Recent Advances in Transmission Insulators

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Module No # 02
Lecture No # 06
Comparison of Transmission Insulators

Good mooring we were discussing about the service experience of all the three technologies ceramic, glass and polymer insulators in the field over a period of installation. So one of the important criteria for the insulator friction in the conditions like polluted or contaminated condition this is very important aspect for installation to perform for both the flash over and also with stand conditions.

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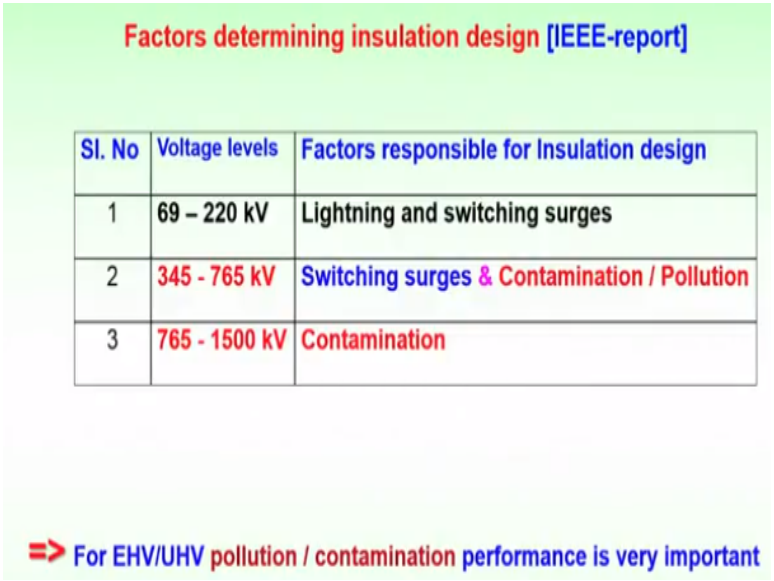

So this insulators are designed or the line insulation as mentioned earlier and I am repeating the slide here the factor which determines the insulations above 220 KV is the lighting and switching surges above 400 KV is the switched surges and contamination or a pollution plays an important role for the line design further to 765 KV level contamination or pollution is the at most important criteria for the line design the very important factor to be considered.

So keeping this in view the insulation could be of ceramic, glass or a polymer as to perform in the field for the contamination or pollution conditions. So what is this contamination or a pollution effect the performance the important factor to be noted is during the contamination or polluted condition it is not the over voltages or which causes the flash over it is at the normal working stresses.

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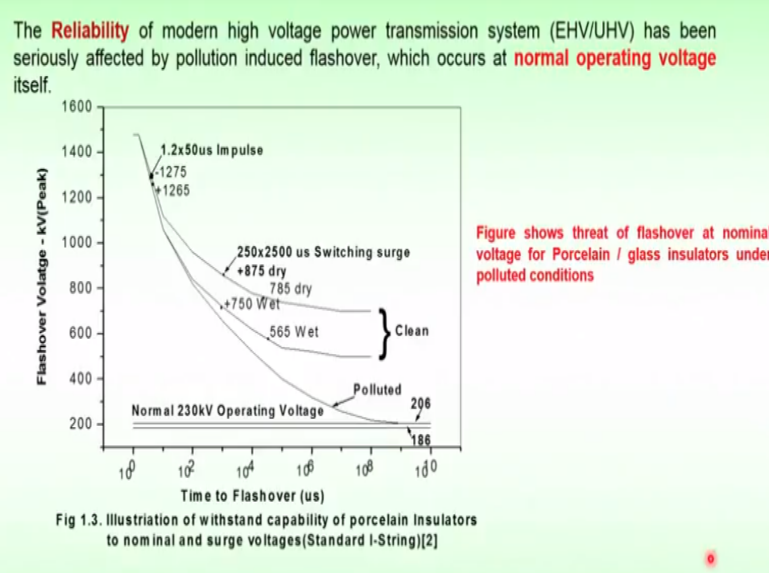

Fig 1.3. Illustriation of withstand capability of porcelain insulators to nominal and surge voltages(Standard I-String)[2]

So this point I have earlier mentioned so the any reliability of power system transmission network it could be extra high voltage or ultrahigh voltage this is very seriously effected and the literature and also the performance of the not only elsewhere in the country. We have seen several outages because of the pollution and used flash over which have occurred at the normal operating voltage.

So normal operating voltage and any working voltages of the system it could be 220 KV 400 or 765 KV system. So there is no over voltages the phenomena occurs at the normal operating or working voltages. You can see the graph here by seeing graph this shows the flash over voltage in peak versus time of flash over. So the example I did here is the 220 KV systems where 220KV operating system you see the 206 is the maximum operating voltage and 186 is the minimum operating voltage for a 220 or 230 KV operating system.

When you carefully look into this the impulse with stand the lighting impulse with stand for 220 KV system for wet and dry conditions is value somewhere 1275 to 1265 is a lightening

impulse which is being applied and insulation is tested. So the performance for 220 KV the lightning impulse is 1.2 micro seconds tail front end tail impulse is applied and verified for the insulation strength.

