Recent Advances in Transmission Insulators

Prof.B. Subba Reddy
Department of Electrical Engineering
Indian Institute of Science – Bangalore

Module No # 02
Lecture No # 10
Coating techniques for insulators

Good morning we were discussing about the various methods for cleaning the insulators in the field and substations. This is to see that the insulators or the insulator strings are properly functioning during the energized conditions. So we have discussed various methods of cleaning both in energized conditions that is live line washing methods and also the de-energized situations where the cleaning is being done.

So various techniques were discussed about the cleaning aspect so the polluted in insulators should not be left and unattended for the better performance of this several techniques are being employed. So one among them is the coatings so apart from cleaning coatings are also being used for protection of overhead network equipment's these equipment's could be the insulators the conductors or other electrical power equipment which is being employed for the overhead power transmission and distribution purpose.

And in particular the coatings gains importance during the winter conditions as in winter conditions wet because of the fog, rain, mist or snow conditions and these contamination which happens in winter will have to be addressed. So there are prescribed methods standard which have been originated which have been recently being discussed in (()) (02:06) working groups one among the group is B2 dot44 which looks into this aspects see the reference 631 which gives the coatings for protection of overhead power network is a very important subject for the utility engineers and also the transmission people who are working in transmission network.

So we will discuss about some of the importance of coatings where is the necessity for coatings what are the types of coatings method? Which are being recently employed for the in-particular to the insulation briefly we will also look into the conductors. But the main target will be the insulator coatings various types of coatings which have been implemented or which are being used performance in the overhead insulators particular ceramic glass or porcelain polymer type of insulators.

So this when the condition is being mentioned in winter conditions so in winter we see the temperature coming very low the formation of ice happens this ice frost which develops on the conductors and insulators is not a good aspect for the transmission or utility personal. So lot of time venue and the maintenance is required.

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So these are few examples of the ice accumulation on various transmission networks you can see the temperature freezes then the ice accumulation between the petty coats and bridging of the line conductors do take because of this conditions so the maintenance of this has to be carried out and the formation of ice has to be eliminated these are again a few of the methods which are there in employed for the conductors and also the insulators you can see the ice accumulation on the insulators string.

So this are creates the mechanical weight on the transmission conductors this further aggravates the situation where there are cases and the towers get collapse because of the mechanical pudding of ice loading on conductors or insulators cascading the wind the tower could collapse. So there are few examples which have noticed the collapse of tower because of the ice loadings.

So ice loading in winter condition is a series issue which has to be tackled in many countries in particular to the conditions in cold countries in particularly where ice formation is noticed. So lot of effort is been made to see that so in such cases whether coatings which are being employed will be useful we will look into this aspects. So cigre is 631 as I mentioned is the working group B244 looks into various aspects of coatings for the winter conditions both on conductors and as well as insulators various types of insulators it could be ceramic or the glass insulators or a polymer type of material.

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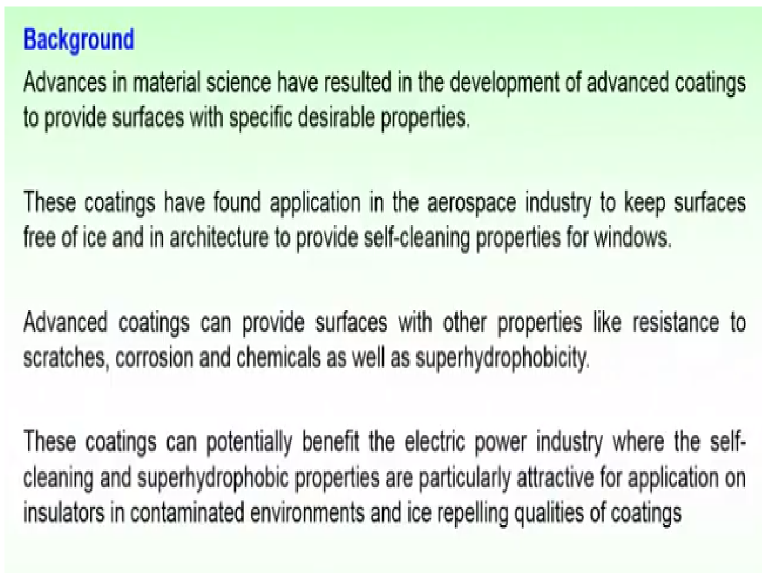

So with this background we would like to just focus on the coatings we know that advances in material engineering have resulted in development of advance coatings this we have seem to provide better surfaces with better desirable properties. So one of the coatings for the application this coating I have also been informed in the aerospace industries in particular this surfaces free of ice.

So here the surface this which are formed in aerospace applications like the windows of the aerospace vehicles are supposed to be clear the fog and the position of the ice. So here some coatings have been employed to provide better properties to the glass there and this architecture is mainly to provide the self-cleaning properties for the windows in case of the aircrafts. So the advance coatings this can provide surfaces with other properties like resistance scratches corrosion an chemical as well and there should be super hydrophobic in nature.

So these could coatings can potentially benefits both the power that is electrical power industry which when the self-cleaning or a super hydrophobic property or material or coating done under particularly better for the application in case of insulators that too for contaminated or polluted environments and also the ice loading condition as we discussed.

So ice loading conditions as we discussed so the ice repelling qualities of the coatings is the welcome conditions where the performance in particular to the cold climatic conditions could be attended.

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- i.e. icephobicity may reduce the risk of flashovers.
- Icephobic coatings are of interest for application to conductors and supporting structures to reduce mechanical load due to ice accretion in winter periods.
- The application of superhydrophobic coatings to conductors may also have the potential to reduce audible noise, radio interference and corona loss on high voltage transmission lines but this has not yet been confirmed.
- These benefits not only have the potential to increase the reliability of transmission assets, but it may also enable a reduction in the capital cost of new construction.
- Before applying new breed of coatings, utilities need to be confident in their performance and life expectancy.
- Critical factors are these coatings, when aged, may not result in a reduction in performance below that of uncoated surfaces and that they may not require a high level of maintenance in the long run.

