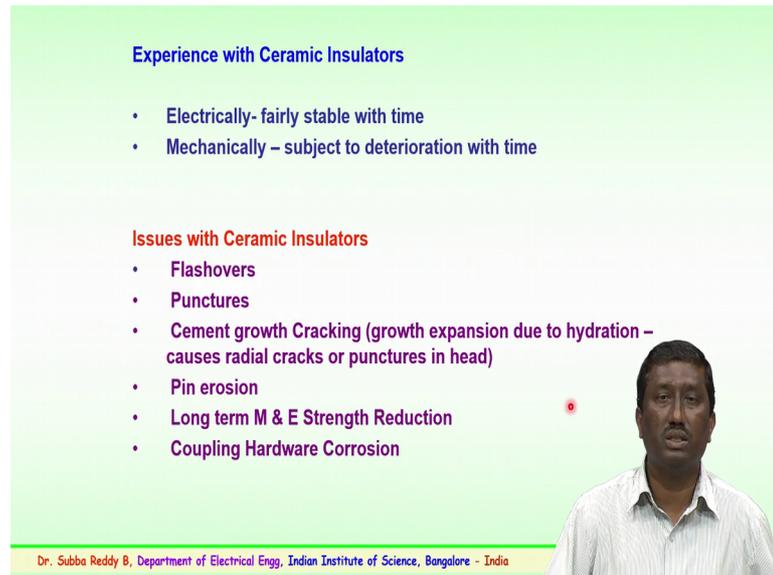


**Advances in UHV Transmission and Distribution**  
**Prof. B Subba Reddy**  
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**Indian Institute of Science, Bangalore**

**Lecture – 05**  
**Non ceramic insulators performance-service experience**

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**Experience with Ceramic Insulators**

- Electrically- fairly stable with time
- Mechanically – subject to deterioration with time

**Issues with Ceramic Insulators**

- Flashovers
- Punctures
- Cement growth Cracking (growth expansion due to hydration – causes radial cracks or punctures in head)
- Pin erosion
- Long term M & E Strength Reduction
- Coupling Hardware Corrosion

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So these are some of the things mechanically could subject or deterioration with the time that is a long period of time. So, what are the issues which have been with ceramic insulators or (Refer Time: 00:25) insulators are the flashovers. This again flashovers depend upon the pollution areas or a contaminated areas, where the insulator over a period of time contaminates get collected on the surface and in dry season the problem of flashover never happens.

In case of the fog miss or the early monsoon conditions where the surface becomes wet and start conducting and the flashovers to happen. We will be discussing about the actual pollution flashovers in next slides coming slides why the important of this phenomena because where for very high voltages extra high voltage and ultra high voltage pollution or a contamination which we have identified is a important design criteria to be taken here.

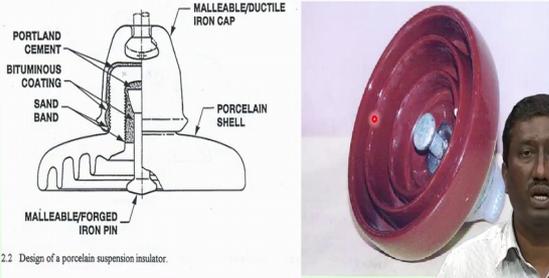
So it is use next being punctures the puncture of insulators have also been noticed in the field where because of the natural lighting or because of the over voltages or because of

very sharp rise of surges, which have notice that the punctures on the ceramic shell have appended the insulation level has been reduced. Than has mentioned earlier the cement growth cement growth and cracking cement growth is again happens because of the expansion due to hydration which may cause radial cracks or punctures in the head of the insulator this cement growth, where I was mentioning the Portland cement is being used for the pin and the cap.

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**Ceramic / Porcelain Insulators**

- Used since 1830s (for telegraph lines)
- Used at all voltages for line insulation
- Provides great flexibility (cap and pin)
- Strong in compression
- Available in various shapes (simple-complicated)
- High degree of standardization