So similarly for switching surge which has a wave form of 250 / 2500 micro seconds here switching surge magnitude is typically around 875 to 765 for dry condition or wet condition the figures are shown here. So switching surges or lightning surges both for dry and wet conditions the insulation with stands in the laboratory or in the field but when you carefully look other the clip condition you can see the curve here.

This curve over a period of time this is the time access which I showed the time to flash over the time access over a period of time this curve touches the operating voltage line here this shows that the insulator in the field over a period of time the pollutants cut collected after this because of dew or light rain or mist the insulator when it comes into contact becomes wet and surface starts conductive once the surface starts conducting depending upon the layer of polluting form and the conductivity of the surface.

This discharges could start which are known as scintillation or partial arches of the surface depending upon the surface conditions the insulator entire insulator there could be a flow of leakage current and flash over across the single disc further cascading effect could also be seen where the entire disk insulator or the entire string insulator could flash over tripping of the network would happen.

So here it is very clear so the pollution levels could happen or pollution flash over could happen at the normal working voltages it is very important point shows the threat of flash over which could happen for glass or porcelain condition insulators at normal working conditions serious threat. So for EHP an UHP or both for AC and DC the pollution phenomena as to be considered while going in for line desire.

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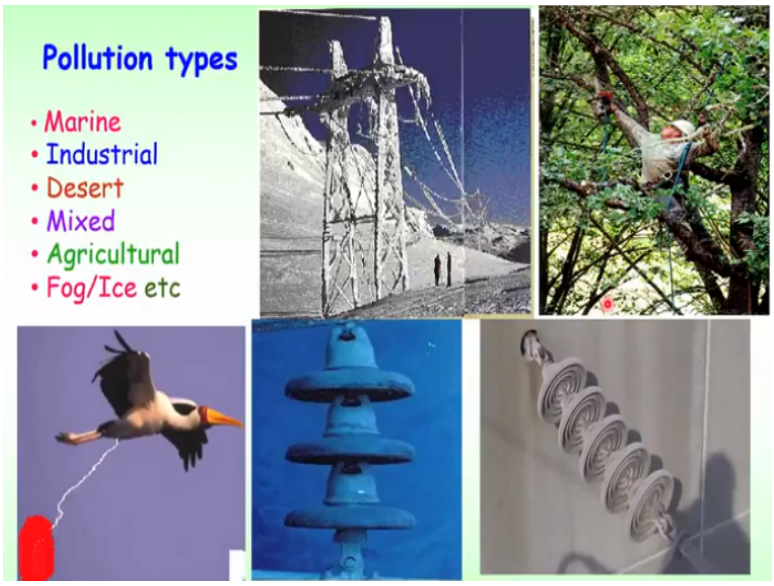

Now pollution what type of pollution? Pollution could be several types and nature of the pollutants in case of the line transmission lines passing near the sea coast the salts from the sea could be collected in on the surface of insulators. So because of this type of pollution or the salt spray which has been absorbed near the marine or the sea coast or the areas where the rivers transmission towers are near to that.

And salts get deposited over a period of time and becomes conductive because of humidity temperature low temperature or fog or mist or because of the raining condition and the flash over could happen. Similarly the pollution could be of industrial pollutant again it could be transmission lines passing nearby the industries.

Industries could be again example of cement industry or it could be any chemical industry or it could be the large brick Kline where the pollutants form this industries could go and collect over a period of time on the surface and later on after becoming wet could cause flash over. The third being the desert pollutant again desert pollutants here the transmission lines which are at in the desert areas or seen that the desert are high because of high winds which are seen the sand from the desert goes and collects on surface have the insulator.

Sometimes sand is of contents very high salty conditions so this over a period of time because of humidity the surface could conduct and that could be a flash over. The mist pollutant could be line that are pass over the sea cost and the industries area also situated so nearly two or

three combination of the pollutant could cause this mixed pollutant or the lines which are passing near the industry and some of the areas agriculture activities and so on and hence so forth.

The third the other pollutants could be of the agriculture activities this agriculture activities particularly during the season or particular spray or because of the agriculture activities the pollutant go and settle on the surface this could the pesticide spray cold be because of the low flying helicopter which they used for fields to spray this could case the surface contaminant over a period of time similar in the transmission line which are near the cold countries or in the places of high altitude where experience of very low temperature fog, snow, ice accumulation over a period.

So you can see here one of the typical example of that the collection of the fog or ice collected on the transmission system. So this again the insulators completely are covered with the ice and here the pollutants this could cause or the flash so lot of maintenance is essential for the overhead transmission lines particularly during this conditions to remove the pollutants on the insulator surface.

Apart from this you have growth of hesitation with the transmission lines could be in this vegetation will conduct during the wind condition regular maintenance of the transmission conductor minimum distances have to be maintained else there could be a short circuit or flash over because of the vegetation or the branches coming in contact with the transmission conductors.

