Recent Advances in Transmission Insulators

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Module No # 01
Lecture No # 04
Design Considerations of Transmission Insulators

Good morning we were discussing about the manufacturing process of various insulators technologies and also the handling of this insulators used for transmission. The manufacturing plays a vital role for all the insulators technologies porcelain ceramic or glass or composite polymer type of insulators. So equally importance has to be given for the handling materials storing and the dispatch processes.

So now we will discuss about the importance or brief induction to the design criteria for this various insulator technologies and the importance of insulation coordination. So why insulation coordination is an important criteria for the selection of any of this insulators for the transmission or the distribution for the traction purposes. So we know that in the power system and the equipment are likely to face over voltages this over voltages in the power system are of normal power frequency of over voltages this could happen because of disturbance in the system sudden throwing of loads or due to the internal disturbances.

This power frequency over voltages could span over few cycles and where the insulation integrity is to be maintained and for the smooth performance. Second important is the lighting over voltages which the equipment face in the field the lighting over voltages are of a typically 1.2 / 50 micro seconds where 1.2 being the front time of the wave form is double exponential wave form.

So 1.2 is the front time and tail time is 50 micro second so this lighting over voltages when impinge on the system could decorticate the performance so the equipment have to be protected for lighting or over voltages further to this at a very higher voltages above 220 kilo volts switching over voltages this switching over voltages could developed because of the closing and opening of the circuit (()) (02:55).

Where the surges typically of 250 / 2500 micro seconds so 250 is the front time of the surge the 2500 is the tail time of the surge. So this way forms which could cause to the insulation have to be taken care. So lightning's surges switching surges normal power frequency operating surges could cause the insulation decoration which of any equipment of the high voltage in the high voltage substation or in the transmission or the distribution have to be taken care.

So for this approper design criteria should be evolved one proper insulation coordination to be done so this will help in the better management of all the better equipment which are in the field.

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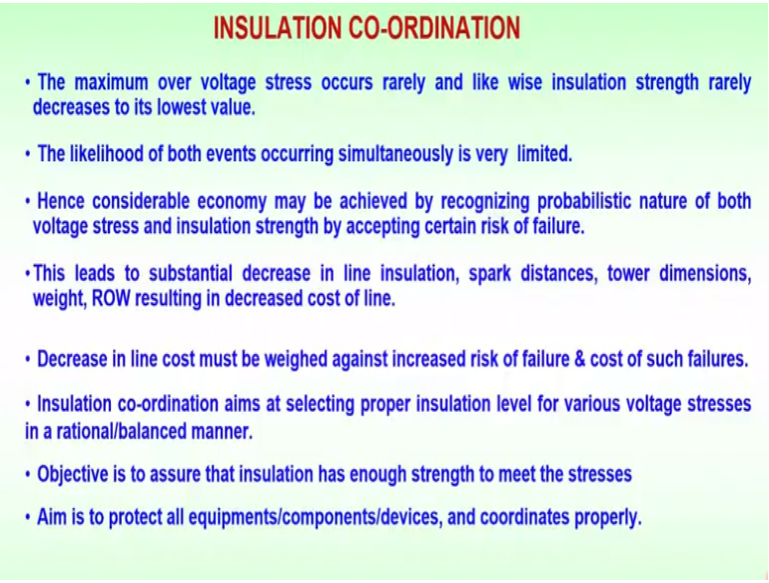

So the insulation coordination to be done for any equipment and to see that the maximum over voltage stress this maximum over voltages has mentioned earlier could be because of the power frequencies and over voltages lighting over voltages or the switching over voltages this stress which is developed because of this could happen rarely it is not an event continuously which happens.

And likewise the insulation strength also rarely decreases to the lowest value so this point as to be considered first it is not that continuously the over voltages are seen by the equipment in the power system network. So the likely hood of both these events that is occurring simultaneously is a very limited in number both hence considerable economy may be achieved by recognizing the probabilistic nature of both this stresses and the insulation

strength by accepting some risk in the design of this equipment so that substantial economy can be saved.

So these could lead to decrease in line insulation part distances tower dimensions, weight write off weight and this results in decrease to cost of line. So several of facts have to be considered while designing the line insulation and proper protection so decrease in line cost or must be weighed again in the risk of failure and also the cost of such failures. So insulation coordination basically or primarily aims at selecting proper insulation level for various voltages stresses which are development in a rational and a balanced manner.

So the main objective has mentioned is to assure that the insulation has enough strength to meet the stresses which it faces in the field which is lighting because of switching or because of the power frequency stresses which are developed at an instant and whether the installation will be able to with stand this. So the main aim of the insulation coordination is to protect all the equipment components and the devise and necessary insulation coordination is to be properly done.