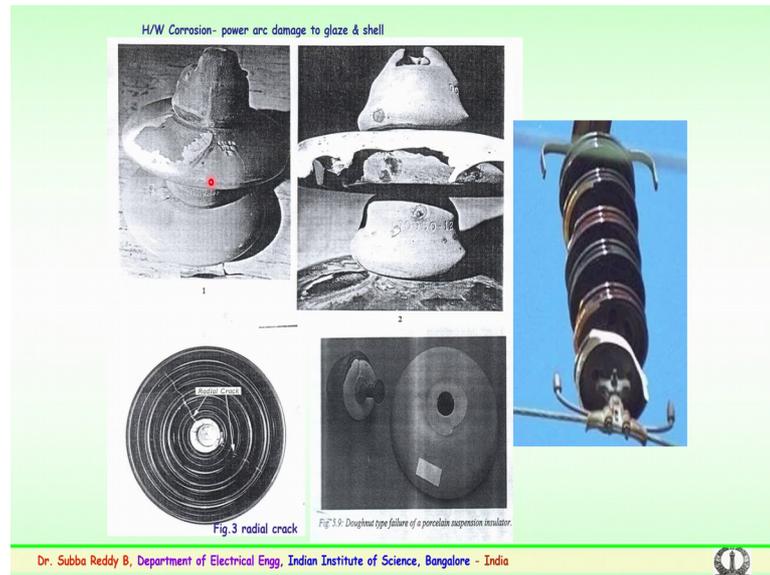
2.2 Design of a porcelain suspension insulator.

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So, this junction where the Portland cement is used over a period of time could lead to the growth and expansion and sometimes a radial crack or a puncture in the head of the insulator or the surface top surface of the insulator is being noticed. Then pin erosion again depending upon the climate or environmental factors over a period of time the erosion on the pin has been noticed this could also lead to the failure of insulators or issue with the ceramic insulators.

Then long term mechanical and electrical strength reduction take place because of this issues, and also the coupling hardware corrosion coupling hardware where the hardware which is being used to connect the insulator to the tower and to the conductor. We have several types of clamps and hardware you played corona control arms and many of this thing hardware which is being employed over period of time because of the environmental factors could lead to corrosion and the failure could be seen particularly with ceramic or glass type of insulators.

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So, these are some of the failures which have been observed over a period of time in the field. You can see the glazing on the insulators over a period of time is completely not available which will lead to the surface flashover and the insulator failure will happen. So, this again are the punctures of the insulator or the breakage of the shed because of the long period of time which has served.

Similarly, because of the Portland cement the cement growth near the pin junction has led to radial cracks or this may be because of the compressive loads which the insulator has seen. This type of failure this particular figure shows you the cap and pin getting detached which is known as a doughnut type of failure, where the material detaches itself from the ceramic unit over a period of time. And this is because of the lightning over voltages the insulator string has seen in the field where the insulator shed could be shattered because of the over voltages of the very sharp price in voltages.

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So whatever we have seen are the natural things which have happened. These shows again the artificial problems or the manmade problems was the insulator strings which could a fail much before their life that is reason may be because of the burning of the agriculture waste in a particular areas or because of the like a sugarcane or many other agriculture after the crop is completed, they try to burn the remains of things which are this cause lot of a the dust lot of contaminants which go and settle on the insulator surface over a period of time, and they become hardened on the surface and during the monsoon conditions the surface becomes wet and likely to flashover.

So, the second being again some of the brick kilns or a very high polluting areas industrial areas, where the atmosphere smoke coming into the atmosphere could go and again settle on the surface of the insulators which are nearby, to these factories or nearby to these industries where the transmission lines which are of extra high voltage and ultra high voltage gets polluted or surface gets accumulated with the pollutants could lead to after becoming wet could lead to flashover.

So these are again the various a types of accumulation of does on the surface of insulators again this is the bird droppings over a period of time many times you must have noticed that on the transmission tower several huge birds make their nest and try to see the droppings of that will again be settled and get polluted the insulator gets polluted over a period of time. And this will lose the property the insulator will lose the

properties, and in case of wetness the entire surface start conducting and the flashover is happening likely to happen. So, this is one more example of how the insulator the dust particularly in near the cement factories or because of some queries the dust which goes on (Refer Time: 06:40) over a period of time makes the insulator completely polluted and may lose the insulating properties which it is a design.

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So, some remedial measures for the insulators so much before the monsoon start. So, remedial measures have been done by the electricity authorities or the utilities to see that the flashovers do not happen. So, one among the thing is what you see is the telescope type of the jet, which is being used to wash or clean the insulators a mounted on a truck. So, this telescopic type of arrangement with water jet at a particular conductive level dry to clear the insulators and see that the contaminants which are deposited over a period of time is done, where in particularly do in the pre monsoon conditions the flashover of insulator is not happening.

Again this is a live line arrangement which has been will be done; technician or a person who does the operation is on a particular insulated arrangement. Where he uses the water jet to clean the post insulator particularly in the substation or as bushings of the (Refer Time: 08:11) and several of these contaminants which spread over a time period have to be properly addressed that is a clean. So, that during monsoon condition the surface of the insulation does not become wet and starts conducting to arrange the conduction. So,

proper cleaning of these contaminants or pollutants is essential. So, one is a live line washing which is being shown here in this figure, the live line washing is also very important because you cannot interrupt the supply over a period of time.