So the ice loading or icophobicity which once this coatings are done this could reduce the risk of flash overs as accumulation of ice gets reduced and the flash over also because of ice formation is reduced. So icophobic coatings are of very interest of for application to the conductors and also to the supporting structure mainly to reduce the mechanical load I mentioned that accumulation of ice deposits on insulators the conductors supporting structure will mechanically load this structures or the conductors and there could be tower which could collapse because of the loading.

So this mechanical load could ice accretion in winter in particularly winter periods have to be attended. So icohobic coatings or could ahh come in better way to stop the loading of the ice on this structures. So the application of super hydrophobic coatings two conductor sin particular may also have better potential to noise that is basically the electrical noise audible noise because o this transmission conductors or because of hardware or due to the corona control rains or any other hardware which is in the transmission network.

So this create an audible noise and also the interface and coronal noise can be dresses because of better coatings which could be employed on the high voltage transmission lines. But this as noted been fully achieve or not yet been fully obtained so such coatings will definitely help to reduce the audible noise RIVE and corona on transmission lines as and also the necessary accessories and insulators and so on.

So the benefits not only have the potential to increase the reliability of transmission equipment's or assets but it may also enable reduction in the capital cost of the new construction. So lot of maintenance cost which is being diverted to the maintenance during the winter condition in case of better coatings are available so this could decrease the revenue schedule for maintenance.

So before applying any new breed or any new type of coatings utilities are the power transmission companies need to be confident in their performance and their life expectancy. So directly going in focus coating without knowing the performance in order with the right conditions so better prior information the aging characteristic of the settings to be studied and have to be implemented in the field conditions to critical factors.

For this coatings in particular age over a period of time aging could be environmental conditions and long performance as served may not results in reduction in the performance below the uncoated surfaces that may be not require a high level of maintenance in the long run. So several factors have to considered for coatings have being planned to be carried out on the insulators or conductors.

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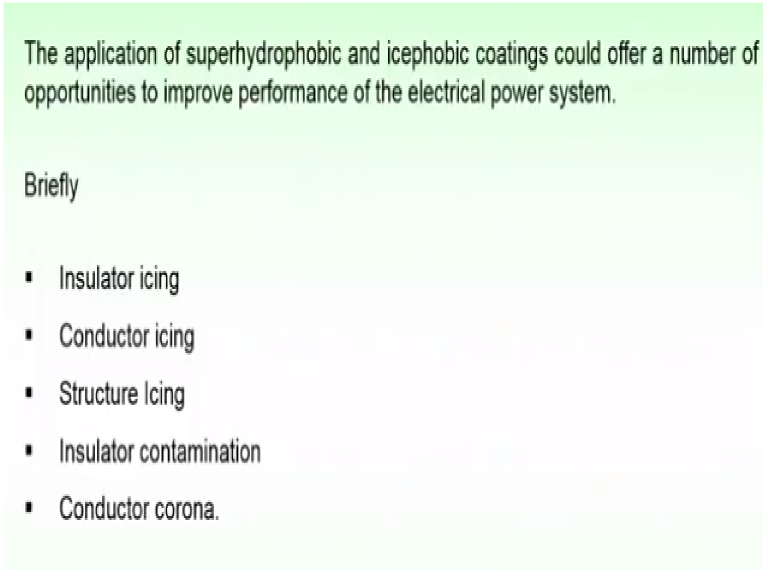

And also the application in particular to the better to maintain better hydrophobic or a super hydrophobic conditions isophobic coatings could offer a number of opportunities to improve performance of electrical power system. So the major advantage of going in for the better property coating use to see that it the equipment performs better in the long run in the field.

So briefly there are classified as insulators icing because the they are looking into the conditions of winter in majority of clod countries insulator icing is main the critical issue again the computerizing again the conductor icing settles on the conductor surface conductor loads and this also an issue. Structure the structure in the tower where tower carries the insulators here also the structure also is loaded with ice.

Then further to that apart from the icing there is an insulators contamination because of the dust because of the chemical because of the formation activities fertilizers minimum of this things we have discussed so there could be insulators contamination and also from the corona from the conductor interference from corona from the conductor. So these important issues have to be looked into so that necessary coating better coating could bring down this issue which are being mentioned here icing and the conductors contamination or insulators contamination or he corona which is being generated because of this contaminations.

So in cold climatic regions the performance of insulators particularly to ice or snow conditions is of series concern as the cold countries we have seen that the ice accumulation on the insulator surface makes the insulator wet and surface gets conducted. So once the surface of insulators gets conducted the discharge activity from the high voltage towards the end in progresses and depending upon the surface conditions there could be a flash over and outage.

So service experience in the field as indicated that any electrical outage due to flash over is one of the greatest if the eyes are no acrreetion that is no ice which is collected on the surface this is again followed during the period of so once the ice starts melting the surface becomes conducting and this conduction helps in the discharge activity and flash over of the insulator strength is noticed.

So the main service cases to be attended are to clean the insulators particular covered with the conductive ice or a snow pre-contaminated insulators or polluted insulators covered with ice or snow or combination of above conditions. So in service during the winter conditions these 2 or 3 conditions the better performance of the insulators strings in the field. So without interruption for power supply for the consumers are the utilities have to be taking care of such conditions in particular in winter.