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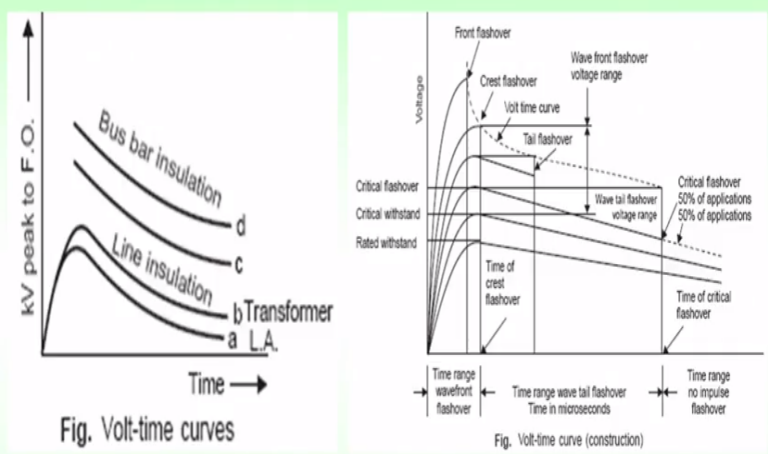

So this is the philosophy of insulation coordination by seeing this to figures we can know the importance of insulation coordination the first curve gives the kilo volts peak to flash over voltages on the Y axis and X axis is the time of time so this gives the volt time curves. Here you can see the typically curves VT or volt time curves are plotted for various equipment

like LA the curve A represents the curve for the lighting the KV peak to flash over voltage to the time.

Similarly for the line in insulation for a transfer was the curve be shown here and for the bus bar typically it is D. So in this is how the KV pack to flash over voltages versus time for various equipment which are operating are shown. When you closely monitor here to protect the transformer we use a lighting arrestor where the lightening arrestor in case of over voltages could of lightening or switching over voltages.

This lightning arrestor should act and see the protection is made for the transfer amount so this is the important formation and in the filed as I mentioned the temporary over voltages. These over voltages are lightly damped oscillations at supply frequency so it could last for few cycles at 50 hertz or 60 hertz operating frequency. The second which because of the opening and closing of circuit breakers which we turned as the switching over voltages where they were could of 250 / 2500 micro seconds.

This is like a damped oscillation at frequencies which could be a lesser than 10 kilo hertz so the lightning over voltages which occur due to the natural lightning these are basically the damped oscillations at the frequency range below some 100 kilo hertz. So this is some information of the equipment's is to be designed for various over voltages. The second curve here you see the voltage versus the time again this is whole time curve which could be construction you can see for any equipment.

There is a rated with stand level for the equipment you have the critical with stand and critical flash over. So critical with stand critical flash over and rated with stand these are the important values of any equipment as to be able to withstand in the field conditions. So the designer of the equipment will specify these values and this are to be used according with the system which are being in place.

So here we have as mentioned earlier the front and the tail of the wave form typically been you take this form it could be of a switching wave form or a lightening wave form. Setting wave form say this front time for switching is 250 micro second and the tail could be 50% of the tail could be 2500 micro seconds here in case the flash over happens in the front of the

forms similar to here if you see the flash over which happens at the front of the wave form at the peak level.

So this is known as the front flash over similarly if the flash over happens on the tails specified tails of the any of this wave form it is known as the tail wave form. So the specification are mentioned for various equipment have to be adhere for lighting switching and power frequency over voltages. There are standards for all the equipment's when we discuss about the testing aspects we will be looking into the various magnitude of lightning, switching and temporary power frequency power voltages what are the values for an equipment to be tested and the time duration to be tested in the future classes.

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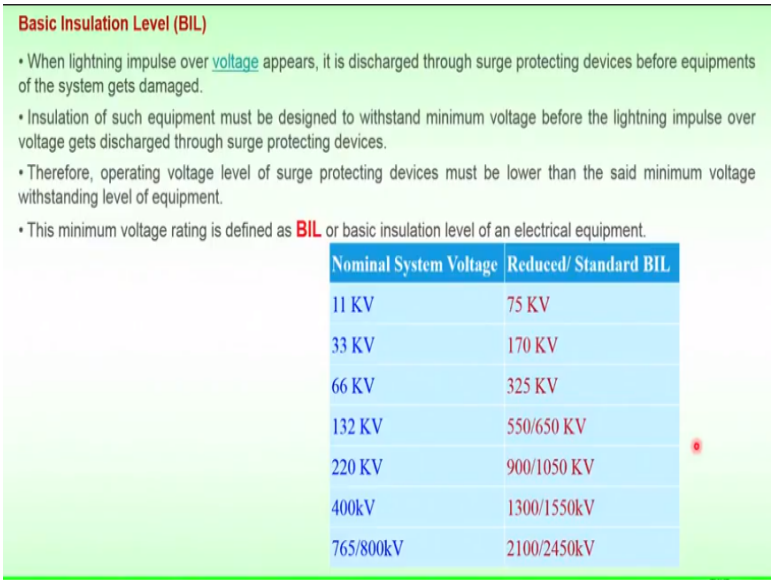

So before going to that it is important to know that what is basic insulation level so basic insulation level or BIL is a very important terminology where we have to adhere and the equipment manufactures or the utility personal are to know the basic insulation level of any equipment.

