Advances in UHV Transmission and Distribution
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Lecture – 07
Pollution flashover phenomena, modeling etc

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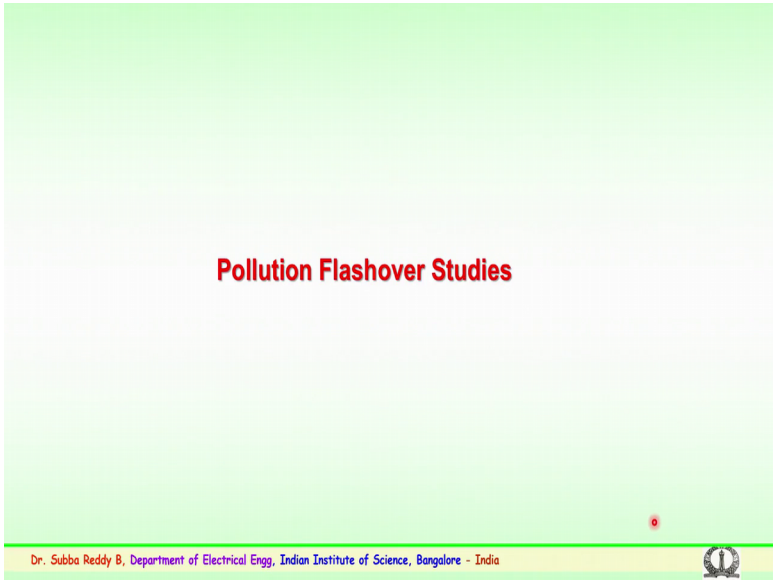

So as I was mentioning as a voltage levels go up from the extra high voltage to ultra high voltage, the pollution or a contamination flashover use of a very important particularly during the consideration of the design aspect of a insulation. So, the pollution or a contamination flashover studies have to be carefully carried out before the insulators are erected in the field or is being erected in the field conditions to the tower.

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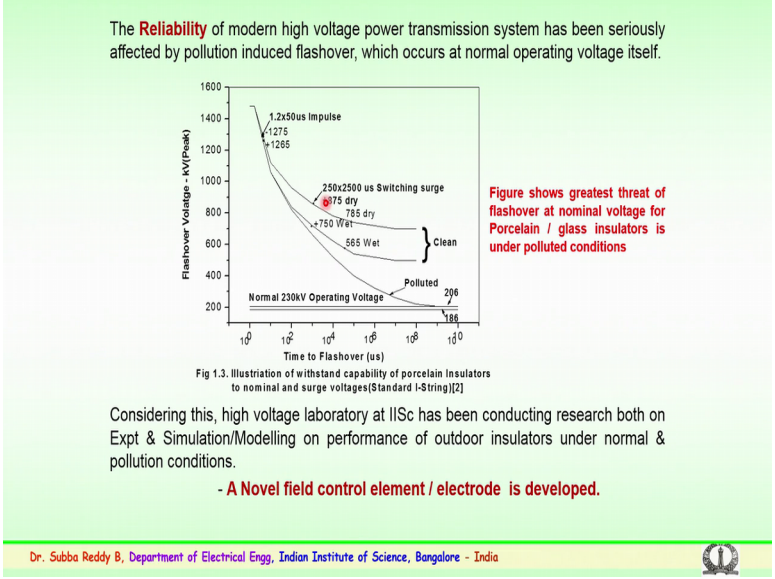

So, how is this pollution threat and why it is unimportant factor, so the reliability as being discussed.

For the modern high voltage power transmission system, has been seriously affected by in the pollution or a contamination induced flashovers. Which important point I would like to stress is occurs at normal operating voltage itself; so the normal operating voltages. So, we are not seeing the lightning surges, we are not seeing the switching surges, we are not seeing the power frequency over voltages, but the contamination or a pollution induced flashover could occur at normal operating voltage. So, this is a serious concern. Just by looking into the graph you can see the flashover voltage verses the time of flashover.

Here an example, I have shown here for a 220 or 230 KV operating voltage 108 y 6 KV is the minimum operating voltage for a 220 or 236 230 KV system. 206 is the actual operating voltage, for a 220 KV system, 1.2 by 50 micro seconds is the impulse voltage or a lightning serge which an insulation has to be applied. So, for dry conditions a 1275 KV is applied where the insulation withstands, so no problems. Then coming back to switching surges which are because of the opening and closing of the circuit breakups. The switching surges or switching impulses are typically of 250 by 2500 micro seconds

duration. So, switching surges will normally be of magnitude somewhere around 875 KV in case of dry and 750 KV in case of wet condition; so the 230 KV insulator string.