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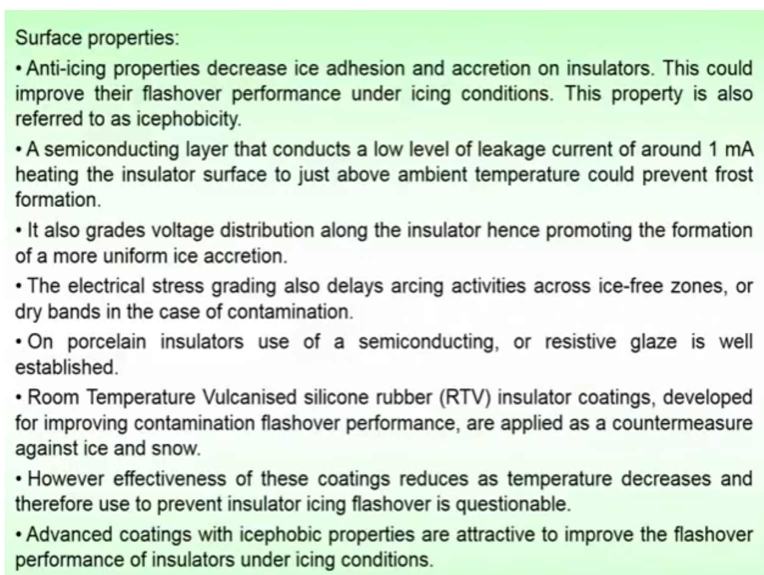

So when we look into the surface properties or during ice loading we have seen that anti icing properties decreases ice addition and accretion insulators. So this may improve once the ice accumulation is being removed from the insulators surface this improves the flash over performance under icing conditions which the properties is also refereed as phobicitty.

So icophobicity is the performance of insulators strength during the icing conditions so better performance in icing conditions so a semiconducting layer that conduct a low level of leakage current approximately around one milli amp heating's he insulators surface to just above ambience temperature could prevent cost formation that is the ice accumulation on the surface could be prevented by a leakage current of one milli amp which heats the insulators this also grades voltages distribution along this insulators hence formation the formation of more unique perform to more uniform ice accretion.

So proper voltage or potential distribution on the insulator surface in case of long insulator strings so better voltage distribution help the delay in arching activities across ice regions or dry bands in case of contaminants or polluted conditions so the utilities on porcelain insulators generally used semi- conducting or a resistive glaze which is being well established. So this semi conducting glaze or resistive glaze which is applied on the surface acts on the better voltage distribution and also will never allow the droplets or formation of ice accumulation on the surface.

So semiconducting glaze resistive is the initial methods which have practiced by utilities then comes the room temperature vulcanized the silicon rubber coatings that is RTV coatings which are generally termed these coatings are being used for better improving the contamination flash over performance on the insulators and are applied as against ice and snow activity where during winter conditions.

However the effectiveness of the above coatings that tis the condition vulcanize silicon rubber coatings semiconductor glazes or resistive glazes will reduce as temperature decreases and therefore use to present insulator icing is again problem to be addressed. So how long the coatings survive or what is the life of these coatings in winter conditions and particularly to the icing conditions or the snow accumulation conditions how long this coatings will serve the purpose.

So further to this efforts where made by many companies and also researches to come up with advance coatings with icophobic properties which could be more attractive and better perform and improve the flash over performance of insulator and icing conditions. So several of this mechanisms or tried and are being used and are being developed.

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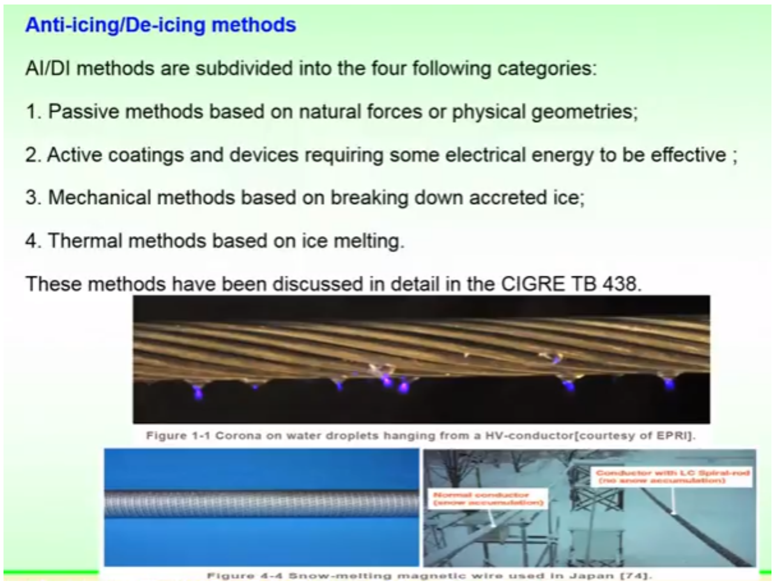

So anti-icing and de-icing methods which like anti-icing are basically divided into four major categories one is the passing methods these are based on natural sources or physical geometries we will discuss about this importance's of in such of the methods second is the active coating and device which require some electrical energy to be effective on the coasting so that accumulating of ice or snow is prevented.

The third it the mechanical methods this is generally to see the formation of ice and the ice breaking down from the conductor or insulators forth is the thermal methods again here the temperature is being used to see the technic based on temperature the ice is melted on the conductors or insulators. So these methods in details are discussed in today 437 technical brochure 737.

So further detail can be seen in this brochure where they have compressively attended to the various methods of the passive active mechanical the thermal coatings. So here we can see few of the examples here during the conditions where the surface of the insulators or a surface of the conductor where the discharge of activity is present here this shows that the droplets get accumulated over the period of time slowly the dust could from and this dust can again contaminate the conductor or insulator in the long run.

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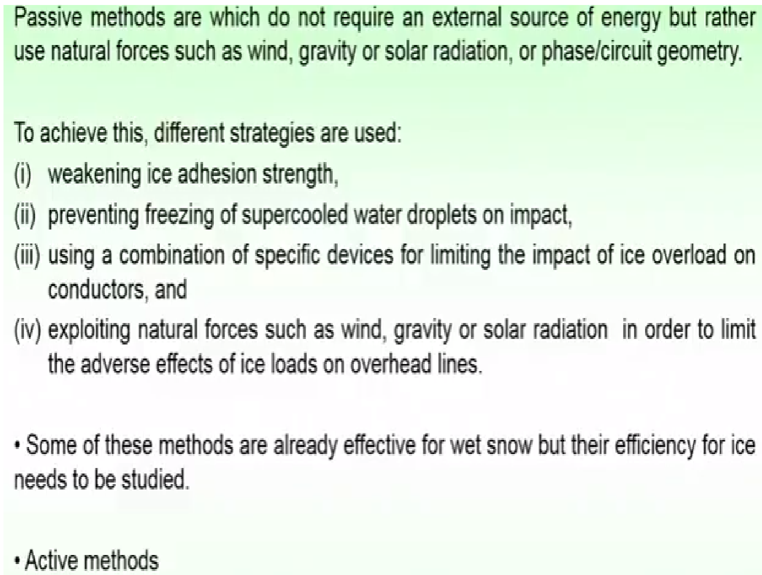

So this has to be prevented in the field so passive methods are one of the methods which do not require any external source of energy but rather they use the natural forces such as wind gravity or solar radiation or phase circuit geometry to achieve different strategies so they are not passive methods passive methods so weakening ice addition strength.