So these are some of the examples of the pollution could be off near the cement it is or because of the slats spray near the sea coast where because of the marine transmission line near to sea coast. So this are various examples of the contaminant this collect over the period time and becomes wet and the flash over could happen.

The example shown here the because of the droppings or the bird excretion during the flight from the transmission tower this excretion of the bird is highly conductive of fluid where the fluid could come in contact with the phase conductor and the flash over could also happen.

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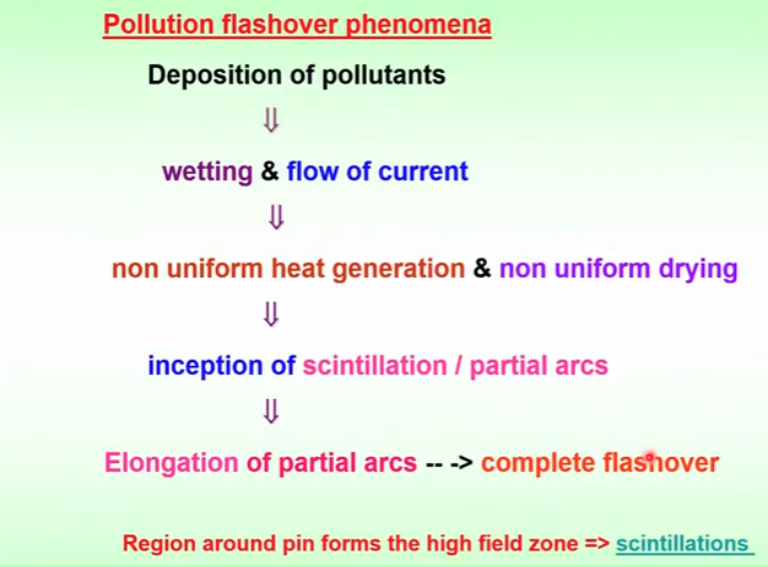

So how the phenomena of a pollution flash over happens I have briefly informed about this so repetition of the phenomena here. So as mentioned in the towers the insulators conductors are there in the overhead transmission system the pollutants could be of marine and the sea salts or could be the industrial pollutants or the agriculture activity related pollutants or because of the other activities settle over a period of time.

And this settlement of the pollutants will be non-uniform or because the wind could carry some of the pollutant or the pollutants settle at a different uniformity on the surface because this over a period of time incase before for the monsoon starts there could be waiting because of a fog, rain, drizzle or snow which is surface and once the surface becomes wet the surface starts conducting.

So the flow of leakage current happens the flow of leakage current again here depends upon the pollutants sprayed on the surface. So in case the pollutants are uniform or not uniform then the because of the wind some of the pollutants could be more at some locations and some could be very less and in some places there could be pollutants also. So here because of this flow of leakage current there could be non-uniform heat generation because of arching there.

And further non uniform drain so both here on the surface the formation of small bands which is dry and wet in nature could be observed. So the permission of this bands dry band and wet band on the surface could create non-uniform condition and the arching particularly across

the dry band is observed. So semi dry band or dry band arching is seen where inception of scintillation or partial arcs what we call.

So these scintillation or partial arcs which happen could along it could depend upon the surface conditions. So and in case the entire surface becomes conducting their could be a flashover of the single disc initially and further the cascading effect or the distribution of the entire potential across the shrine takes place and there could be a complete flash over of the entire string. So here a very important point to be noted is the scintillation usually start from the high voltage conductor zone high voltage field that is near the pin junction.

So this we will be looking into that so the region around the pin the stress is very here and the field is higher in this where scintillation start from this pin region and further travel towards the petty coats and could bridge to the cap of the insulators. So this is again a schematic of pollution deposits the wetting which happens because of the rain, fog or the mist or snow the discharges you can see here the discharges could happen.

Partial discharges are scintillation small arching and dry band arching or wet where formation of dry bend arching takes place then the small arching happens. So further surface conditions are mentioned there could be flashover disk and entire voltage redistribution could takes place and flash over could happen for the across the entire insulator string.

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This is one of the laboratory experiments which has been performed in the lab you can see as the stress voltage level is increased polluted insulated string this is in case of (()) (15:45) here. You can see the discharges developing near the pin junction this is the high voltage conductor so other side being the conductor sorry connected to the tower earthed conductor.

You can see the initially scintillations a partial arches which start near the pin junction spread towards the pet coats slowly and as the voltage level is increase further depending upon the service conditions you see here the discharges the scintillation initially then the discharges will be higher and bridging could happen like this once the bridging happens across the single disc then the voltage re distribution takes place and the entire string could flash over.

So this happens similar phenomena happens in the field and as I mentioned earlier exact time it depends on the pollutants which are collected on the surface and the phenomena could take time and this entire phenomena could happen for the normal working voltage condition. So that is the point to be noted.