So, the activity of live line washing has to be carried out which is one of the method to see the flashover of the substation equipment or switch gear does not happened and during the working conditions particularly during the monsoon conditions.

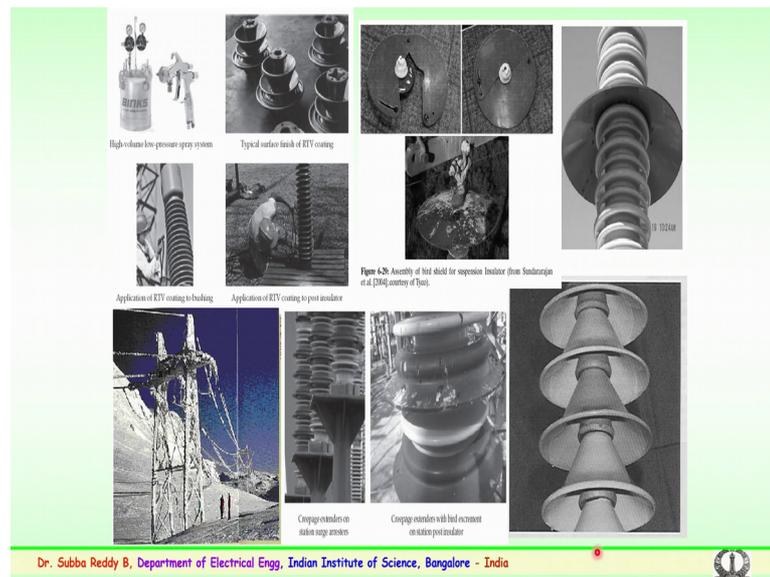
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And there are other methods which are being employed, where areas like high altitude mountainous areas or the areas where the vehicle that is truck with jet could not approach in such cases, helicopter mounted nozzle sets are being employed. And here the help of helicopter mounted jets the water jets is cleaning of insulators is being done. Even though, it is of higher economy involved in these aspects, the cleaning or the washing of insulators very important. In areas in the forest where the normal truck could not be will not be able to go there. So, such cases helicopter mounted nozzles are being used in high altitude and the some forest areas.

Apart from this they are also try the trimming of the branches how to be carried out much before the when or much before the monsoon happens where this trimming of branches it is also very important. So, these are some of the measures which are being employed regularly by the utilities.

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To see contain the flashover of insulators some again apart from this you see various types of remedies I have been employed to improve the performance of the insulator. This is one such small arrangement on the surface of the insulator to increase the creep age of that again insulating material, which is known as creep age extender is employed to see that the bird droppings or this particular insulator improves for a certain period of time.

So, this also has been tried out again this is for a substation post insulator which is known as a creep age extender to tries to see the flashover does not happen even the surface is become contaminated this will help partially to see the flashover do not happen. And some designs I have also been tried out which is a without the petticoats where contaminates does not settle over a period of time. So, such designs are also being tried for the better performance in the field. And this figure shows the transmission lines particularly in high altitude and very cold areas that is the high altitude where the temperature is very low and freezes.

So you can see the insulator strings are completely covered with ice and the conductors completely covered with the ice. So, this will lead need lot of revenue particularly for the utilities to maintain the clean of these things else the flashover will definitely happen of the conduction of the surface which is in continuously ice formation which is happening in cold countries. So, lots of measures have to be taken by the utility or a transmission

engineers which is very important particularly during the monsoon during the fog during the ice conditions in the field.

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**2. Glass Suspension Insulators**

- Good contamination performance due to self cleaning properties
- Good for remote areas with no gun shooting & helicopter patrols
- Outer glass surface under higher tension than inside glass
- Damage to outer surface causes violent shattering of shell
- Spontaneous failures
- Attractive to shoot because the shell “explodes when hit
- Shattered glass is a safety hazard
- Not popular in US, used in Europe, Canada & Brazil