So weakening freezing of super cool water droplets on impact using a combination of specific devices for limiting the impact of ice over load and conductors and exploiting natural forces like wind gravity or solar radiation in order to limit the adverse effective or ice load on overhead transmission lines or insulators. So these are all the passive methods which have been mentioned here so some of these methods are already being used and are effective for wet snow but the efficiency for ice conditions needs to be still monitored and studied.

The next is the active methods we will be discussing about the active methods and techniques which are being used for the insulators and also the conductors.

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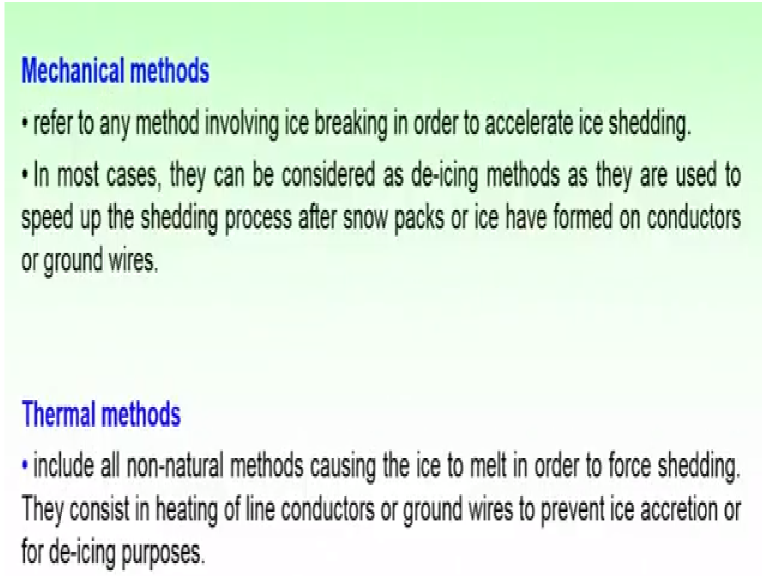

So third is a mechanical method again the mechanical methods refer to any methods involving breaking of ice which is formed on the surface of the conductor or insulators this is mainly to see that to accelerate ice shedding which is being loaded on the conductor or insulators.

In most cases mechanical methods which are being used can be considered mainly to see that de-icing takes place as these used or speed up the shedding process after the ice or snow accumulation forms on conductors or ground wires so that removal icing and de-icing is done. The forth is the thermal methods here again this includes all non-natural methods here that causing the ice to melt in order to force shedding this methods consists mainly in heating of conductors and the ground wires to prevent ice accretion or for deicing purpose.

The temperature of the conductors is raised or the ground wire is raised to prevent accumulation and the conductors or the ground wires.

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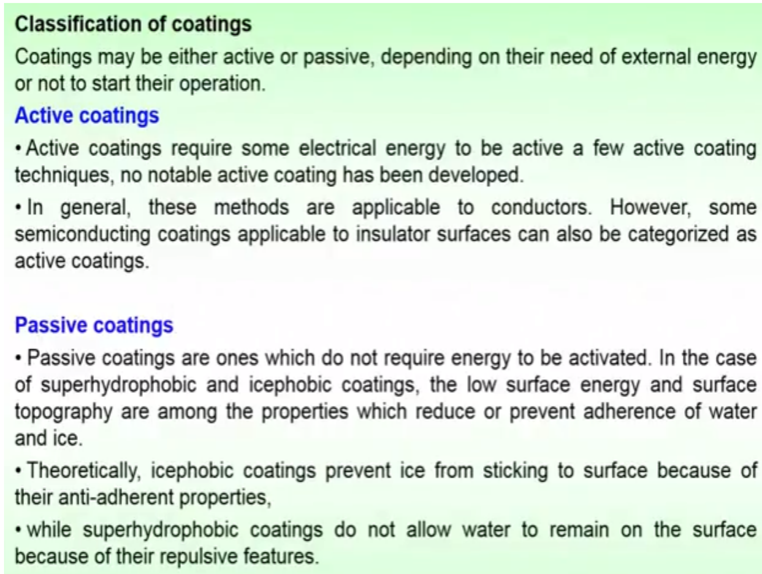

So we go to the coatings or the classification or coatings so coatings which are being developed or which are being used there could be active or passive depending upon the need of external energy or not to start their operations so the active coatings what are this active coatings requires basic some electrical energy to be active a few active coating technique is being employed notably active coating as been developed in general these methods are applicable to conductors.

However some semi conducting coatings are also been used for insulators surfaces and can also be categorized as active coatings. So presently for conductors and also for insulator these coatings are being used. Passive coatings as mentioned earlier coatings the once which do not require the energy to be activated here the case of super hydropobic and isophobic coatings low surface energy and surface topography are among the which reduce or prevent adherence of proper ice and surface.

So theoretically isophobic coatings prevent ice from sticking to the surfaces this is a important point for a passive coatings the ice should not stick to the surface either conductive or the insulators because of he anti-adherent property. So while super hydrophobic coatings because of the repulsive feature this is like hydrophobic coatings which are much better above the it does not allow the water more repellent water repellent at property is being embedded in super hydrophobic coatings.