Normally under goes lightning impulse voltage levels switching impulse voltage levels both for dry and wet conditions, does not have any problems with that, but when you follow the line here, the third line the polluted conditions, you can very clearly see that the flashover voltage over a period of time this is a time to flashover. This could happen at normal working voltages. So, the pollution insulation level could come down to the normal working voltage. So, this is the serious threat where the flashover at working or nominal voltages for porcelain or a glass insulator under contaminated conditions could happen without any surges, where the surges lightning or switching surges without any affect of the lightening or switching surges.

So, considering this, a very important the high voltage laboratories have to see that the pollution facility has to be developed. And suitable performances have to be carried out under polluted conditions for various polluted zones.

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So, pollution or a contamination when we are discoursing again will have a various types of pollutants as we discussed. The pollutants in case the transmission towers are passing near the sea coast, the pollutants may be because of the salts from the sea shore which are being carried out by the wind and gets deposited on the insulator surface, there could

we have industrial pollutants in case the transmission towers are run near the industrial areas an example if there is a cement industry.

The cement dust gets collected on the transmission insulators over a period of time. Similarly in case of desert, desert sand sound which is highly conductive in some of the countries. So, this desert sand also gets accumulated on the insulator surface during humidity become wet and the surface starts conducting. So, this is again desert pollution is also a impotent fact to be noted. Mixed pollution, again mixed pollution could be the transmission line running both near the industry as well as a sea coast. Or it could be in the desert where the industries could be there or it could be because of the many combinations. So, such pollutants also get accumulated on the surface over a period of time. Then the pollutants could be due to the agricultural activities; so agricultural activities particularly.

Plowing of plant using pesticides by employing mini helicopters for spraying in the fields these chemical vapors or pesticides or agriculture activity related pollutants go and settle on the insulator surface and again because of the mixed or fog or during the rain becomes conductive and could be a contamination or a pollution is flashover could happen. Similarly fog or ice this again happens in the high altitude and the countries where ice loading is seen on the transmission tower. This could again become impediment for the smooth functioning of the insulator where pollution or a contamination flashover creates a major hurdle for the transmission or utility engineers.

So, apart from this type of pollution we also come up with the forest where the transmission lines run across the forest huge trees and branches have to be regularly trimmed, where the flashover could happen because of the branches coming in contact with the live transmission conductors. Then we also see the bird related flashover the excretion of the bird is a highly conducting fluid. So, when the birds take shelter on the transmission towers during there are depart also there could be a high excretory thing which could be a conducting fluid or comes in contact with the 2 transmission conductors a flashover could be happening. So, this again also is a threat to the transmission lines and the utility engineers have to be looking in to these aspects as well.

So, similarly we have a various types of pollutants in the industry where they get accumulated over the period of time, and degrade the properties.

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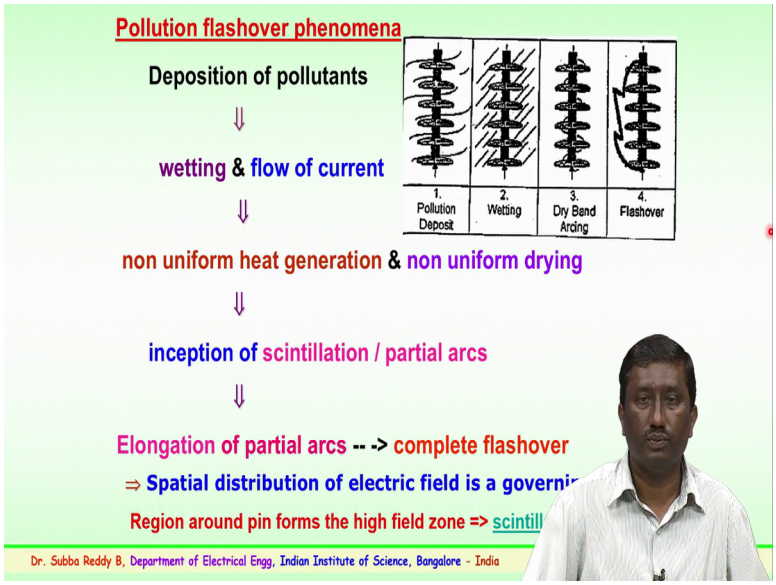

How this pollution flashover happens basic phenomena? So, just to explain the physics of this in a brief manner; the initially as mentioned the deposition of the pollutants have could be contaminants or a pollutants could deposit over a period of time on the insulator surface depending upon a transmission lines, which pass on near that areas. In case of industry the industrial pollutants in case of the towers or lines passing near the sea coast the sea salts could be the pollutants. Or agricultural fields the agricultural activity related pollutants could go on settle on the surface of the insulator.

over a period of time because of the pre monsoon conditions or because of high humidity these becomes a wet. So, mist because of fog because of light rain surface becomes wet and heavy rain is a complicating factor. So, it could even wash the pollutants on the surface of insulator. And the flashover may not happen. Or it could also bridge the flashover between 2 sheds. So, rain is a complicating factor, but fog dew light rain mist is very unwanted or dangerous event which could trigger the pollution of flashover on the surface. Because this wets the surface and the surface becomes conductive and the flow of a leakage current starts on the insulator from the conductor towards the ground and in case number of insulators the surface condition dictates the

flow of current, because the pollutants or the contaminants which are collected on the surface are not of uniform in nature.

