Advances in UHV Transmission and Distribution
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Lecture – 14
Surface morphological techniques for composite insulators

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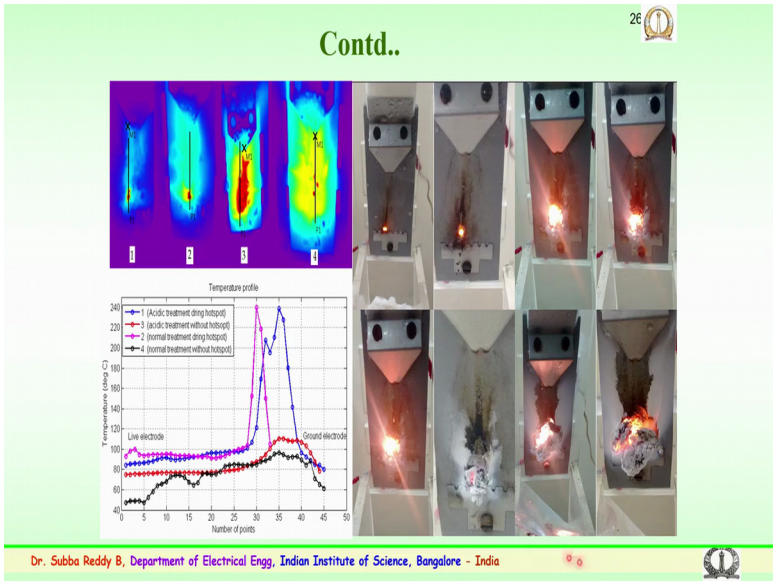

So, the degradation because of the inclined plane experimentation happens at several locations, these are the various samples which you see the degradation which has happened.

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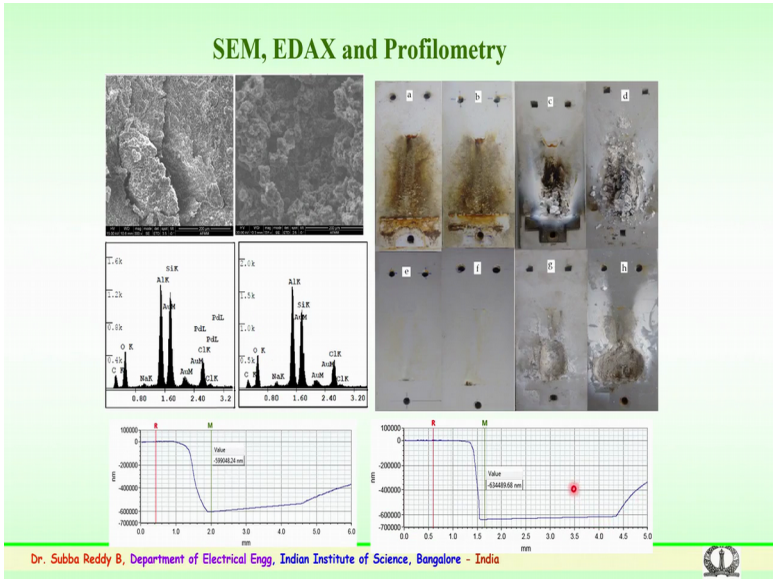

These are the surface morphological studies experiment analysis which have been carried out, and we know that samples which are investigated using the inclined plane method particularly.