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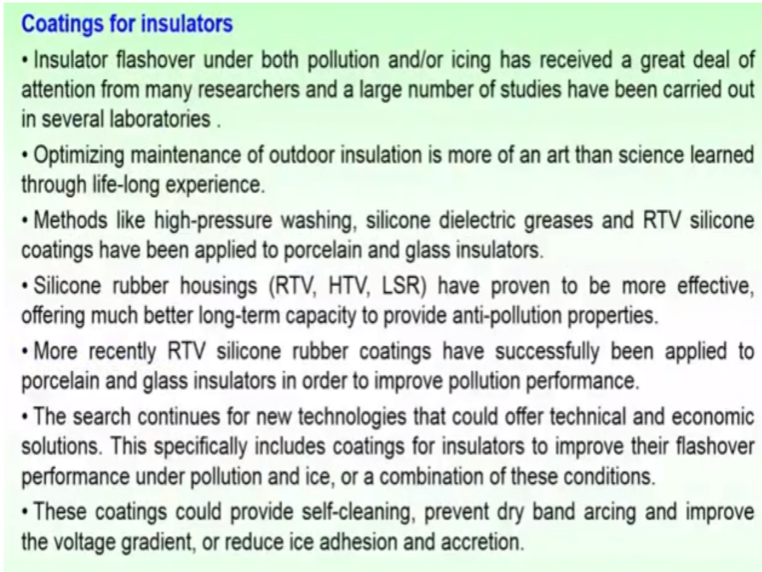

So which do not allow water to remain in the surface so coming for coatings to insulators. So previously coatings are conductors being available so we will focus on the insulators part so coatings on insulators are mainly used to see that insulators flash over and both pollution contamination or icing as received a great deal of attention from the any researcher large number of studies as been carried out in several laboratories the development as taken place large number utility personal transmission companies and so on.

So optimize and maintain the outdoor insulation is more of an art and then science learn through life and experience. So experience gives us the information for maintenance and optimize the methods. So methods like high pressure washing which we have discussed during the cleaning process for insulators and other equipment’s. So methods like high pressure washing silicon dialect application of silicon directly graces removal then artificial coatings have all been applied to porcelain glass insulators which are being followed for a long period of time.

So these coatings perform these initial period of time and silicon rubber housing is particularly RTV high temperature vulcanized room temperature vulcanized and silicon rubber vulcanized and this silicon rubber. So these housings have proven to be more effective offering much better long term capacity to provide the anti-pollution or a contamination property.

More recently RTV silicon rubber coatings have successively been applied to porcelain and glass insulators in order to improve the pollution performance this happens at higher voltages above 400 KV were pollution or contamination is series threat for AC and DC transmission systems. So applying RTV coating is to ceramic or glass insulators have shown netter performances of the insulators in the field.

So the search again continues for this technologies this could offer both technical and economic solutions for the improvement during pollutions conditions. So these specifically includes coatings for insulators not only for porcelain glass and also polymeric type of insulator to improve the flash over for flash over for contaminated and ice loading or snow or a combination of this conditions.

So these coatings could provide a better self-cleaning properties prevent dry band arching or scintillating activity and improve the gradient or reduce ice addition and accession of ice on the simulators. So such coatings are being developed are developed and are being practiced lot of work as been progress to develop better coatings for the transmission insulation.

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So once of the coating of the insulators on the bushing on the substation where it is being attended so our own temperature vulcanized coatings is being done on the surface of the shed of the porcelain high voltage bushing is this in the transmission system or distribution system this could be CTA or PT bush be and sub-station.

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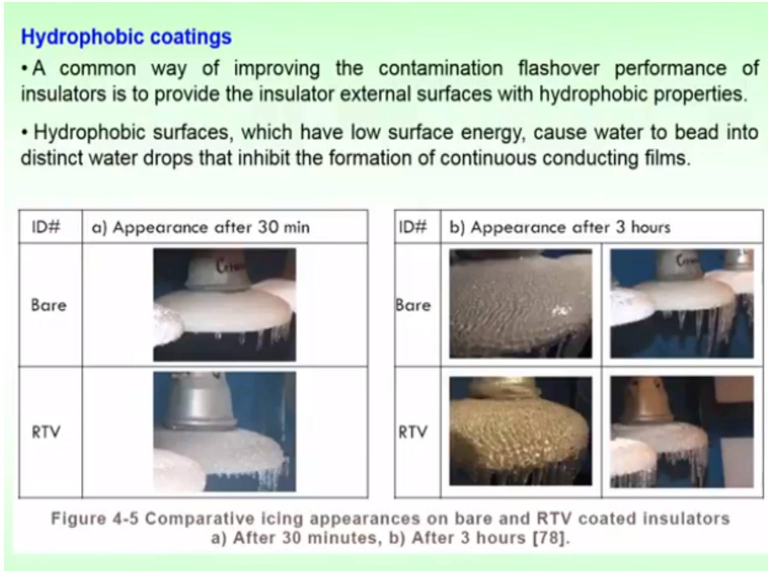

So various coatings we were discussing so the one falls in the hydrophobic coatings this is important one as a common way to improve he contamination flash over performance of insulators is basically to provide the insulators external surface with hydrophobic that is the water repellent property on the insulator surface properties. So that the droplets do not accumulate contaminants do not accumulate over a period of time.

So hydrophobic surfaces which have low surface energy cause water to bead in the form of beads in distant water droplets that in levied the formation in continuous conduction films. So the coatings made which are known as hydrophobic coatings makes the surface hydrophobic that is water repellent and sees that the formation of water droplets and the form of beats it is not continuous film.

So these will help in the better performance of the insulator in the origin of insulator strings. So some of the examples you can be seen here for a bare insulator this is a room temperate vulcanized coatings which has been this is without the coatings so appearance after 30 minutes is given here again this is been given to the cigre broacher which has been shown at the initial starting of this talk.

So appearance of three hours you can see how the insulators the bare insulators after the coatings performance is appearing here where you can see the better performance similarly RTV coat insulators you can see the improvement aspect after three hours. So these are comparative icing appearances on bare and also for RTV coating insulators and 30 minutes for three hours.