They could be because of the wind flowing in particular direction. The contaminants are getting accumulated on the surface is not uniform. Some of the areas could be more some of the areas could be very less, and some area of the insulator no pollutants may not be also deposited. So, here because of this non uniform distribution of the pollutants on the surface, when the surface becomes wet the leakage current starts flowing. Because of non uniform nature of the deposit on the surface, the current which is flowing also is of non uniform in nature. And there will be a formation of wet and dry band the area where wet band is the flow of current.

Where the pollutants are accumulated, and non dry area where the pollutants are not existing. So, here because of this non uniform dry band wet band formation is happening and non uniform heat generation and non uniform drying of the insulator on the surface of the insulator happens. Here because of the wet and dry bands formation non uniform heating a small discharge across these dry band wet bands where dry band normally conduction across sorry wet band conduction happens dry bands there will be a small arcings which we normally termed as a partial arcs or a scintillations, small discharges which are not of continuous in nature depends on the magnitude of the surface currents which are flowing and also the surface wet nest. So, the inception of scintillation or a partial arcs take place this.

Activity goes on till the surface or conduction on these partial arcs or scintillations, which could along it depending upon the voltage stress and or the surface condition of the insulator. And it has been observed the complete flashover or bridging of the entire insulator could happen where the entire line trips in the substation. So, this phenomena is normally observed during the pre monsoon conditions. So, the pollution flashover or a contamination flashover is a phenomena which could happen over a long period of time and has to be properly addressed. Several types of insulators are being used as mentioned ceramic glass and polymer. So, there are several methods to overcome this pollution. Flashover some of the methods are also being developed to see the pollution flashover is delayed or improvement for the existing insulator is happening.

So, this shows the schismatic of how the pollution deposit is the wetting of the surface, then the dry band arcing small arcings which take place and further depending upon the surface condition the entire flashover happens across the insulator string.

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So, pollution or a contamination flashover that is which we have discussed is a phenomena, very complex in nature. It is very difficult to theoretically calculate or to have a model or where theoretical calculations could be done because involves several factors.

Type of contaminants, the spread of contaminants, the thickness the wind the moisture several types are involved. So, the flashover of a contaminated insulator is itself a very complex of phenomena. It is also mentioned earlier, it is a relatively very slow electro thermal process. The time which could happen when it could happen is totally unpredictable. It could happen over a period of time few hours or much more than that. So, that is one of reason the process is electro thermal in nature with temperature and electrical stress. So, continuously exact simulation in the laboratory is also equally difficult. So, experimentation is also it is difficult to similar the actual condition. And the influencing parameters as mentioned or the wetting rate of the insulator whether mist fog, light rain, drizzle the pollution types what type of pollution or a contamination

which is spread on the surface of the insulator, wind and it is direction play also a role some of the pollutants could be carried away by wind.

Some could be again deposited on the surface, and what type of insulator is being employed for the transmission at that particular zone. So, all these are the factors which influence the contamination or pollution induced to flashovers across the insulator string particularly at extra high voltage and ultra high voltage of the transmission, which is of a very serious concern. So, for this some remedial measures do exist, for the silicon sorry for the ceramic or glass type of insulators.

There are coatings like a silicon grease, room temperature, vulcanized rubber, coatings resistive glaze coatings sometimes the utilities go on increasing the creepage lengths and going in for special designs live line or hot line washing of insulators before the pre monsoon conditions. So, these are several methods being followed by the utilities to see the pollution or a contamination flashover does not happen at VHU and UHV levels. There is also some work which has been carried out to suitably mitigate these techniques, which is cost effective and gives better performance in the field.

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So, effort was made to develop a special field control electros or a field control elements to reduce the surface field. It has been seen that to enhance the pollution of flashover strength is mainly to reduce the maximum surface field.

So, this observe in the field and experimentation, we have come across that a maximum stress occurs at the pin junction at the high voltage end. So, the innovative solution to solve this problem mechanically could be the extension of or the dimension of the pin without affecting the clearances, without significantly sacrificing the creepage distance that is a creepage is metal to the cap the distance between the metal to the cap is known as a creepage distance without amplifying the bulk stress in air. So, several of these things have to be taken and also the mechanically the insulator has to have a rugged addition.

So, we have try to theoretically as well as experimentally try to come up with both a simulation and an experimental arrangement by establishing a special experimental facility for the pollution studies on insulator strings and we have developed a novel a field control element particularly to improve the flashover of insulator during a contaminated or a pollution conditions this work mainly focuses for the ceramic disc insulators.