So how it is done the basic insulation level of any equipment this is assumed in case when lightning surges or lightning impulse whatever it is 1.2 / 50 wave form is impulse on any equipment. Over voltage appears across it this over voltage lighting impulse over voltage is

discharged as mentioned earlier through the surge protection or a lightning protection devices before equipment the systems gets damaged.

So it is mainly the maintain surges have to see that it will never pass to the equipment in case it is the transformer. The transformer should be hit by the lightning surges so there is a protection device known as the lightning arrestor or the surge arrestor these devices should act and see the surges are diverted. So insulation of such equipment must be designed to with stand lightning or switching type or surges have to with stand minimum voltages before the lightning impulse wave and gets discharged to surge protection.

So this data or this minimum insulation coordination is very important and therefore operating voltage of any surge protecting devices must be lower than the said maximum voltage with stand level of the equipment. So previous slide we have seen that in case of the transformer and the lightning so there are lightning arrestor should act before the lightning insulation strength of transformer.

So to protect the transformer lightning arrester is used so that the break down strength of the lightning arrestor is slightly lesser than the insulation strength of the transformer that is the information which has to be known. So the minimum voltage rating is defined or a BIL. So BIL or a basic insulation level of any electrical equipment is therefore to see that the protection against the lightning surges is done and this will help in the long performance or the long run of the equipment's field.

So the table shows here the normal or a nominal system voltages with reduce and standard basic insulation level for various voltages. So you can see for 11 KV the minimum BIL specified 75 KV similarly for the higher voltages you see the values which are specified both for reduced and for the standard basic insulation level reduced could be for the wet conditions or the normal conditions or the dry conditions the standard BIL also specified.

I case of 132 KV systems the reduced value of the impulse wave is to be applied is 550 KV and for normal conditions it is 650 kilo volts. Similarly for 220 kilo votes system it takes 875 to 900 with reduce impulse level and 1050 and that is a 1050KV is the specified limit as per the

standards. So for 400 KV it is 1275 or 1300 is the reduced value and 1550 kilo volts is the specified is the BIL for the 400 KV systems.

And for 800 KV or 765 KV a systems a value of the BIL is to 2100 and 2450 KV respectively. So any equipment's which is manufactured has to be taken care for the basic insulation level to see the equipment's the performance is not disturbed because of the surges which it counters or in the field.

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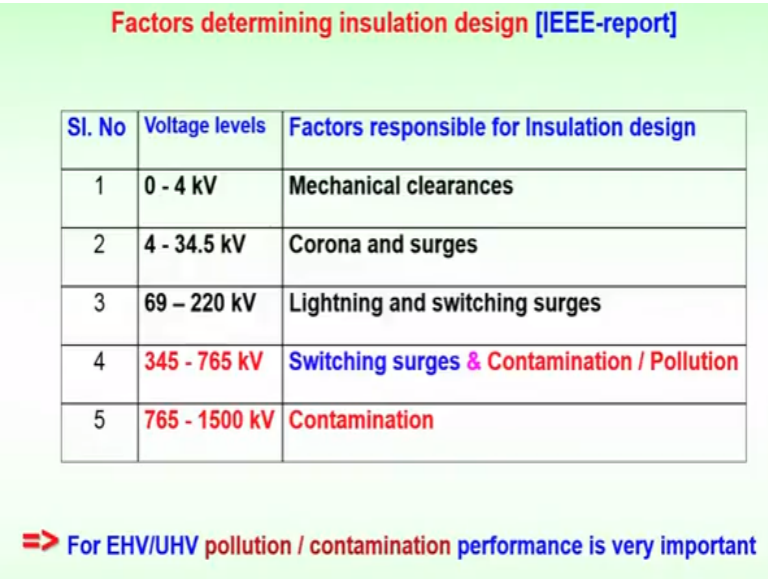

So this slide I am again repeating as this is a very important information where this factors which determine the insulation strength of any equipment is based on this values. So above 200 KV above 220 KV systems lightning and switching surges play a very dominant role so the protection the BIL values of this equipment's have to be added seen that they need to requirements for various over voltage surges.

Similarly for 400 KV and above system lightning switching and the pollution or a contamination this pollution or contamination we will be discussing in detail the importance of that why apart from the lightning and switching surges the pollution place a role in flash over of any equipment in the field. So higher the voltages contamination problem is the series thread to the system and this have to be taken into consideration for 400 that is EHP levels and above.