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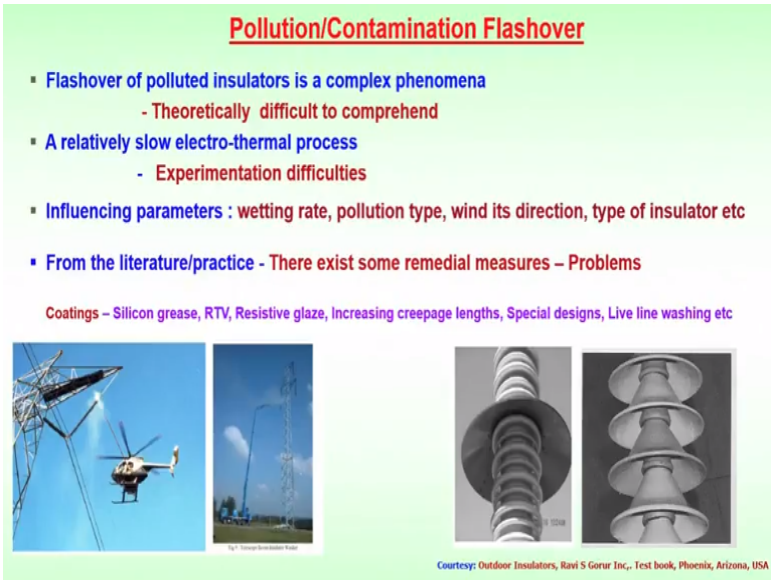

So how to contain this or how to see that pollution or contamination flash over to understand in a better way and how to tackle this problem very important particularly in extra high voltage or ultrahigh voltage ranges. So pollution or contamination phenomena is a very complex as I mentioned at theoretically it is very difficult to comprehends this phenomena.

So considering all the parameters simulating the conditions or deriving this condition is very difficult task as the phenomena is dynamic depends on several of the parameter. So very difficult to theoretically come to a conclusion and arrive that the following this problem could happen. Second dimension this phenomena this time very slow electro thermal process. So it involves not only electrical process.

It involves eating of the surface layer for machine of dry bands wet bands so it could take (()) (18:08) could extent long large time or depending upon the surface condition. So similarly the experimentation in the lab or exact simulation in the lab is equally difficult so theoretically is also difficult experimentation simulation exact conditions is also equally difficult.

So what is the parameters which arc is influencing this as mentioned earlier the wetting rate so how whether it is a rain, fog, mist or due to humidity conditions. So how much is the wetting happening in the surface and how the conduction is happening. So it is very difficult to exactly point out at the surface of the condition of the insulator in the field various dynamically because of the wind and several other factors.'

So pollution what type of again the pollutant are spread of the surface it could be industrial waste it could be a chemical vapor it could slats which are spread it could be the sand it could be any other pollutants like the ash and deposits so on and so. So the influencing parameter along with the pollutions depends upon the wind and direction. The wind and the direction will also play major role the wind could carry the pollution away or sometimes it accumulates the pollution to the existing thing.

The type of insulators so what type of insulator is being employed for that particular location so several of this parameters play a role in the contamination issue or contamination pollution flash over phenomena. So apart from this ah it is not there are methods which are been this phenomena is not understood but the methods which are available in the literature and which are practiced by the utilities in tackling this there are some remedial measures suggested by the various working groups and several utilities do follow and they have tried several methods to overcome this phenomena.

Some of the examples could be coating from the surface of the insulator to avoid the pollutants getting collected on the surface. So applying the silicon grease again a silicon grease making it hydrophobic where water droplets or the pollutants should not accumulated on that going in for RTV coating that is room temperature vulcanized RTV room temperature vulcanized coating which are normally done on ceramic insulators to see that this coating will help in preventions of pollutant getting collected on the service.

Similarly resistive glaze this is basically glaze coating on the surface to make uniform conduction on the surface has been tried out by the utilities several literature do exist on this. So people from the utilities also tried using the creep age length that is increase in the creep age length. So increasing the creep age length sometimes additional insulators have been tried out or sometimes the new type of insulators have been tried out.

One of the example could be the bell type of arrangements or going in for the special creep age extend us you can see here the extender portion of insulators is intentionally done to see the extra creep age is being provided for the insulator to overcome this live line to washing. So there are methods which are being employed by the utilities not only in several countries in our own country the utilities employ the high telescopic type of arrangement with a special knowledge nozzle to clean the insulators on monsoon conditions.

And there are live line methods where live line method are being adopted for insulator cleaning the this could be the water jets from the telescoping boom ladder which is mounted on that trucks or through live line washing methods where this phenomena is carried out. Recently here is also where it is very difficult to see the truck goes particular the transmission towers which are on the high attitude range or in the mountainous area where it is very difficult to such places helicopter mounted nozzles with the special arrangements are also being used to clean the insulators during the monsoon condition and see that the flash over is contained.

So several of this measures are being tried out and most of the methods are being used for cleaning of the insulators lot of maintaining is being lot of maintenance personal and use to be is being used for this phenomena.