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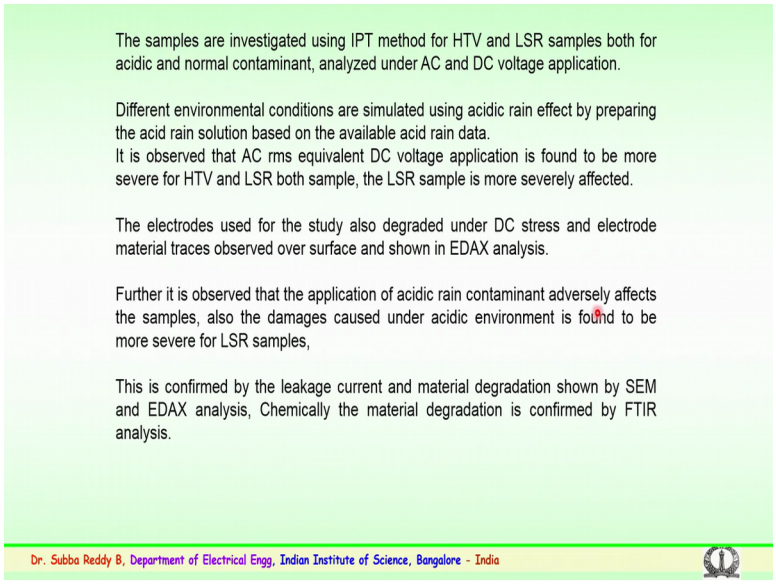

For the high temperature vulcanized and liquid silicone rubber samples, both for the acidic and normal contaminants are analyzed, both under AC and DC voltage applications. Under different environmental conditions were simulated using the acid rain affect which is available the details available in the literature as per the data

available. So, it is observed that during the experimentation both for AC and DC we have assume the AC RMS equivalent in case of DC voltage application, this is found to be more severe particularly for the high temperature vulcanized and liquid silicone rubber both samples and further in case of liquid silicone rubber this is so much more severely affected during the experimentation.

So, the electrodes used for the experimentation also were seen degraded under DC stress in comparison to the AC stress and the electrode material traces were observed to be left over on the surface this was observed in the energy dispersive x ray analysis EDAX analysis which was conducted, further it was observed that the application of acid rain contaminant adversely affects the samples also the damages which are caused under rustic environment is found to be much more severe for the liquid silicone rubber samples. This is confirmed also by the leakage current which was measured continuously during the period of experimentation, and also due to the material degradation which are shown by the surface analysis like the SEM and EDAX analysis. So, chemically the material degradation is confirmed by the Fourier transform infrared analysis. So, very important experimentation and the analysis for the estimation of the surface degradation on the polymer samples.

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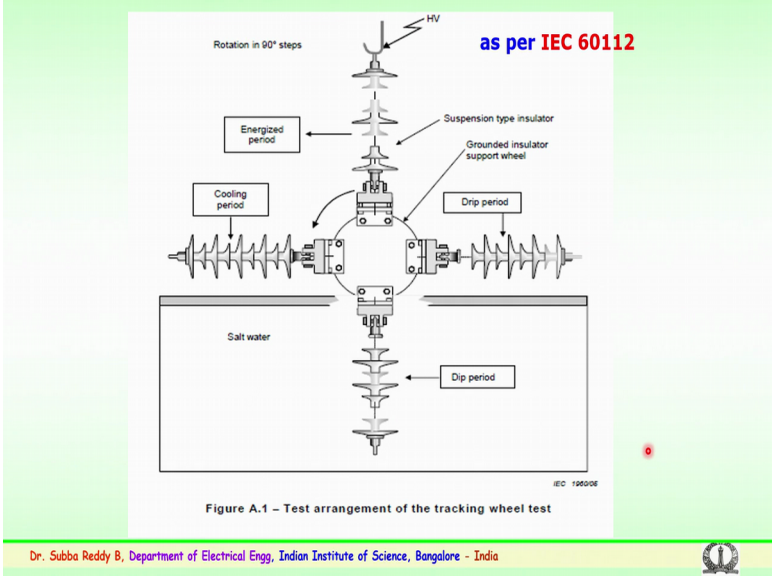

So, after the inclined plane arrangement on the surface erosions studies, the aging of the polymer or a composite insulators of utmost importance aging as mentioned it consists of

three types of experimentation which is being carried out in the laboratory, one is the salt fog method which is applied to the insulator continuously for 1000 hours, and the electric stress is applied surface changes are observed. The second is the rotating wheel arrangement as indicated here in this schematic, this is as per IEC 60112 standard, very clearly shows that these are the 4 insulator samples all these are fixed to a mechanical arrangement for insulators are fixed this is a tank where the contaminant or a water of conductivity is placed in the tank here. The insulator undergoes the dip period that is the insulator gets dipped in this period then after the it rotates and come to the horizontal position for a period which is known as the drip period, that is a dip to the drip period where the droplets drip during this period.