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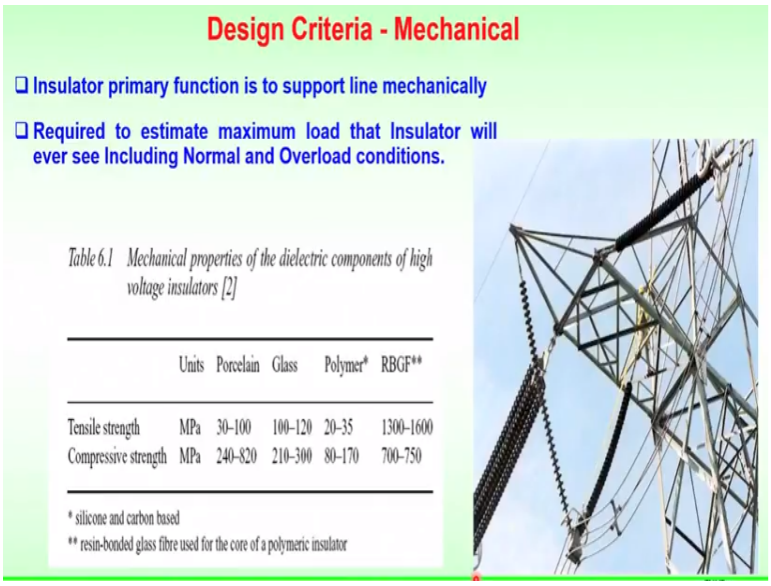

So the design criteria is based on the several factors few of the factor could we will be discussing are the mechanical or the electrical aspects. So any insulators we are focusing on the insulators in the transmission system where you can see the insulators again I repeat here this are the conductors the insulators apply a very important role in the mechanical support to the tower.

This tower mechanical support and to isolate the electrical conductor from the tower so various types of insulators assemblies are you see at extra high voltage ultrahigh voltage transmission you have attention arrangements it could be a quarter pole or any twin conductor or a conductor bundle of 6 or more you have V type of configuration you have a suspension type of configuration and a single suspension double suspension so several of this combinations are being used in the transmission network.

So important function of the insulator have mentioned is to see that is supports mechanically and also electrically it isolates so it is required to estimate the maximum load that the insulator will ever see under the normal and also over loaded conditions. So any type of string it has to take the load it could be tension mode or it could be a suspension mode the conductors various accessories the wind several dynamic conditions the weight of the insulator, weight of the hardware, weight of the corona control rings several of this things have to be considered when estimating the maximum load the insulator assembly as sees in the feed.

So these table use the mechanical properties of the insulating components which are used for high voltage insulator you can see here for porcelain glass polymer and resin-bonded glass fiber. This are the four simulator which are being used so the mechanical properties for this you can see the mega pascals this is a units you can see the mechanical strength required for a porcelain it will be 3200 in case glass it is 100 to 124 polymer it is 20 to 35 and resin-Bonded it is 39 to 60.

Similarly the compression strength of this materials when you see is 240 to 800 porcelain it is 210 to 300 in case of glass 80 to 170 in case of polymer and 700 to 750 in case of resin bonded glass fiber. So these are the mechanical properties of the directory components which are used for high voltage insulator. So the polymer has mentioned it could be combination of silicon rubber and the carbon based with filler additives.

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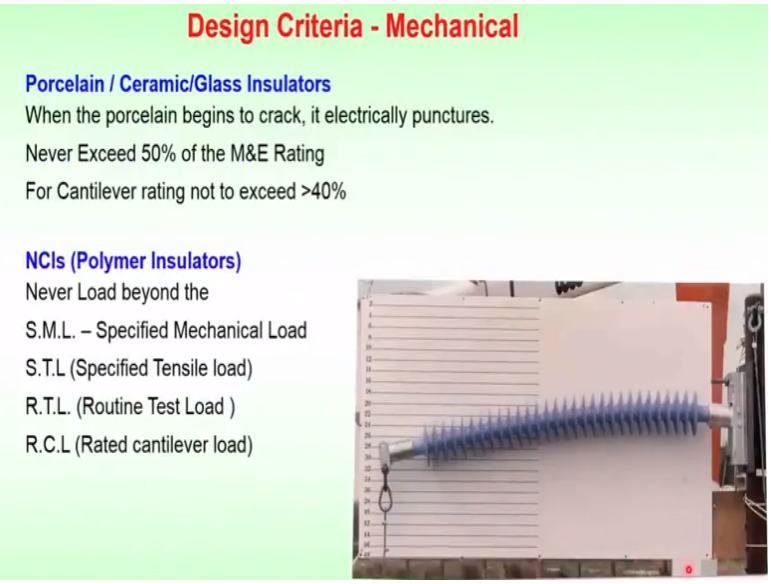

So this as also the mechanical strength which is required for the transmission systems so the mechanical consideration for the porcelain or ceramic or glass insulator is equally important because when the porcelain or glass beings to crack or it electrically punctures that is the information. So once there is loss of insulation the puncture could happen initially it is surface discharge and later because of the crack puncture directly could happen so this should never exceed 50% of the mechanical and electrical rating of the insulator assembly.