So better performance is being noticed the second is the super hydrophobic coatings here the surfaces with the combination of micro structure and low surface energy are known to exhibit so hydrophobic property so much better water repellent property then the hydro phobic aspect. So even slight amount of water drops can restrain dirt particles adding to the surface and clean the surface completely.

So it is known that if effective self-cleaning is to be obtained on an insulators surface the surface must not only be very or super hydrophobic but also have a certain roughness. So how this roughness is defined so surface structure should be composed of protonbances and small depressions which are required for self-cleaning purposes and must have a spacing of the range of 50 nano meter to 200 micrometers anywhere between this range and a protorbance height ranging between 50 nano meters to 100 micro meters.

So here you see a comparative icing approaches bare and super hydrophobic coated insulators for 30 minutes and also after 30 hours. And also you can see this is the bare insulators this is super hydrophobic conductor super hydrophobic coatings insulator for 3 minutes here you can see the appurtenance of after 3 hours, So this coatings to help in better performance in the field.'

The third is the self-cleaning coatings here the low addition force that is generated between liquid droplets and surface the liquid droplet and the surface falls on the insulators surface the energy or a addition force which is being between these two can manifested self in some in interesting characteristic so such as cleaning effect self-cleaning effect. So generally surface is a referred to a self-cleaning it can show somehow clean the surface by itself.

So on a hydrophobic surface where the water repellent surface is observed so self-cleaning is usually done by absorption and transportation of dust particles in liquid plate moving on surface. So the surface which is contaminated small droplets move with the precipitation therefore self-cleaning will remain contamination free in outdoor environments when it is exposed to precipitation.

Clearly self-cleaning can be of great outdoor insulation and therefore several self-cleaning coatings can be developed with electrical insulation in mind for all the three technologies ceramic glass or polymeric insulators making in mind. So several self-cleaning coatings are also developed.

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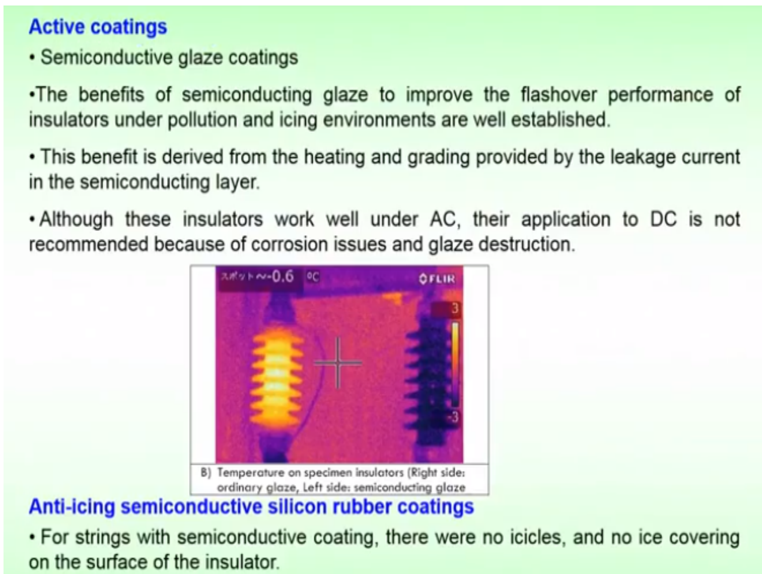

So next is a active coatings these active coatings are basically like the semi conductive glaze coatings which we have discussed. So semi-conductive glazed coatings the benefits for going in ease to see the improvement in the flash over strength or performance of the insulators particularly under the contaminated or polluted conditions and also under icing environments and these have been established well with the coatings.

So the benefit is also derived from the heating an degrading provided by the leakage current in the semiconducting layer which is done. So the coatings which is done although these insulators work well under AC conditions also these insulators works well under AC conditions the semi-conductive glaze coatings or application to DC is not yet recommended because fo the corrosion shoes and also the glaze destroyed incase of DC application.

So this is one of the typical example of temperature on the specimen here the insulators this is an ordinary glaze and this is semi-conducted closed coated insulators ceramic insulators. So anti-icing the next is anti-icing or a semi-conductive silicon rubber coatings for the insulators string with semiconductor coatings these helps in formation of more icecles or ice covering on the surface of insulators.

So these are being tried for insulators string where semi-conductive silicon rubber coatings help the performance of insulators by seeing that the does not allow the formation of ice on the surface. Next we look into the methods for characterization of the coatings we have discussed about various types of coatings like the room temperature vulcanized silicon rubber coatings for both ceramic glass and also the polymer methods polymer insulators but the techniques for polymeric insulators are also being developed.

So the presently for the bushings substation hallow insulators and the transmission insulators some of the coatings why are the utilities are being employed. And they are being used extensively and some of the methods are also being developed so methods for how to characterize the coatings is also equally important.

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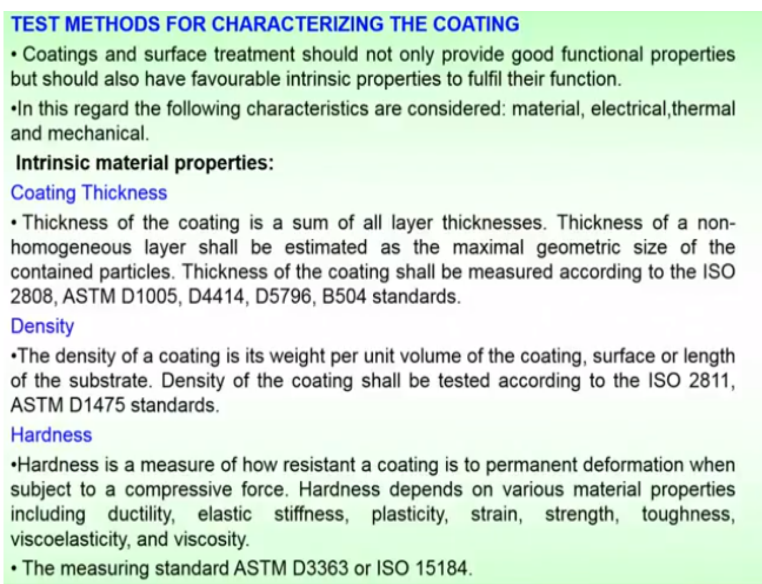

We look into the methods that is the test methods for characterizing the coatings so here the coatings and surface of treatment should not only provide good functional properties which should also have favorable intensive properties to fulfill the functions. So in this regards the following characteristics are important that is material electrical thermal and mechanical properties.