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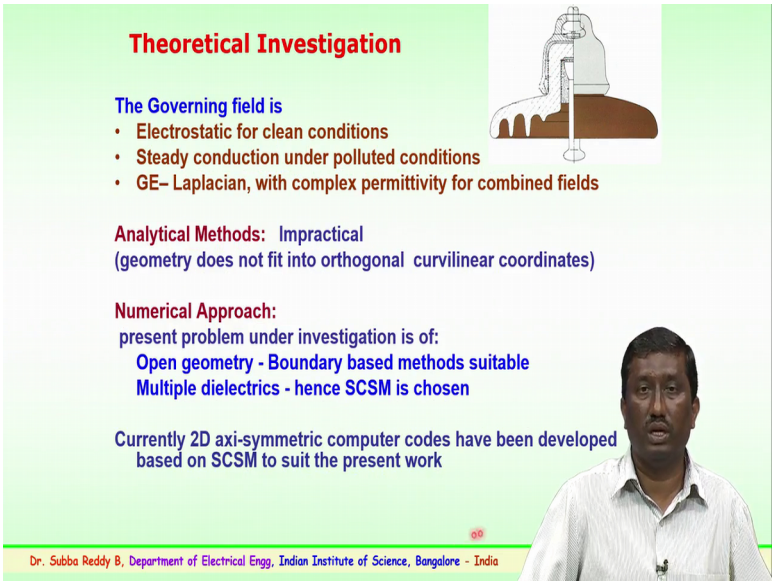

So, we have carried out theoretical investigations, where we have assumed the governing field as a electrostatic particularly for clean conditions; and steady conduction under the contaminated the conditions. So, the theoretical investigations we have used a governing equation as the Laplacian with complex permittivity's particularly for the combined

fields. So, simulating the or developing a model using analytical methods is a impractical because the geometry of this insulator is so complicated it does not fit into the orthogonal or curvilinear coordinates.

So going in for analytical methods is a tough procedure or it involves lot of analytical methods and it is really impractical. So, hence a numerical approach has been followed for the method which we have adapted. So, the insulator being of a open geometry. We have used a boundary based methods which are normally suitable because of the insulator consists of multiple dielectrics that is a metal a ceramic the porcelain Portland cement and again the metallic cap and a Portland cement. So, this has a multiple dielectrics. Hence we have chosen a surface charge simulation method for the numerical simulation aspects and we have try to develop a 2D 2 dimensional axi because the insulator is an axi symmetry model could be considered axi symmetry model.

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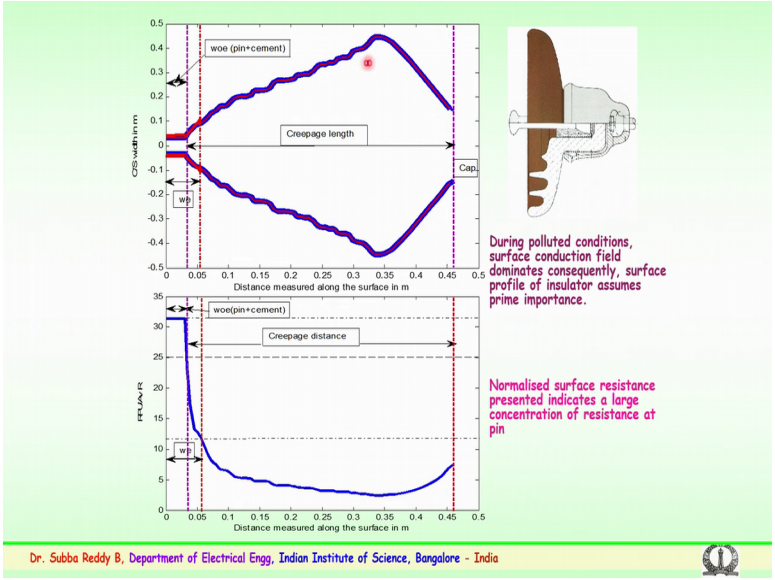

So, we have developed a computer course for the surface charge simulation method particularly looking into the effect of pollution conditions, and the surface conduction field which terminates over the conduction period. So, the profile of the insulator assumes very important prime important this geometry up, in junction this is the cap and this from here to is the creepage or the petticoat region which has been shown here. So, this we have try to carefully counter the pin area.