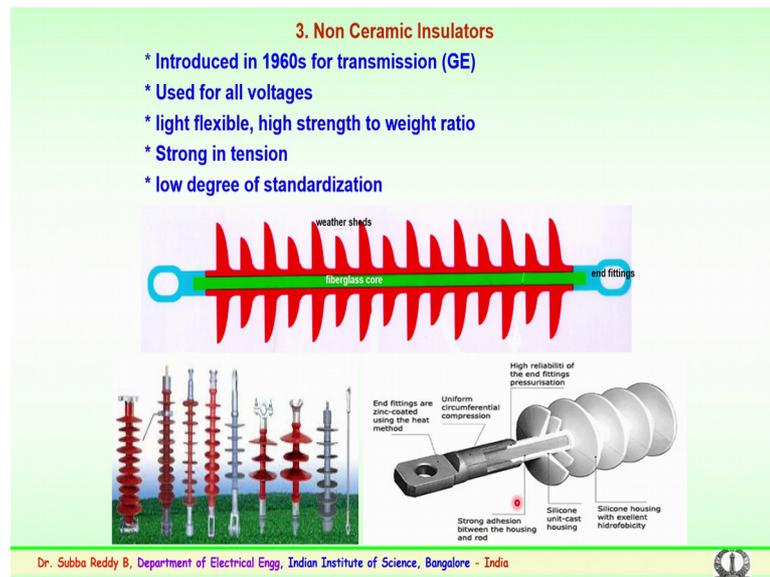


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So, that was about the ceramic or a porcelain insulator which we have seen quick look at the glass suspension insulators. Again glass insulators are of very old like almost similar to the ceramic or porcelain. They have good contamination performance due to self-cleaning properties. And they are good for remote areas particularly with no gun shooting or helicopter patrols where some people shoot the glass insulator for fun where the insulation sheds shattered and the insulation level decreases.

So again the outer glass the glass which is being used is a under high tension compared to the inner side sometimes the failures or a shattering of this happen on the outer surface. So, with a violent shattering of the shell sometimes a spontaneous failure also I have happened in the field. As mentioned attractive shoot because the shell explodes; so some people take it as a fun and try to bring down the insulator or shoot the insulator. Later this again the shattered glass is a safety hazard as per again disposing of these shattered glasses is environmental issue.

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So, this is a how not much popular in the u s, but still used in Europe Canada and brazil and many other countries, where the material cost is lesser and in our country a few of the transmission lines we are also employing with glass type of insulators. So, the final or the recent origin is a non ceramic insulator or the polymer or the composite or a silicone rubber insulator which are being a written or which are being used as a terminology.

So these non ceramic insulators are again recent origin, and advanced technology particularly in the insulator field. These where introduced somewhere in 1960s in initially for transmission particularly by the general electric presently being used for all voltages from a very low voltage to up to ultra high voltage levels. And these are light flexible and I have a high strength to weight ratio that is a very important and strong intension and low degree of standardization. So, this is how typical polymer insulator looks.

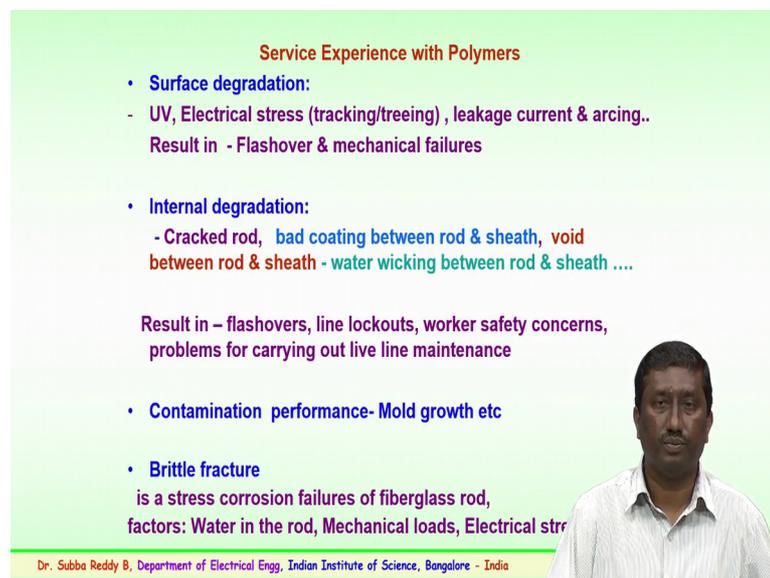
Polymer insulator as I mentioned will have a fiber glass a rod which is shown here. In the green color this fiber glass rod is a fixed with the metals end fittings. This metal end fitting one of the fitting is connected to the tower and other is connected to the conductors with suitable hardware. So, the fiber glass rod is connected with the metal end fittings, later on with the help of the liquid injection molding the silicone rubber or polymer sheds or a weathering sheds what we call are being molded on this fiber glass

rod. Again the length the type of metal fittings depends on the voltage level which the insulator has being used.

And the Creepage distance of the insulator required. So, all these factors will dictate for various voltage levels. So, this are of recent to origin are being used abundantly in the country and also several other places across the globe. And they have a promising characteristics particularly for a particularly for the pollution performance there immediate better performing then the ceramic or a porcelain insulators. So, long term performance as mentioned a recently third generation type of insulators are being used. So, we have to have long time data for this.