So in case of cantilever rating the load the mechanical load should not exceed more than 40% these are the standard specified values for the insulator assemblies. Similarly for non ceramic insulators or polymer composite insulator the load should not be more as specified in the standard any of the load it could be the specified mechanical load or a specified tensile load or the routine test load and the rated cantilever load.

All these values are informed to the manufacturer and the utilities where each insulator assembly depending upon the voltage rating the values are given and it has to be followed for this functioning of the in the field.

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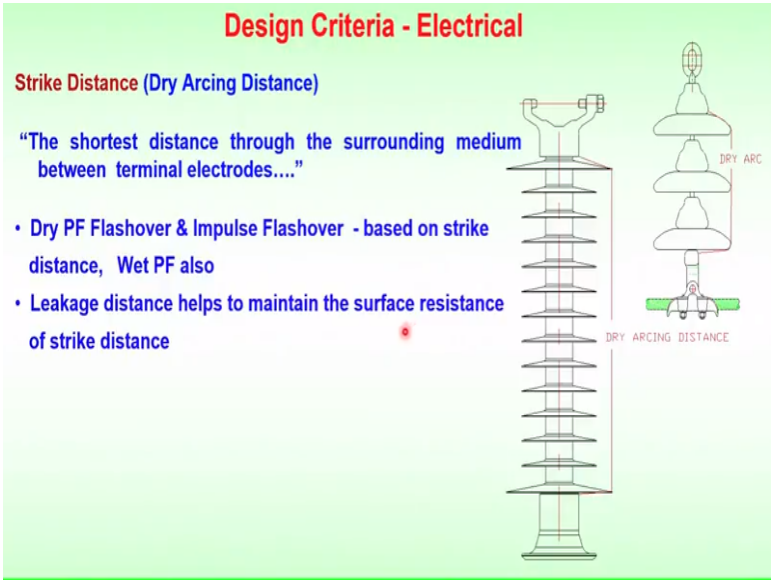

So in case of electrical design criteria here the two important things are defined one is the dry arcing distance when you see any insulator assembly it could be a ceramic or a glass bells or it could be polymer or long rod insulator you have two metal fittings on either side one could of high voltage or is the ground. Similarly this is high voltage and this is a ground you have three insulator.

The shortest distance through the surrounding medium between the thermal electrodes here we call the earth or a ground electrode or a ground metallic part and high voltage electrode. So the shortest electrode so from this end and to this end the distance which is specified here is the dry arching distance of this particular insulator. Similarly from this metal end near the pin junction of the third insulators to the cap junction of the first insulator here.

So this is the minimum dry arching distance of the insulator assembly so the shortest distance surrounding medium between the terminal electrodes is known as the dry arching distance this we will be requiring in case of the testing of insulators when we will be covering the testing aspects.

So similarly dry power frequency PF is the power frequency flash over and impulse again impulse it could be lightning which is exponential value double exponential wave form of 1.2 / 50 or switching wave form of about 50 / 2500 and the impulse flash over or the power frequency flash over test are conducted based on this strike distance that is the metal to metal portion of the insulator assembly.

Similarly for wet power frequency flash over also so wet power frequency or dry power frequency it is at 50 or 60 hertz both with stand and flash over values are decided with the help of the strike distance minimum strike distance to be maintained for any insulator assembly. The leakage distances helps in maintain the surface resistance of the strike distance so this is the important point to be considered.

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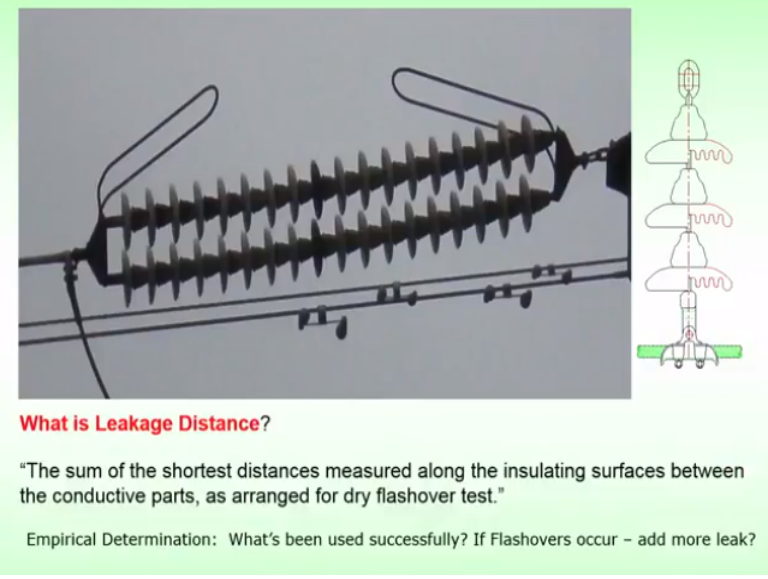