So all these properties are the methods to characterizes the coating which is being used so entrance material properties like the thickness of the coatings ho is this defined so what is the extent of thickness to be applied on the equipment that is on the conductor or insulators. So here the thickness of the coating is some of all the layer thickness.

So thickness of non-homogenic layer shall be estimated as a maximum geometric size of the contain particle so thickness of the coatings shall be measured according to the ISO standards to 808 and there are 8TM standards prescribed and D1OOand D414 and other standards of which give the information about the information about the thickness of material to be coated on the surface.

The second is the density of the coating this is again how much density that is weight volume of the coatings the surface of this length of the sub state again the density of the coatings is done or tested in accordance to the ISO standards 811 and STMT standards. So here mentioned suppose the density of the coating to be made third is the hardness again hardness the measure of how resistance coatings is to be permanent deformation when subject to compressive forces.

So hardness depends on various material properties including ductility elasticity, stiffness, plasticity, strain, strength, toughness, Viscosity and visco elasticity. So all these properties are important in deciding the hardness of coatings which is being applied. So for this again is standard measuring CM and 3363 is or the ISO standard 15184 is being referred so material properties which are being employed will also play a role in the that is the thickness density hardness to characterize the coatings.

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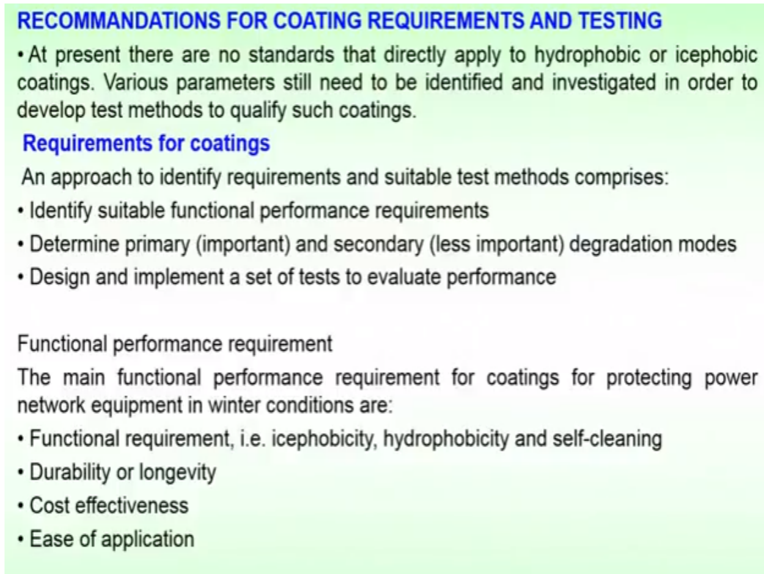

So what is the recommendations for the coatings and requirements and testing is also important task here at present there are no prescribed standards that directly apply too hydrophobic or iseophobic coatings. So various parameters are still need to be identified investigated in order to develop suitable test methods to qualify such coatings.

So lot of effort is being made by the manufactures by the researchers utilities and many transmission companies to see that suitable solution is obtained and suitable position is obtained or coatings is made or recommendation is done to see that this worked better in the earning through the performance of insulators or the conductors.

General requirements for coatings is to see that an approach to identify requirement and suitable test methods it comprise basically like it identifies the suitable functional performance requirements it could be an insulator it could be a conductor or it could be any substation equipment's.

To determine the a primary or the important and secondary less important degradation modes the third is the design and implement asset of test to evaluate the performance that is once the coatings is done before the coatings after the coatings performance of the equipment or the insulator or conductor is to be evaluated and check for is improved performance.

So the function performance requirement could be the main requirement for coating for protection power network equipment in winter conditions mainly are the functioning requirement that is iso phobicity the repellent and action of the ice formation of the surface hydrophobicity that is water droplets should not be formation on the surface on the insulator or the conductor and it should be able to have a self-cleaning mechanism where the formation of droplets or the contaminants to be spread are to be able to clean up on its that is the self-cleaning properties.

Then durability or longtivity again how long the performance of this coating exist so is also equal importance then the economics the cost effectiveness how much is being invested for the coatings and how effective the cost effective is also important is of application. So the method or technique which is being employed for coating so how is to implement or the use the coating or the conductors for any of this equipment.

So several of this functional performance also play a role in the insulator or the conductor coatings.

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Table 4-2 Summary of passive coatings for insulators

Main Chemical Components	Deposition Technique	Properties and Applications	Durability	Comments
RTV silicon rubber	Spray coating or brushing	Hydrophobic	10-15 years	Well established technology for polluted conditions Not efficient under icing conditions
PDMS resin + Silicon oil + SiO_2 nanoparticles + Pt (as catalyst)	Spin coating	Hydrophobic ARF between 30 and 40	Not tested	Ice adhesion strength was calculated from direct synthetic atmospheric icing on the insulator
Organopolysiloxane gum + silicate filler + aluminum hydroxide + organosilane or organosiloxane oligamer	Not a coating (silicon rubber composition)	Superior electrical performance	Improved stability in salt-fog test 10 000 hours of accelerated weathering	For detailed chemical composition refer to the patent
Various silicon-based or fluorine-based monomers (Notably hexamethyldisiloxane, tetraethylorthosilicate, Vinyltrimethylsilane, Octofluorocyclobutane)	Low pressure plasma polymerization	Hydrophobic Applicable on various types of insulator	Not tested	Only suitable for small insulators due to vacuum requirement
Organofluorine-functional silane and/or siloxane with a mineral acid	Dip coating	Applicable on ceramic, glass or plastic Water, oil and dirt repellent Increased flashover voltage	Excellent pH stability, heat resistance and UV stability	At least one salt of aluminum, tin, iron or titanium should be used in the dip solution as the catalyst

We look into the summary of passive coatings for insulators here again we have various parameter we have shown here the main chemical composition is on the first column the second is the deposition of the techniques the third is the properties or the techniques the fourth is durability the fifth gives the information about the commonest which are being done for long period.