So, that it can be exactly compared with the life of the porcelain or a glass insulator. And economic earlier when the insulators were introduced the material cost and the insulator cost is very high in comparison to ceramic. Presently there is the cost has been substantially reduced and it is in par with ceramic or may be as slightly lesser in comparison to the ceramic insulator.

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**Service Experience with Polymers**

- **Surface degradation:**
  - UV, Electrical stress (tracking/treeing) , leakage current & arcing..
  - Result in - Flashover & mechanical failures
- **Internal degradation:**
  - Cracked rod, bad coating between rod & sheath, void between rod & sheath - water wicking between rod & sheath ....
  - Result in – flashovers, line lockouts, worker safety concerns, problems for carrying out live line maintenance
- **Contamination performance- Mold growth etc**
- **Brittle fracture**
  - is a stress corrosion failures of fiberglass rod,
  - factors: Water in the rod, Mechanical loads, Electrical str

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So several industries are particularly manufacturing the non ceramic insulators or polymer insulators have come up in the country and elsewhere. So, various types of polymer non ceramic insulators are being used for the various voltage applications. So, service of experience what utilities have is earlier comparison with particularly surface degradation internal degradation so on.

These service experiences which have been with utilities are again from the initial technology which was adopted as a first generation or a second generation. Now the third generation much improved insulators are available. So, we earlier there were issues there were some problems. So, some of the, or most of the problems are being overcome and few of them do exist. So, we will look into the important aspects where the polymers or a polymeric insulator or a non ceramic insulator phase in the field.

So surface degradation is the important aspect; the surface degradation may cause because of the ultra violet rays this is because of the sun or from the corona of the hardware which we mentioned. Electrical stress continuous electrical stress on the insulator over a period of time could track or treeing track or treeing is again the slow failure of the insulator surface where a tracking could occur and the insulator could see the leakage current flows and degradation of the material could happen.

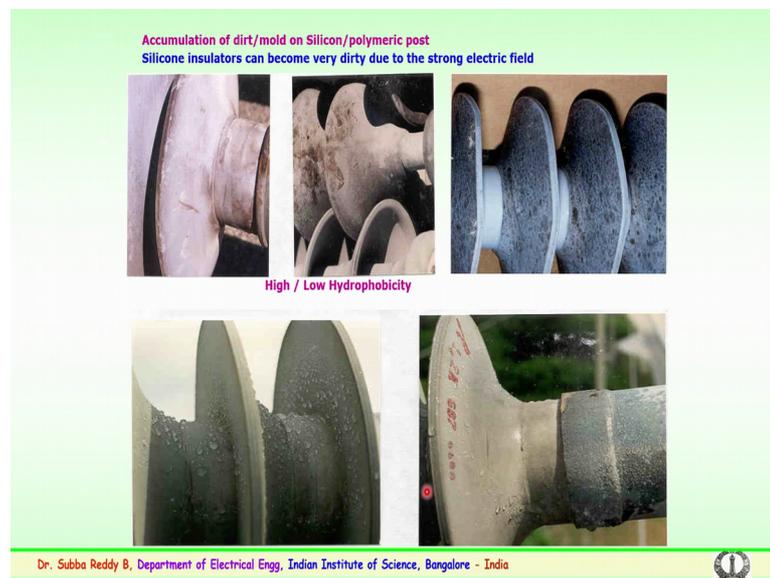
So, this tracking or treeing of the surface could happen over a period of time, because of the electrical stress where in the leakage current and small arcing which are known as a partial arcing or the scintillations could happen which could result in the flashover and sometimes the mechanical failures because of the surface degradation. Then internal degradation this internal degradation we know that internally fiber glass or rod is being used where some times because of the hydraulic pressure which is being use to crimp the end fittings the metal fittings to the rod could lead to a cracked rod or sometimes bad coating between the rod and the sheath there is a coating which is applied this could lead to very small voids between the rod and sheath, where the reports have a seen or the service experiences seen that the water could entire with the very small blow holes or a hole and this could in case of the water entering surface of the rod.

And the where the nitro nitric acid is form formation is as seen and because of this nitric acid the rod and the sheath failures are happen where the brittle fracture of the insulating rod could lead over period of time. So, these have also been seen in the field. So, the result is the flashovers sometimes could be temporary or continuous flashovers could happen line lockouts or blackouts or the line may give away. So, workers safety concerns. So, very important in case of failures, it should not lead to the safety concerns particularly for people who are caring out the live line maintenance.