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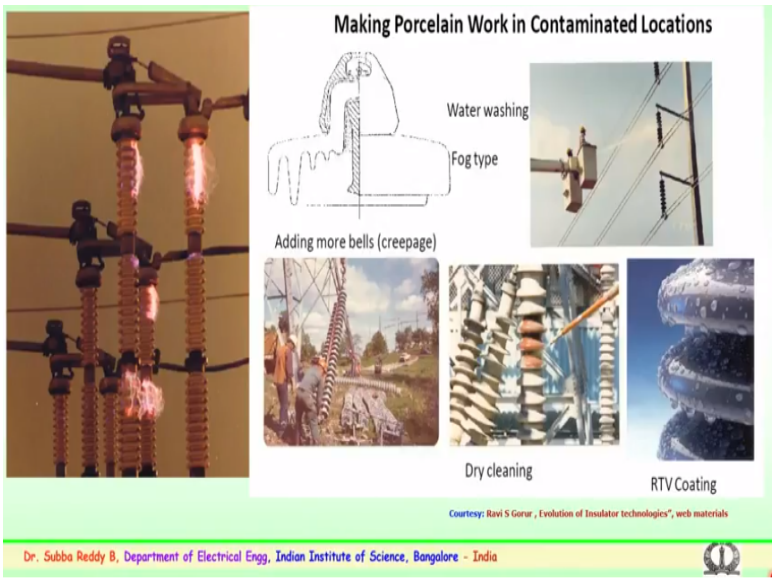

So the again this slides shows how the methods are being used one of the method again the water jet on the transmission systems earlier like the shown using helicopters are lorry truck mounted nozzle type. Here also a washing of the insulator is one of phenomena which particular trying to see to improve the conditions adding more bells as I mentioned this. This is simply to see that increase in the creep age of the existing insulator where this could help or to contain the contamination.

Dry cleaning with higher power jets that is cleaning without water in some of the utilities are also being then as mentioned RTV coatings. Again RTV coatings it is a coating to see that the surface of the insulator becomes hydrophobic and does not allow the contaminants to settle on the surface. So several methods has been employed in the field by the utilities as this phenomena at monsoon conditions is ah thread to the normal conditions working conditions.

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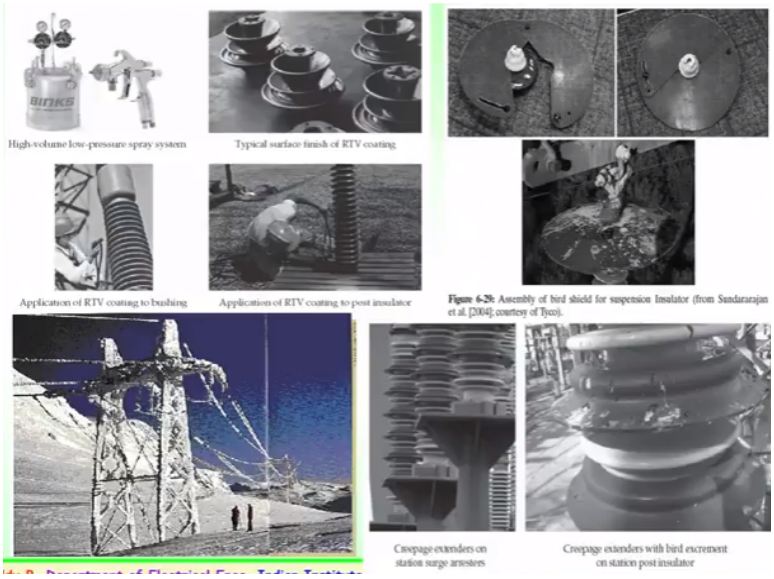

So these are some of the examples using with a low pressure spray gun for the cleaning purpose as mention the RTZ coating for various insulators it could be post insulators it could be application of bushing wall bushings. So lot of effort has been made in that as mentioned extending the creep age. So there is again arrangements to see that bird shielding particularly to contains the bird dropping to the insulators surface and it is performed should be improved.

So there are several methods of have been suggested for this practically to improve the pollution condition. Then creep age extender as I told so some of the sheds are increased with the help of creep age extenders so that the creep age length is increased this will help in the pollution condition.

And several methods have tried few are being used by the utilities regularly so in case of the ice accumulation lot of effort as to be made to clean up the ice loading the ice on the insulators and the conductors during the winter conditions.

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This causes lot of revenue loss for the utilities this is one of the again example of the telescope boom insulator to cleaning method used by few utilities his is live line washing method.

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Figure –10: Truck mounted Helipad

Figure –11: Washing of V- string using Helicopter.

This are again the tuck mounted helipad where it is being used for the cleaning of insulators.

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So we have looked out into the several options of intro the pollution conditions. Some of them are being practiced by the utilities but the reason is still there is a need to develop suitable medication technique which could be cost effective all the methods suggested in the literature and also been practiced are being highly costly and also the performance is to be lot of maintenance personal also employed of are the cleaning and so on.