Taking the example is the artificially rubber coatings this can be either done by either spray coating or using the brush type of method. So basically this is used to see the hydrophobic property is used improved the durability set to the 10 to 50 years and this methods ash been well established for polluted or a contaminated conditions but not an effective under icing conditions. So second is the PDMS resin plus silicon or silicon dioxide nano particles here again the uses pin type of coating which is mainly to see the properties of hydrophobicity or improved.

Here it is been in development stage or not fully tested and proven technology here again mainly targeted for ice addition strength was calculated from direct synthetic atmospheric icing of the insulator. So several of these things again combination of various materials various compositions are being used to see mainly for an this is a for a various methods which is being employed and some are being developed and some are being used and not testing you can see some or tested and some have better properties initially but in long run the performance have to be verified.

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Table 4-2 Summary of passive coatings for insulators

Main Chemical Components	Deposition Technique	Properties and Applications	Durability	Comments
Various fluorinated homopolymers and copolymers	Various deposition methods (Plasma etching, spin coating, solvent casting, plasma functionalization, dip coating, spray coating or CVD)	Superhydrophobic and self-cleaning Applicable on ceramic, polymer or glass Prevents dry band arcing in contaminated environments	Excellent UV resistance	Various methods presented to improve the UV resistance of superhydrophobic coatings
Silicon rubber and SiO_2/ZnO	Spray coating	Superhydrophobic Self-cleaning	Superhydrophobic properties is retained after 10 days in acidic and basic solutions Excellent thermal and UV resistance	
Silicon rubber and stearic acid	Spray coating	Superhydrophobic	Not tested	
Various organosilicons, fluorocarbons, solvents and catalysts	Sol-gel process	Applicable to glass, polymer, ceramic and metal	Proved to be stable in multi-factor aging test UV resistant	
OH-PDMS and Modified silica nano-powder	Spray coating	Superhydrophobic Significantly lower accumulated ice weight compared to RTV coating	Not tested	Icing test was performed in a climatic chamber on a treated insulator

This is again summary of the passive coatings for insulators here similarly various chemical composition of the material are given used for silicon dioxide zinc oxide and silicon rubber.

So various techniques are employed like plasma itching and spin coatings spray coatings then several of this properties like super hydrophobicity property and self-cleaning methods are because of this fluorinated hydro homo polymer and co-polymers are being used.

This is have an excellent we resistance and various methods are presented to check to UV resistance of suitable super hydrophobic coatings. So again silicon rubber and silicon dioxide and silicon oxide coatings are being employed to get the super hydrophobic or self-cleaning property here again super hydrophobic properties retained after ten days definitely in basic solution excellent thermal and UV resistance have been noticed and some of the silicon rubber and be like acid coatings also been tested which are being not been used and there been verified.

So again you have a various floret solvent and cat resistance methods so again OH, PDMS, nano and modified silica powder that is the nano powder is being also used like spray coatings is being employed as the method. Here super hydrophobic properties is noticed and significant lower accumulation of ice compare to RTV coatings. So this method also tested or being tried out so icing test was performed in climatic chamber of pertained insulators.

So several of these methods have been developed various types of coatings passive coatings have been developed for conductors insulators for better performance.

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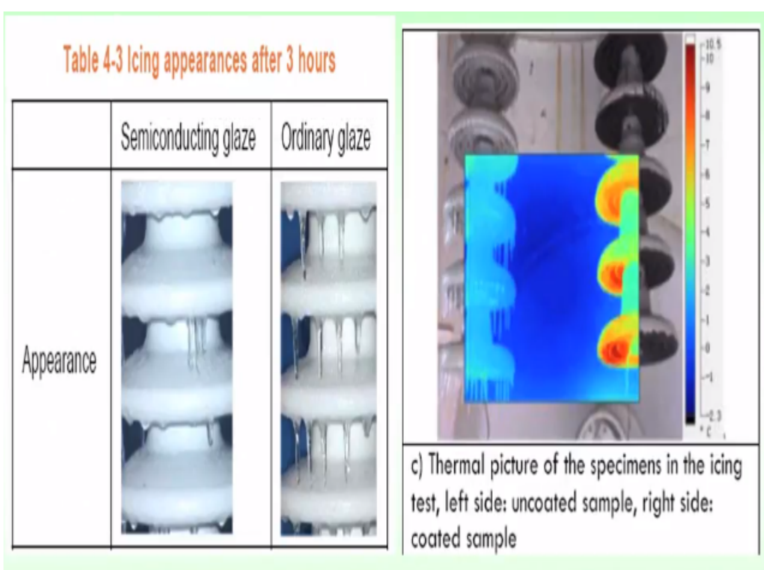

This is one of the methods which has been shown here icing appearance of the semiconducting blaze you can see the appearance of the semiconducting glaze this is ordinary glaze. So after the semiconducting glaze the ice accumulation is being drastically is reduced the second picture shows the thermal of the specimen in icing so this shows the uncoated sampled on the left side and the right side shows the coated sample which has been attributed in a better performance showing in a better performance.

So several of this glaze ordinary semiconductor glaze and coatings are being used for period of time in the transmission systems. So summary of this passive coating again this is been treated as been noticed that lot of effort is been carried out lot of effect is being made to see that the coatings are being used for both ceramic glass and polymer effort by the utilities researches and also the manufacturing to come up with better methods and techniques and also durability in field for longer sustainability.

So here we have tried to look into various coatings for the insulators which are being employed and we have also look into the cleaning aspects of the insulators so with this we end the important of this topic on the coatings of ah the insulators thank you.