So, very important these internal degradation or surface degradation have to be seen and addressed. And contamination performance here initially the contamination performance what we see is polymers are much better when compare to the ceramic or a porcelain for a short term performance, but later on there are report which a mold growth has happened on the surface and sometimes whether this mold growth will likely to create a not of studies have been carried out on this aspects. We will be looking into the failure where there are problems related to this and brittle fracture.

Again I was mentioning brittle fracture this is again a stress which is happened on the fiberglass rod corrosion failure of the fiberglass rod. Factors could be the water entering into the rod because of the mechanical load electrical stresses happen and the formation of nitric acid because of this moisture and over a period of time could lead to the fiberglass rod becoming brittle and the fracture of also taking place. So, this few of the experimentation which we have also carried out in the laboratory will be demonstrating that in the feature slides.

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Some of the early failures of the polymer insulators which have happened in the fields this may be because of the accumulation of dust mold on the polymer or silicone rubber post. So, silicon rubbers cold become very dirty due to the strong electric fields we can see a over a period of time the insulators becoming dirty and the surface getting rough and where the water droplet us start collecting and the failure could happen.

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So, these are earlier polymers, but some of them have the improvements have happened over a period. This again is corrosion because of the end fittings of the polymer rod could lead to the failure of for the insulator string. This is again hardware or clamps which are being used for the terminations and terminations could lead failure over the period of time again. This is a crack rod and these are the older generation of polymer insulator, not the liquid sorry molding machines which are being presently used liquid injection molding machines.

So, earlier the sheds use to be made in a different where it used to be fixed on the surface of the polymer rod such gaps or such cracks will lead to the failure of insulator in the field.

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So these are some of the exposed because of the damage which has happened you can see the fracture or a brittle fracture of the rod, this is due to the likely because of the gunshot or the failure has happen. Here you can see the during the manufacturing stages water bubbles or a air bubbles during the manufacture in case the insulators are being used in a field over a field of time, because of the electrical stress this bubbles could break and the water could (Refer Time: 23:37) into that and the failure is likely to happen.

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So, this again are some of the earlier failures of polymer insulators which have been seemed by the utilities. Likewise, these are a failure because of the end fittings which the hardware which is being employed for the polymer insulators. And also this is a corona controlling for the non-ceramic insulator polymer insulator. Over a period of time this insulator if is not properly designed not properly oriented and placed could lead to the continuous discharges, and this discharges on the surface of the insulator could be completely damaging the hydrophobicity effect on the insulator and could lead to the failures.

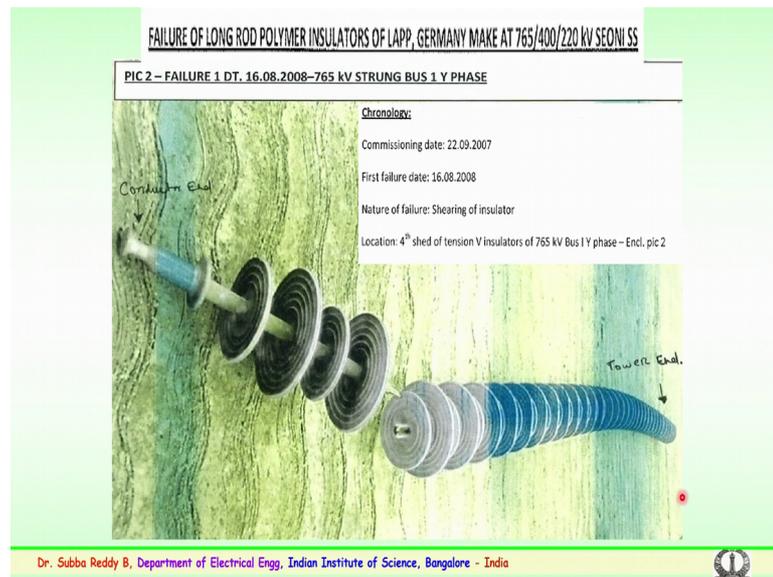
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So these are some of the various failures which are happen because of the electrical stress mechanical and corona related issues, but when you look into this slide it may look strange why this slide has been put. So, this silicon rubber polymer or a porcelain type of insulators as I was mention is a organic material very important to take care. So, sometimes the storing of the material is very important.