So the leakage distance I pointed out again here the dry arching distance which we mentioned or which we discussed is from the electrode of the high voltage to the electrode of the ground side the leakage distance basically is the sum of shortest distances which are measured along

the insulating surfaces. So you can see that leakage distances again I stress here from the pin of third insulators it goes through the creep age of entire insulators and comes here near the cap.

The distance from the pin junction completely covering the petty coats or the sheds of the insulator up to the cap position. So this is the leakage distance or the crepe age distance what we call so this crepe age distance multiplied by that number of insulators so neglecting this distance this is the metal distance is neglected only the crepe age distance of all the insulators are summed up which is known as the creep age leakage.

So some of shortest distances measured across the insulating surfaces along the insulating surfaces between the conductive parts in case of a arranging like a dry for test. So this is known as the leakage distance. So now we have discussed about the importance of insulation coordination why insulation coordination has to be done for any equipment including the insulators and the second being important criteria where this insulators or insulators assembly it could be of pin type insulators or the long rod insulators how this help in the field both mechanically and also electrically in the transmission system.

And we have also looked into the importance of the dry arching distance and the difference what is the leakage distance so this place a important role in the insulation system to decide for the service conditions which this insulators are used in the field. So service experience for this three technologies when we look there are insulators ceramic and glass which are being since the beginning of the almost the century where other performance is a being done in and the polymer or a composite insulator are of recent origin and there being the organic in nature.

So we will be seeing in to the service experience of various technologies or the importance of the experience has to be considered and see the failure are improved or the failures rate is come down in the service.

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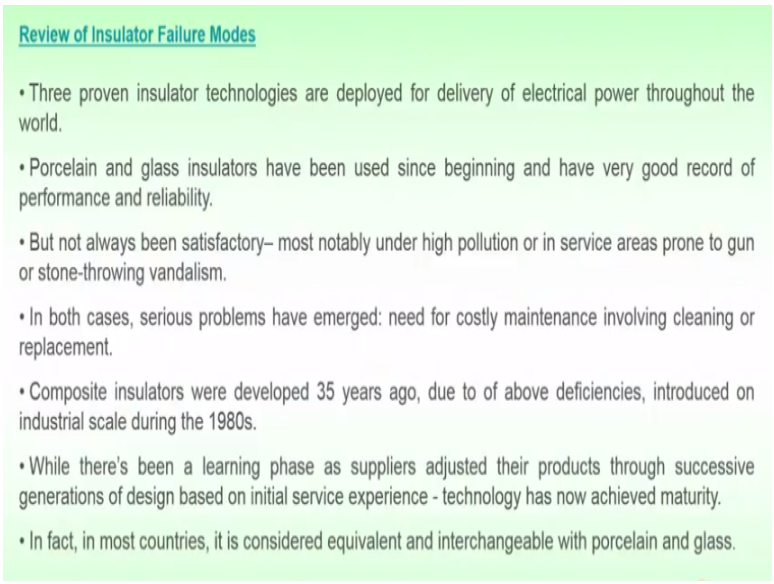

So review of various insulators failure modes in the field this is again an important information which is required for all the required technologies. So there we have discussed about the important technologies the ceramic or the porcelain the second being the glass and third being the recent organic type of material composite insulators. So all the three are technologies have which are used for the delivery of electrical power throughout the world.

Particularly porcelain and the glass insulator have been used since beginning that is from the start and have a very good record of performance and also the reliability. So since century these are performing and the reliability also is good but it is not always been satisfactory in some of the cases particularly under high contaminated or high polluted conditions and also the performance is not been satisfactory in case of this insulators in service areas which are prone to gun shots or the stone throwing vandalism.

So such a vandalism due to this effects have been destroying the shells of the insulators assemblies where the insulators strength reduces and the flash over has been seen this in both the cases series problem has been noticed and where need for costly maintenance particularly very high maintenance involve in cleaning and or replacement of the damaged bells which could cost the utilities adhere.

So composite insulator has earlier also discussed where developed 3 decades ago due to mainly because of the above deficiency because of the costly maintenance aspects. Particularly for

the vandalism and also for the performance in highly polluted or contaminated conditions this was noticed for EHP and UHP levels.