So there is a need to develop suitable technic which should be cost effective and also used better for formatting for utility. So with this in the institute at the department as tried to look into this problems seriously and there was an effort to come up a suitable method for reducing the flash over conditions and see that insulated it stands for higher voltages then the normal conditions which used to happens.

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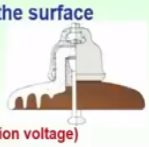
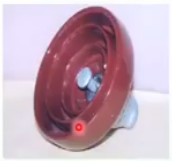
Main aim is to enhance the pollution flashover strength by reducing maximum surface field - The maximum surface stress occurs at the pin region

Innovative solution to problem involves extension of pin along the surface

- Without affecting the air clearances
- Without significantly sacrificing the creepage length
- Without amplifying bulk stress in air
  (which deteriorates with corona inception voltage)
- Remain as mechanically rugged addition



- Intuitive approach employed iteratively with field solution



Contributions of the our Work

- Development of SCSM code for theoretical simulations
- Establishment of A National level experimental facility for conducting pollution studies on Insulators/strings
- Development of a Novel field control element to improve flashover strength of insulators during polluted conditions

So the main intention was to see that and enhance the pollution flash or strength particularly by reducing the maximum surface feed. As mentioned near the pin junction surface feed near the pin junction. Pin junction is where the conductor gets the high voltage conductor is connected and this is connected to tower. So this junction is a critical junction where the field is high and this field ash to reduced so that the scintillation or partial arches which occur from this junction is reduced.

So with this information some solution was though and how it could be done is should be done again without deserving the normal extension the conditions of the pin cap and the insulator which is fixed. So without disturbing the exact insulator without affecting the clearances from the metal to the cap or on the creep age lengthen bringing on the creep age length.

So and also see that the bulk stress which from the insulator is not decorated particularly whatever the addition fitting is to be done should not create an issue for the corona inception voltage or it should also be mechanically fixed to this insulator where it could have a better solution for this conditions. So here initially for this theoretical code was written based on the surface chair simulation method.

This is again a numerical technique which was employed for the simulation of both electric field bulk stress and electric potential across various insulators which are being used in the country various ceramic insulators up to 765 KV to the system 800 KV systems. So various

insulator configurations have been taking exact dimensions have been considered of and the code was developed here and for this a preliminary experimentation has been carried out.

So the establishment of the facility of the institute was done particularly to see the improvement in the pollution flash over stress. So the development of this information particularly for the polluted condition are to see that the improving the flash over strength of the existing insulator later this particular technology could also be used during the manufacturing time.

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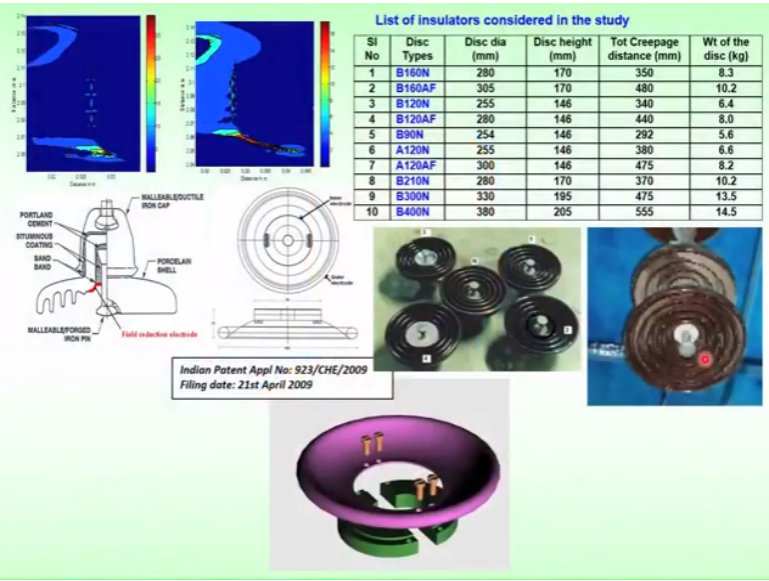

So this is with this lot of effort has been done and both theoretical simulations as well as the experimental investigations were carried out as mentioned several insulators you can see various insulators which are used in the country for high voltage and extra high voltage, ultra high voltage transmission with various diameters disk heights and creep age lengths are given here.

So which are used for 220 KV to the 800 KV systems these insulators are evaluated and filed reduction electrode or field control electrode or a field control electrode which it is known it is been developed this is a small gadget where it is also (()) (31:28). So this gadget can help which will be fixed near the pin junction here so this will only take a very small portion of the cement junction that is creep age not disturb so very little creep age is used the cement junction which does not form the creep age.

So the disk is fixed here it is the mechanical disk where the field is intestinally seen that it is distributed and what is the surface area is the more scintillations or the partial arches which occurring gets reduced. So this is the intention out to that so suitable countering of this electrode is also important hence the corona could start from edges. So very important we have tried to see the countering this electrode has been done and it has been placed for all the insulators various types of this electrodes have been designed and tried for the performance.