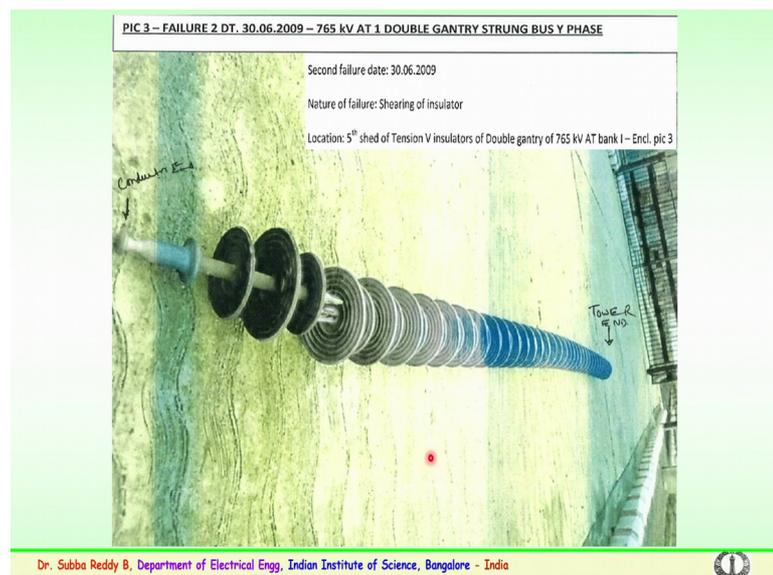
If we do not store in a proper way small animals could a try to the insulation could be damaged by these things and also some parrots and huge birds which are normally reside on the tower of the transmission lines would like to peck the surface of the silicone rubber so they could damage the sheds. This is again a issue pertaining to the birds and small animals.

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So, every care has to be taken as compare to the ceramic or a glass insulator. These are to be much more attended in the transmission systems. These are some of the failures which have been reported because of the brittle fracture you can see after the forth shed over a period of time the brittle fracture has happened and that detachment of the insulator has observed in the field so very important.

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So, polymer insulators of (Refer Time: 25:54) lot of things have been happening and these studies the failures people have improved their performance. And your

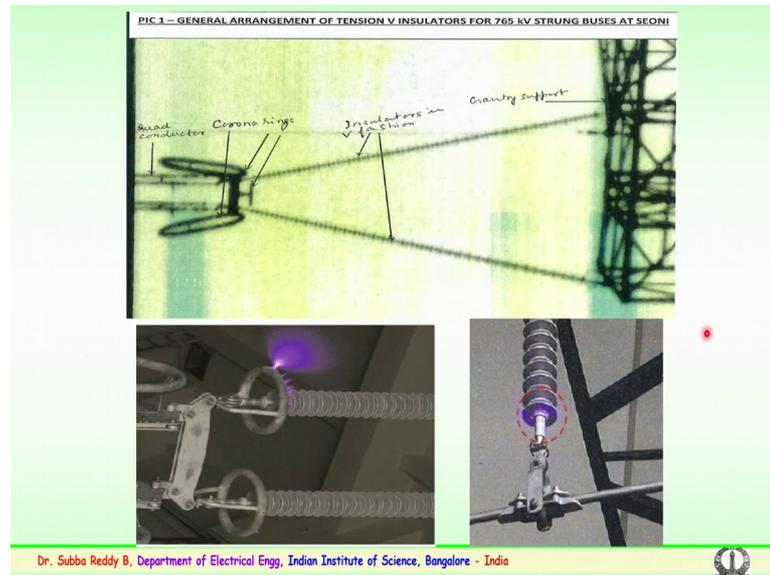
technologies are being used and the new type of methods particularly in the manufacturing side are been done to see such failures. So, would not happened and how for the long performance long duration or a long period of performance must be reliable that is one of the important aspect with this type of insulators.

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So these are again various failures which are been noticed over a period of time, and the polymer insulator. This is particularly for one of the transmission system for a 765 KV line we have the tower failure has happened after 8 to 9 months after their action so very serious concern. So, ones the technology which were adopting have to be carefully also looked. So, that equal important is given not only to the material the newer technology the adoption how it is being use, how it is being erected in the field what are the orientation of the corona control dense this has led because of one of reason being the placement design and orientation of the corona control rings.

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So, how corona is important why it degrade the surface, yes as you see here the corona comes from the hardware. Here you see from the corona control rings. This corona which is generated the discharges which are continuously discharges are likely to damage the sheds which continuously (Refer Time: 27:25) on the surface of the insulator.

Over a period of time the surface of the polymer insulator which is supposed to be hydrophobic, loses its properties and the surface degrades, and could lead to the failure of the insulation. So, these are some of the hardware fittings which are used for the polymer insulators consist of IO plate arrangement for a double tension string you have a corona control rings with necessary brackets and hardware to fix for the tower end.