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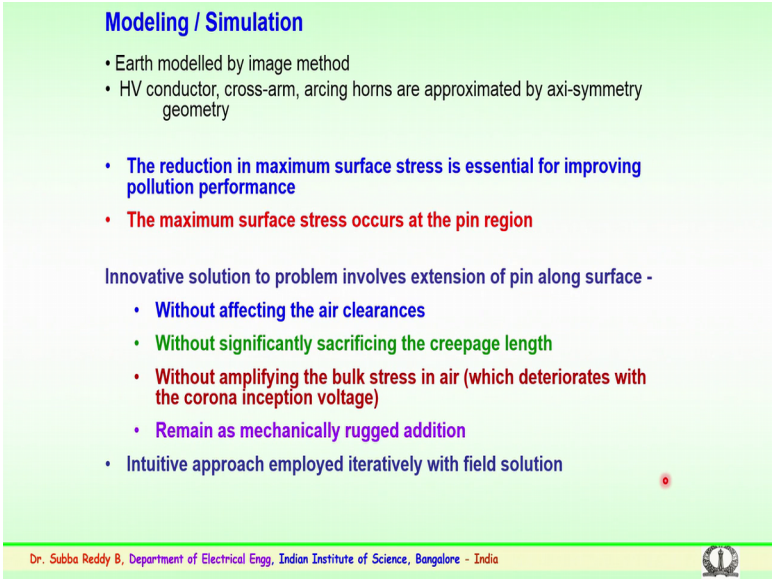

And we have successful in developing a electrode for the various ceramics discs which are being used in the country. We have modeled the high voltage including the high voltage conductor cross arm arcing horns when I have these things I also been taken care and we have seen the reduction in maximum surface is very important which is essential for improving the pollution or a contamination performance. So, the maximum surface stress as mentioned earlier will normally occur at the pin, reason because the pin is at high voltage potential the pin which is connected to the ceramic disc.

Again with the help of for the Portland cement is a week junction where the scintillations or the partial arcs start occurring and the discharges or the partial arcs or the scintillation near the pin region. In case if they are produced the ultimate flashover could also be reduced and the insulator could perform much better in the field for pollution or a contaminated areas. So, in a innovative solution, we have try to see that the pin of the insulator has been suitably modeled without affecting the air clearances without significantly sacrificing the creepage length of the insulator without amplifying the bulk stress near which could destroy deteriorate .

With the corona inception voltage and the component which we have developed is also mechanically in rugged in addition.

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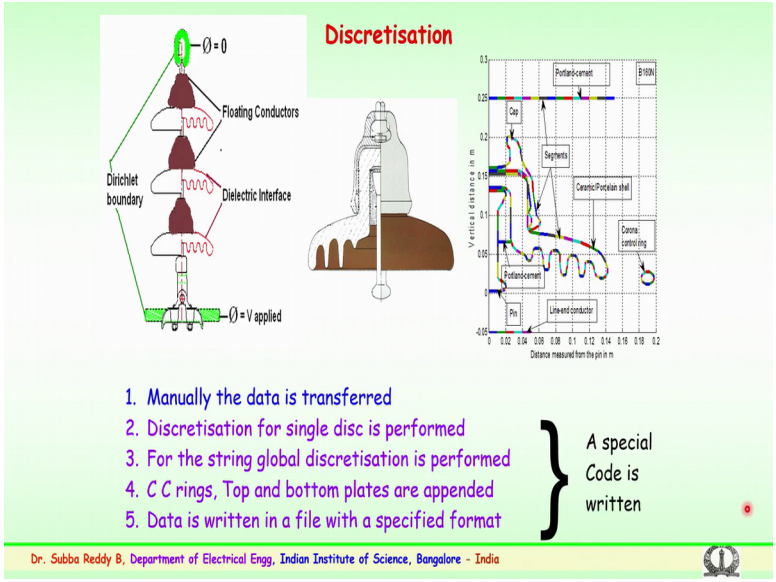

So, an intuitive approach has been employed iteratively with field solution and simulation aspects has been conducted the actual data of the manufacturer of the insulator dimensions has been taken and it is transferred to the code where discretization initially for the single disc is performed. And later on for the string global discretization is carried on. The corona control rings the top and the bottom conductors are also appended in the program, and the data is written in a file with a specified format a special code has been written to see the to obtain the potential field bulk stress and many of these things.

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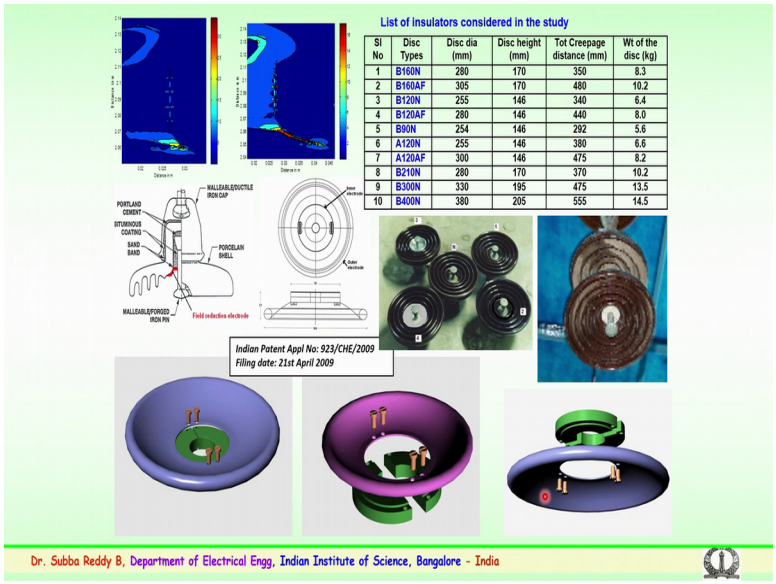