So this composite insulators which are initially introduced during 1980's or mid 80's started being the used by the utilities where initially lot of learning had to be made or learning phase as it is known to the suppliers or the manufacturers they have to adjust their products through successive failures or through the problem which were observed in the field. So in this several generation of design based on initial service experience was considered and the technology was improved at various levels.

So the present technology which is being adopted in the field as considerably achieved the maturity in the polymer or composite insulator technology. So in fact presently in several countries it is considered equivalent and inter changeable with earlier technologies of porcelain and gas insulator. So several of the place is or in the countries the utilities are trying to use the composite and your generation units with the replacing the porcelain or a glass type of insulator assembly.

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So now looking into the various failure modes which I have happened over the period for all the technologies and we have seen the failure in case if it is a mechanical separation that is insulator string getting detached from the tower or from the conductor the service experience

has indicated that toughened glass strings are significantly less in comparison to the porcelain or composite insulators.

So the performance of glass insulators particularly for mechanical separation have shown better with other technologies. In case of failures involving puncture of dielectric or insulating body which is seen or which was seen in the older porcelain insulator units where the toughened glass was not used and a rare occurrence of this composite insulate was available. So it was difficult to identify the puncture it is from the ground because the insulator height on the tower the being distance.

So the extract identification of the puncture is difficult and it required additional testing equipment to find out the punctured disk for replacement more over unless the puncture results in a short circuit it is not easily deductible in the field it is very difficult to detect the puncture disc in the field. So further failures particularly because of the climatic conditions the cement growth near the pin junction of the insulator or the radial cracking all this we will be having the pictorial information.

So these have been also reported on the ceramic insulators this could be due to improper cementing or because problems are hard to deduct at the initial stages of the manufacture. Subsequent to the cement growth or radial cracking we the utilities have come across the pin corrosion this pin corrosion it has happened in the areas of high pollution which affects the gas or both the porcelain disk insulators.

Particularly in earlier design the older designs later on the to see that the pin corrosion is reduced for both technology the zinc sleeve was adopted as a counter measure as a sacrifice device so that in case of the corrosion the zinc sleeve falls and the insulators still is connected to the insulator string that is the development which happened for the corrosion to reduce. So further dealing with vandalism as mentioned string with missing either glass or porcelain shell are easily observed form the ground.

Although in countries which vandalism particularly this means very high maintenance cause so every time the vandalism because of vandalism the disk are shattered the replacement of disk needs lot of maintenance and lot of time for this. So the organic nature of material that

is the composite insulators have also given raise to failures it is not that there are completely failure free this initially lot of information was tackled and information was noticed and improvemental aspects have been done by the industries and the utilities and there are failures which in comparison to the porcelain to the glass which are of different in nature because of organic material.

So the tracking and erosion of the housing material is a very important point to be noted and the surface discharges this happens the hydrophobicity loss the tracking, the erosion of the material and the surface discharges or noticed. And the material is of the insulators or the polymer material sheds of the polymer material are observed or the birds pecking by the birds also observed as the silicon rubber is been damaged because of the birds tracking of fiber glass rods so also noticed and a brittle fracture are some of the possible modes of failure reported by the utilities.

So despite all this issues or problem the composite insulator technology is being growing is improving and significantly is being also coming up with newer remedies and is being used in the present conditions in many of the utilities across the globe for voltage levels up to EHP and UHP systems.

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Ceramic and glass looking into the summary of the failure modes here as mentioned the ceramic or porcelain or glass insulator are being used since 1800 and 30's initially for metallic happy

systems these insulators are used for various voltage levels from very low voltage to a voltage level of 800KV AC systems or in 800 KV DC systems. This provide have provided the later flexibility because of the cabin pin they are very strong in compression and available in various shapes and the construction is a simple in construction you can see the metal pin and the cap surrounded by the porcelain or the enlarges shell.

So these have a high degree of standardization a various or types size used for various location it could for normal conditions, desert condition where higher foil type of insulator used or in the condition of contamination where anti fog insulators are being used so HP AC and also for DC systems.

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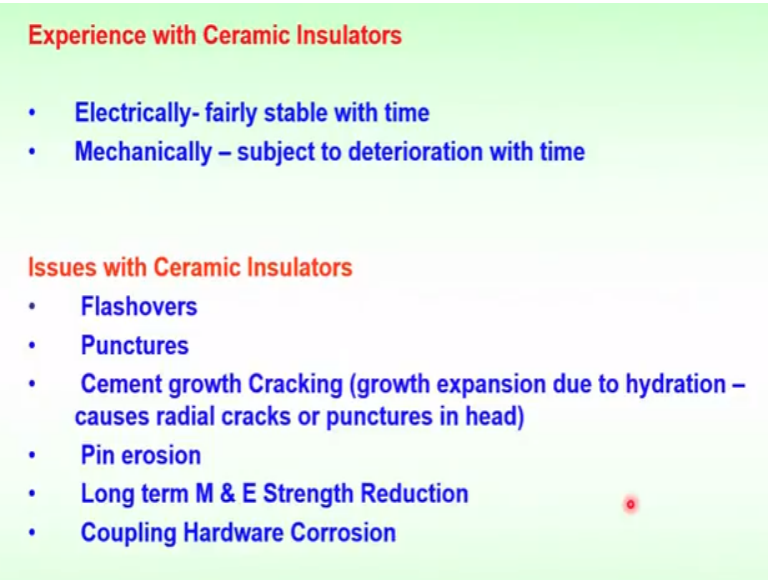