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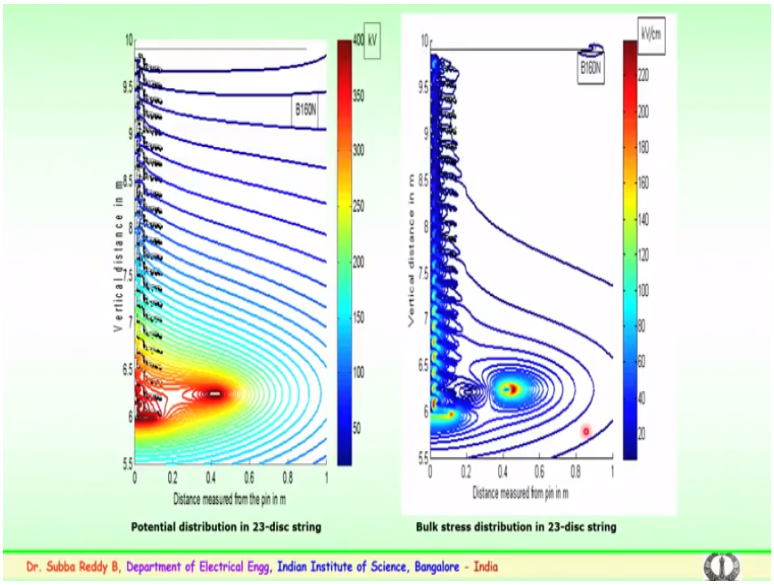

So here the simulation as well as experimentation as carried out as mentioned the simulation carried using this surface charge simulation method for various voltage levels and we have tried to see that the field and potential is distributed and particularly the field is reduced when using the this failed control electrode which has been mentioned. So the potential distribution here in case of the 400 KV transmission system is simulated were the field here the equi-potential lines which have been shown.

The similarly we show here the bulk stress are the volume stress which insulators sees you can see the over stress is very high near to line junction that is the line end the conductor voltage conductor end slowly gets reduced towards the ground end. Here the potential is very high near the ground end so this bulk stress which is very high could be very dangerous are a period of time.

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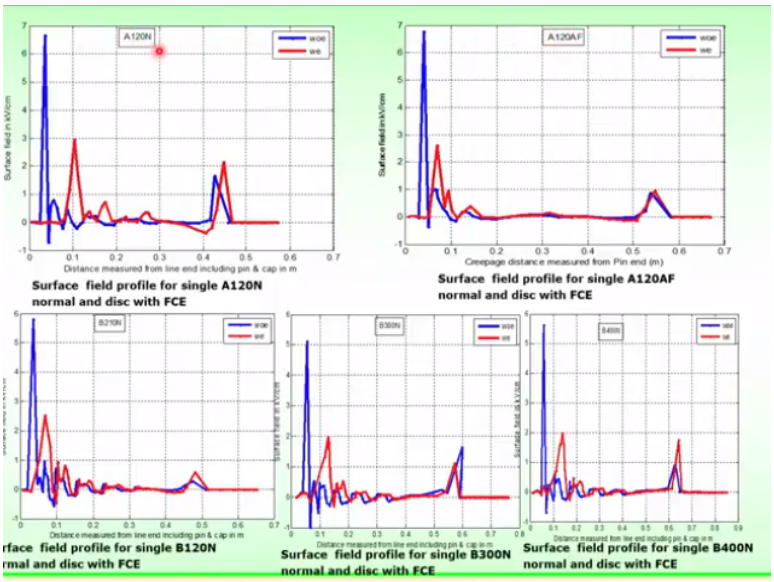

So it has to be reduced so that proper functioning of insulator could happen so various option I told you various types of insulators so this are various insulators for normal conditions anti fog similarly for very high creep age length insulators. So several of this insulators both theoretical as well as experimentation as been performed you can very clearly see this blue curve shows performance of electric field near the pin junction for the conditions without any electrode.

The red curve shows the performance with the electrode or the field reduction electrode you can very clearly see the reduction in the field near the pin junction example here it is reduced by more than 50%. So this is a very important point to be considered once the filed gets reduced the partial arches the scintillation happening or reduced or completely eliminated because that this working voltage if the arcs or the scintillating do not have in the flash for phenomena could be arrested.

So that is the intention of this so we have carried out various situation simulation studies for different insulation suspension tan different insulators conducted for used for various voltage levels you can see most all the cases the field gets reduced drastically by using the field reduction electrode or field with electrode. So this is a very important this gives us an encouragement to conduct the experiments in the laboratory and similarly find the performance using the lab.

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So for this facility was developed for testing the source and the pollution where in the source limitation we have is the 150 KV the current rate in is 6 amps where we can use up to 160 KV system so we tried to conduct the experiment on single disk where few disk in a strength in the limitation of a setup.