So, we have based on the simulation for various of insulator discs which are used for UHV and UHV levels in the country, various manufacturer data has been obtained and we have try to develop the field control element for the insulators for different insulators. And this is how the field control element which consists of 2 types of electors will be used to fix near the pin junction to improve the pollution performance where it increases that the surface field (Refer Time: 23:27) the scintillations or a partial arcs which are being seen at the inception have been completely reduced.

And ultimately the flashover performance of the insulator in case of all their types of insulators 10 different types which are used for UHV in a ultra high voltage have seen an improvement with a using of the field control element. This is the potential distribution for different types of insulators.

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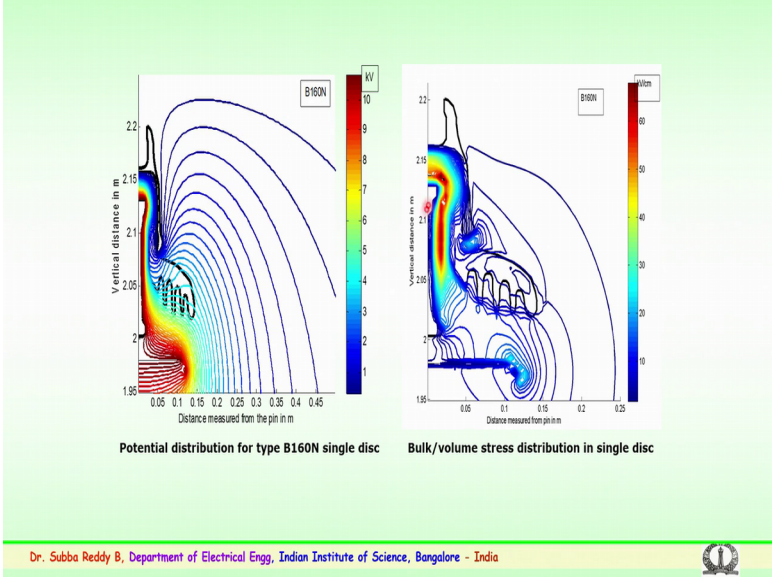

We have also try to simulate the bulk stress the point where the insulator could behalf high stress zone. So, the potential the electric field and the bulk stress have been simulated for various insulators and various strings.

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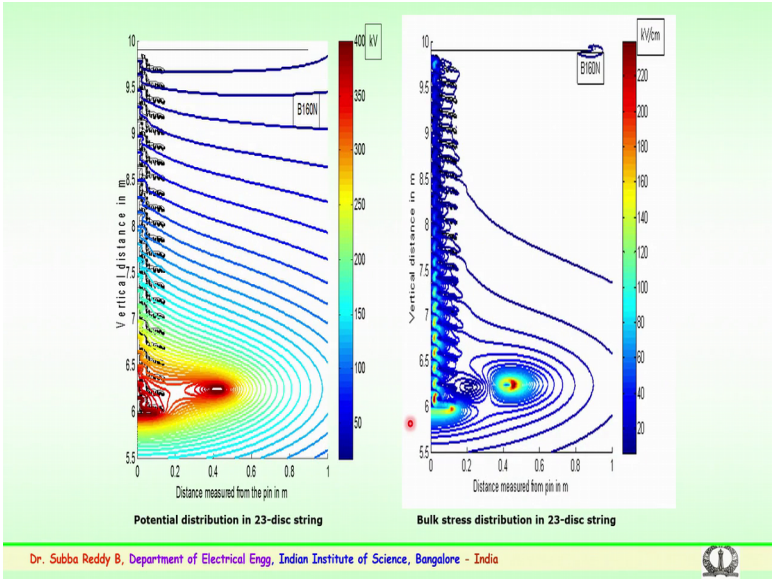

For up to 400 765 KV and all these gives an equi potential plot for a 400 KV transmission tower consisting of 23 disc this shows the bulk stress what is the volume stress which is seen for the insulator string.