Some experienced with ceramic insulators where also discussed. So electrically fairly stable over the time at almost century there fairly stable mechanically they are subject to deterioration over the time period and some issues were also noticed in case of ceramic or porcelain insulators over a period of time this could be the flash over which have been noticed because of the surface getting degraded punctures this could be because of the cap and pin failure or the punctures happening.

The cement growth mentioned this is again due to the expansion because of hydration which causes the redial cracks or punctures in the head which have been noticed in the utilities. The pin corrosion which we discussed this again to counter the pin carrions zinc sleeve has

been also being used long term mechanical and electrical strength reduction over a period of time was noticed then coupling hardware corrosion.

So because this hardware which is connected to the insulators and the conductors happen to be in the outdoor system because of the climatic condition or the environmental conditions and the hard ware corrosion also has been noticed which degrades the insulator assembly.

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So this are some of the failures or the changes which have happened to the insulator porcelain or a ceramic insulator you can see here the surface of the insulator the complete glaze has been removed over a period because of the condition and here we see the breakage of the sheds this will definitely lead to the flash over and the reduction of the insulator strength.

A typical radial crack arrangement because of the pin and the cement and ceramic shell junction the cement growth happening and there could be a radial crack which further the puncture of the insulator could happen. So further to this the insulator can get detached mechanically that is the cap and the pin of the insulator failures are also been noticed in the field where detachment happens. This again is one of the typical example of the lightning phenomena been striking the insulator assembly where due to the lightning the failure of insulator assembly as happened.

So several of these failure modes have happened due to corrosion hardware corrosion the damage could happen due to the pin junction where the cementing port land cement giving away or the growth cement could damage the insulator and helps in the puncture of the insulator. So this have to be clearly taken into consideration before the line.

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And apart from this there are natural conditions which we discussed these are again the manmade or the condition which because of the growth of industrialization where because of the burning of agriculture waste or you see the ash settling on the insulator surface over a period of time because interacting with dew fog the insulator flash over though happen. Similarly the insulator or lines which EHP or UHP line which are passing hear the industries so lot of smoke from the industries are the brick kilns or from the cement industry or from any of the chemical industry.

This pollutant or the contaminants settle on the insulators over a period of time become brittle then become conducting because of the monsoon condition or because of the fog dew or the layer which is formed their conducts and the flash over happens. These are for various contaminated conditions which have been accumulated over a period of time as I said it could be of any industrial contamination or because of some places where large birds are nesting and large birds create issue where bird droppings further degrade the installation or reduce installation strength.

So several of this are to be considered by the utilities smooth functioning of transmission network.

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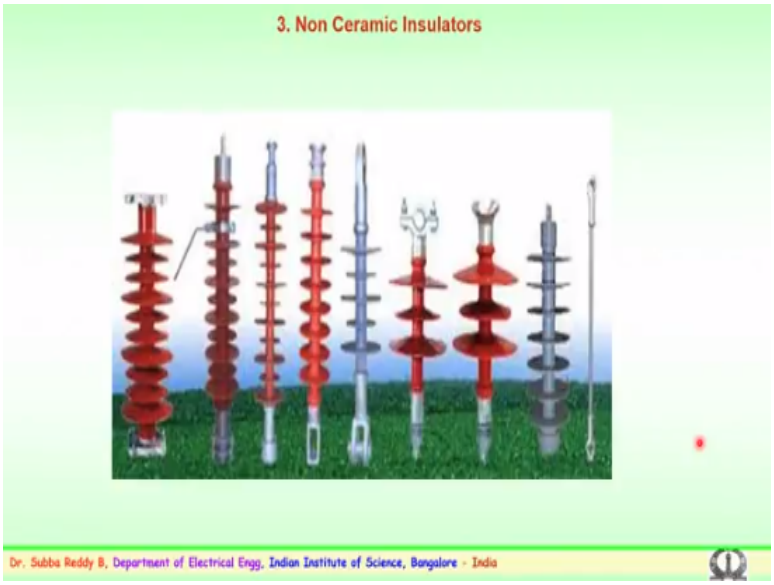

So we will look into the non-ceramic insulator similar to the porcelain or glass in the coming class so we will stop here thank you.