is taken in to consideration for design it gives 170 value is 170, this will be using it later. So, further peak of line to ground voltage is nothing, but the value which have got in

170, 170 into rote to that is 1.414 gives you 220.5 is a number which obtain for line to ground.

So, this how electrical parameter are calculated further the leakage distance how leakage distance it is calculated. So, for leakage distance we have to consider where the transmission line or a transmission tower is being erected. So, that is very important. I was mentioning you various type of pollution joules exist if it is pollution zones as per the standard a pollution level system classified into very non pollution level very clearly clean level. Then there will be a light pollution a moderate pollution or a heavy pollution zones. So, the transmission line passing through different zones while calculating the leakage distance have to were in mind about the factors to be considered. So, in case your transmission tower is running near a moderate pollution zone area the factor of 1.5 to 1.7 considered similarly if it is high 2 to 2.8 is considered.

So, next after the leakage distance the insulator minimum leakage distance is calculated simply with the help of 170 is the b is 170 into the inches per kV that is simple for 220 kV it will be one hundred and 70 inches that is a leakage distance which have converted into inches per kV.

Then for calculation of switching over voltages a factor of b that is again 170 is taken and multiplication of factor a particularly for 250 kV and lesser some where the factor will be 3 to 5, I have assumed 5 has a factor multiplication factor. So, one for 220 kV the b is 170, 170 in to 5 gives you 850, is a switching surge voltage level for a 220 kV system this all the thumb rule which a have been indicated here.

Next for calculation or designing for lightening over voltages this simple formula is considered here where the current is a resistance and the value of p v is taken for the calculation so typical value of current in case of lightening strike it is taken anywhere between 2 to 50 kilo for a transmission system and during that period resistance is likely to be anywhere between 10 to 20 ohms. So, for a 220 kV system I have considered 44 kilo amps somewhere 90 ohms plus 220 kV approximately. This gives 1056 kV if u want to maintain the insulation level for lightening volt for switching it is 8 50 for lighting 1056 k V.

So, when you summaries the system requirement, it approximate value for a 220 kV system. You see the leakage distance should minimum be 170 inches switching surge voltage should be 850 kilo volt and lighting impulse with stand voltage should 1056 kilo volts. So, these are the values which you obtain or a design engineer is likely to look in to these aspects as a voltage level goes up in case of 400 765 800 kV. Similar excise will be done much before insulate also apart from these several other consideration will be taken into consideration.