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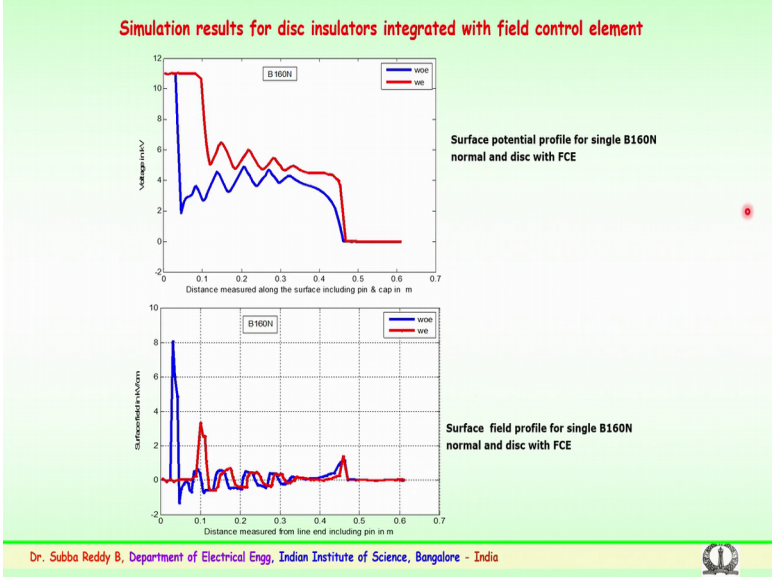

In case of 400 KV for a type one type of disk insulator similarly several types that is 10 types of disc insulators which are being employed in the country have been used for the simulation and suitable integrated with the field control element and a improvement aspects have been assumed. So, this shows the surface potential profile for a particular type for the normal condition and with the field control element we can see without the blue color shows the potential of a single disc the single disc we have applied 11 KV. This is the pin region, this is the petticoat of the insulator or the sheds and finally, this is the cap which is at 0 potential.

You could see the distribution of the potential without the control element which that is end control element is showing. The red color indicates the potential distribution with a field reduction electrode which we have developed. This very clearly shows the field it is exactly the mirror image here surface field profile for the same insulator, you can see the blue color which is a very high a 8 KV per a centimeter is a electrical stress which is sees for a 11 KV with a introduction of field control electrodes the stress comes down to 2 to 2. This very clearly demonstrates.

Once the field reduces near the pin junction the inception of scintillations gets reduced ultimately the insulator will never have more stress and the flashover which is happening will also get.

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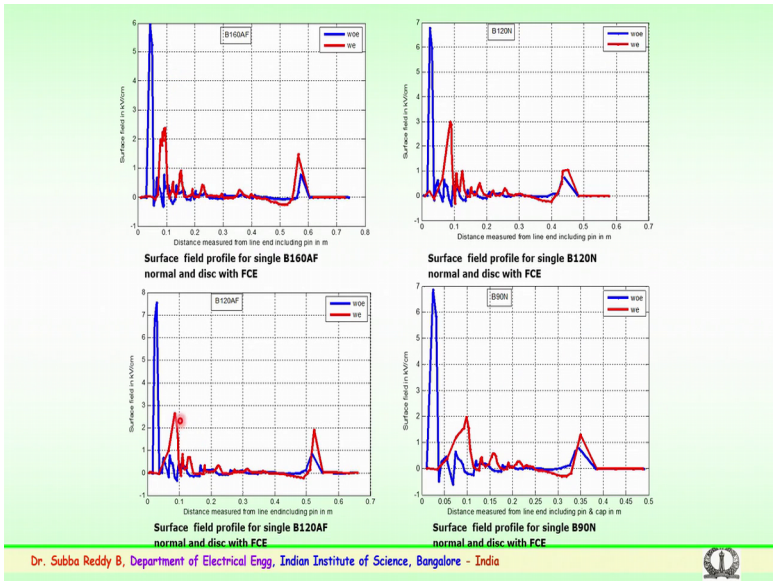

So, we have try to carry out for various type of discs which are being employed in the country. And try to simulate the field control elements and practically used for all the type of insulators.

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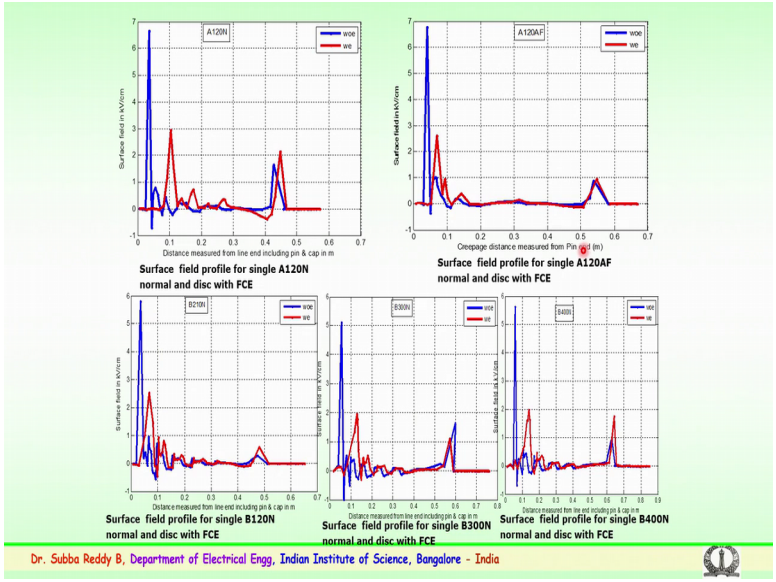

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A laboratory has been established keeping this (Refer Time: 26:33) 150 KV 300 KV a source with the 5 meter cube of the pollution or a contamination facility, where insulator strings could be erected inside the chamber. This is from the bushing of the transformer as special high voltage lead is taken inside the chamber consisting of the fog nozzles and the pollution.