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So experimentation has been conducted with available standard high PC50600507 which clearly gives the information about the contamination how the insulators are to be contaminated or polluted. So in accordance with this procedure followed in the EC s experiment were also

conducted for normal conditions and for the insulators with the field electrical field control electrode field fixed to them.

So here two types of experiments were done one is by the dipping other is by the spring method both methods have been tried out and the performance of all the type of insulators single disk and also disk in 3 to 6 as limitation of the equipment was is done so the experiments where performed.

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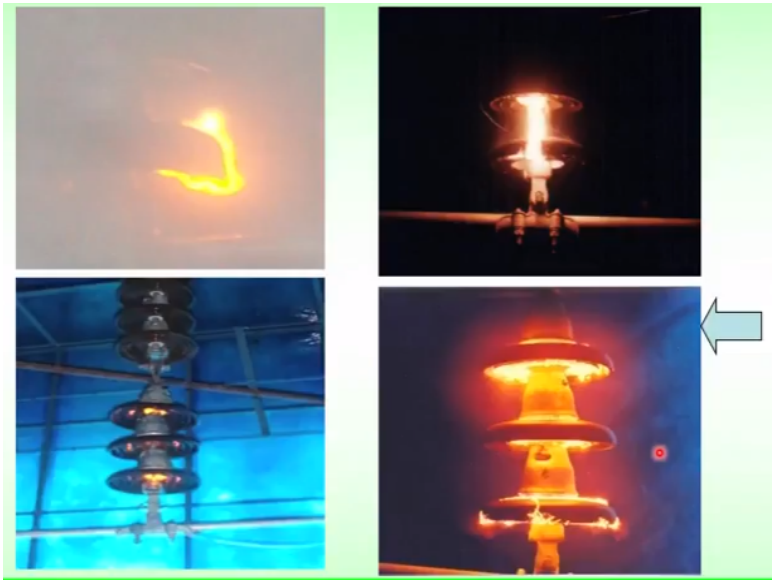

So various experiments with stand he flash over of single disk three disk were conducted.

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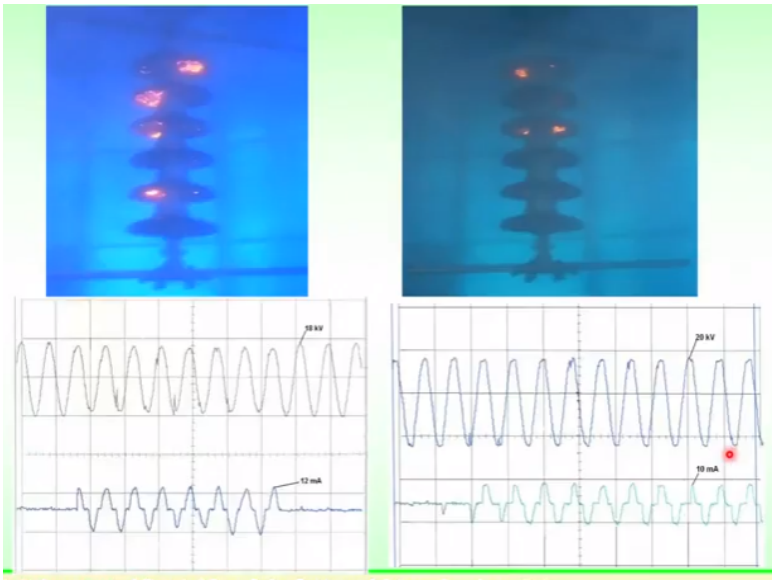

And during the period leakage current also tried to measure with and without the field and reduction electrodes. So you can see in one of the case where the leakage current also reduced drastically with employing the field control electrodes. So this string when we compare this is the string with without the field reduction electrodes this is the string with filled reduction electrodes. The leakage current what you see here when the voltage is supplied 18 kilo volts the current was 12 milli amps.

Similarly you can see here for the 20 KV that is the 20 kilo volts is applied to the string with current is only 10 milli amps. So this shows with the field reduction electrodes the current also leakage current and is also drastically produced and performance you can see the discharges which are seen early in a lesser voltage or reduced to an extent here.

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Again a several experimentation both for single disk three string 6 disks in a string and tried out with and without eh field electrodes. You can see that the string which does not have the field control electrodes do not flash over or other flashes early this experiments have shown that there is a better performance in using the field control electrodes so several trials.

So trials were carried out and this technology is carried out were in pollution particularly for any of the ceramic disk electrodes this electrodes could be used for the any of the disks which are being used for EHP and UHP transmission levels. So this is about the pollution performance and importance is the mitigation techniques which are being used in the field

and the techniques which has been developed at the institute where this will be very useful for the ceramic industry or manufacturer.

With this I will conclude we will look into the failures or the conditions in case what does it happen I case the insulator strings in a string some of the faulty insulator are there how to estimate this field and potential what could be the reason and how to take a decision pertaining whether this insulator should be changed or the condition or the utility engineers. So this we will try to discuss what happen in case there are of 40 disk in a string and how potential and electric field gets distributed with the faulty insulators so thank you.