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**Ceramic vs. Polymeric Insulators**

**Ceramic**

- Made from inorganic materials ⇒ do not age
- 80 years of experience
- Flexibility in length
- High leakage distance profiles
- Can be coated and washed

**Polymeric**

- Made from Organic materials ⇒ age
- Approx: 30years, latest designs < 10years
- Lighter, less susceptible to vandalism
- Smaller viewing profile
- Good short term performance in polluted environments
- 90% weight reduction, Reduced breakage, lower installation costs
- Aesthetically more pleasing, improved power frequency insulation

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We would like to look we have seen the ceramic performance or a porcelain performance under polymer insulators. As mentioned ceramic insulators are made from inorganic materials this do not age, they have more than 80 to 100 years experience flexibility in length particularly ceramic insulators we can have number of disks and increase the length. A high leakage distance profiles could be a manufactured without difficulty and these can be coated and washed at regular intervals of time. So, polymer insulators these are made from organic materials, the age that is why important.

And approximately maximum 30 years is the period which this technology has started seen and the latest designs are slightly less than 10 years old. So, it requires lot of studies lot of field data lot of field performance of these insulators. So, that improvement design could be carried out, but they have much lighter and lesser susceptible vandalism. And they have smaller viewing profile. And good short term performance in polluted environments as we have studying which will fulfill the criteria for the better performance particularly for the utilities, there will be very happy to have a better performance of the insulator strings in polluted environments. And reduction in weight again it depends on the voltage level where comparison could be made. And most of the time the weight reduction is anywhere between 90 percent and also the reduced breakage lower installation costs in compare to the ceramic insulators.

And aesthetically they are more pleasing look much better and also have better improved power frequency insulation level.

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**Comparison of attributes of Insulators**

Insulator	Positive Attributes	Negative Attributes
Non Ceramic/Polymeric	Weight (60-90% reduction) Contamination withstand Low installed cost Impact strength Small profile/ Cost - ? (1.5times - 1985-86 0.5times 1997-98)	Reduced strike distance Susceptible to aging Susceptible to arcing damage Brittle fracture possible Not easily inter changeable Limited Experience, Handling, Storing, Transporting Live line techniques to be developed
Porcelain/Ceramic	Performance quantified Long history of use	Weight Pin corrosion Post cascade failures Hidden defects "Fun" to shoot
RG Porcelain	Contamination withstand	Price Power loss
Glass	Spotting damaged units	Weight Attractive to vandals Negative perception - glass is fragile

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So, this gives you the comparison of attributes for different insulator which are being used for transmission over a period of time. So, same non ceramic porcelain for a polymer or a composite insulator what are the positive attributes and these are the negative. So, as mentioned earlier the weight reduction anywhere between 60 to 90 percent depending upon the voltage level and the hardware which is being employed. Or contamination withstand has much better comparison to ceramic. Low installed cost and has better impact strength.

And small profile and also cost less are decrease this is very important. Negative attributes when you look into the non ceramic or a composite insulator they have reduced strike distance, so susceptible to aging because of the material being organic in nature. They are susceptible to arcing damage. Brittle fracture has been noticed over a period of time. And it is difficult to easily interchange the different type of insulators sometimes because of different designs. And as mentioned they have a limited experience. So, handling storing transportation and live line techniques are still to be developed. So, these are a very important because a technology is being a newer.

So, lots of issues which are a cropping up have to be addressed. Where a porcelain or a ceramic performance has been quantified with the long history of use for more than

hundred years, but yes negative attributes being the weight of the string goes on increasing as a voltage level, pin corrosion are been observed and sometimes cascade failures have happened and hidden defects could of the material could lead to problem. And RG porcelain is a resistive glaze porcelain is a newer version of the porcelain insulators which have been coated with the resistive glaze to improve the voltage distribution on the surface of the insulator in also for better contamination withstand, but again here the price or the cost of the insulator goes up and sometimes, it has been notice the power loss happens because of loosing it is properties over a period of time.

Glass again we have seen the spotting of the damage units. It is very difficult because glass in it is transparent it is difficult to see the exact field the insulators in the field. Again it also has a weight comparison to the porcelain, and mainly attractive to vandals people should for fun and negative perception is a glass is fragile material. So, these are the major comparisons of the attributes of 3 types of technologies or 3 types of insulators which are being used in the high voltage or extra high voltage or ultra voltage transmission systems.

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So, I will compare the working of the technical or technical engineers or technicians in a tower. So, very clearly you can see in case of porcelain insulator for a 400 KV system how much if there 25 days with the hardware the material weight is very high. This shows the polymer insulators with the lesser hardware and lesser corona control rings.

So, people like to work in this area and comparison to this area so that the technology has been improved. And lot of new type of polymer insulators are being used for the UHV and ultra high voltage and transmission systems.