Facility are consists of 5 meter cube chamber where the experimentation is carried out for various types of discs.

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So, the procedure as per international standard is being employed for the ceramic insulator disc and the pollution or a contamination coating is normally carried out, which verification of or the insulator the flashover performance for a normal string and also the strings with the field or reduction electrodes have been carried out and successfully demonstrated for the string consisting of a single disc 2 3 disc in a string.

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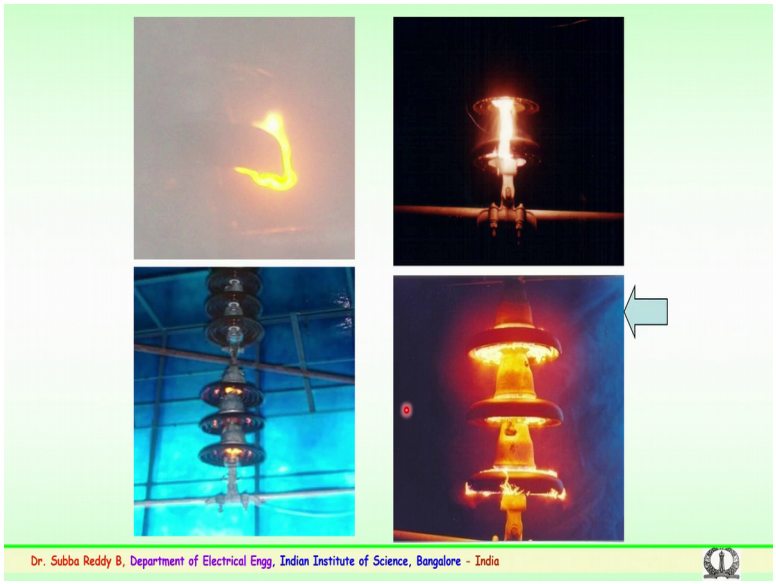

So, you could see the scintillations which happen in the voltage levels where the scintillations or partial arcs or the discharges happen. This is the high voltage conductor this simulates the tower. You could see the discharges particularly near the pin and surrounding the pin region the cement region which are of significantly seen as the voltage level increases the scintillations or the partial arcs starts higher and they could again bridge a single disc. Further this bridging could create the non uniform voltage distribution across the entire string, and the flashover of insulator could be seen. This is similar to the field where of same phenomena could happen in the field.

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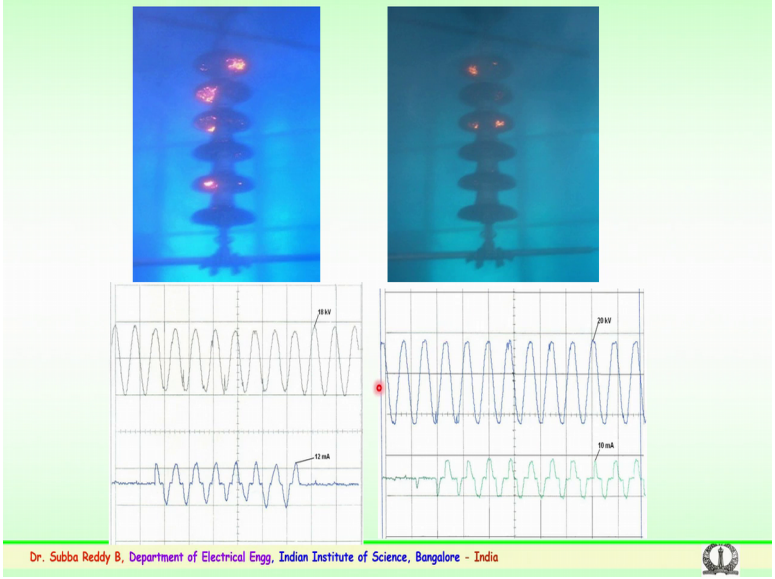

So, lot of experiments I have been carried out for the normal string and the string containing the field or reduction electros which have been developed in the laboratory. We have try to see various configuration for the doubled junction arrangement, a single type of insulators.

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A comparison you can very clearly see here the insulators containing the field or reduction electros the flashover has not happened whereas, without the field (Refer Time: 28:57) flash over has been noticed.

So, this shows that the element or a field control element this has been developed will be helpful for the ceramic disc insulators to see the pollution flashover phenomena does not happened.