Further the insulator comes in contact with the high voltage this is the high voltage point for a period, and after the high voltage it comebacks to the cooling period. These are the 4 stages of the rotating wheel arrangement each rotation is shown here this rotating wheel as per standard 40 seconds is the dip period in the contaminant, 40 seconds later 8 seconds is the transition from the dip to the drip period. So, from here to here 8 second transition 40 plus 8 seconds it comes horizontally here, and it will wait here for 40 seconds for dripping. So, after 40 seconds again further from the drip to the high voltage contact, it has a transition of 8 seconds and further it halts here for 40 seconds. So, the contact from the high voltage will be there for 40 seconds. Further 8 second transition and rest for cooling for 40 seconds. So, totally 40 into 4 160, plus 8 into 4 that is 24 28 4 za 32. So, totally it is 192 seconds is one cycle a complete one cycle is 192 seconds. So, this is a very important experiment and other fabrication and simulation of this facility is very important the task and involves lot of effort particularly to simulate this condition, where suitable a sensor mechanism a suitable release and a timers have to be used and the fabrication has to be carried out as the experiment proceeds for more than 1000 hours. So, several thousands of cycles have to be done continuously with break as mentioned in the standard are 8 days during the period of after the 8 days, there is a break of one hour for the change of the contaminant in the tank. So, this as per the standard is allowed. So, this experimentation is a very important experimentation for the ageing analysis on the polymer insulator.

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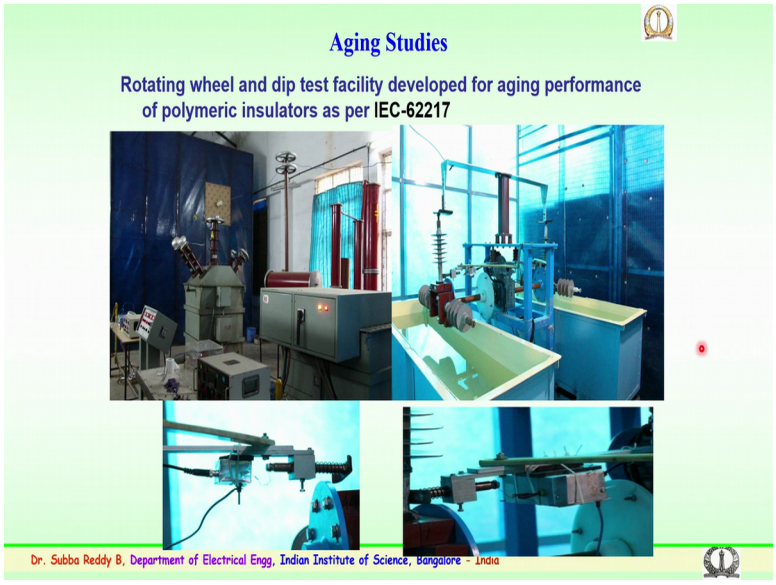

This shows the aging studies experiment a rotating wheel and dip facility developed in the laboratory for performing the aging performance of this insulator, you can see the high voltage transformer control panel here which is used to control the output of the voltage, here is a regulator of the high voltage transformer. So, from the bushing of a high voltage transformer it is taken inside small chamber of 8 feet by 8 feet where the facility is been fabricated and arranged you see the rotating wheel arrangement you can see presently three insulators are connected at 90 degrees and fourth is not used intentionally. So, we have fabricated in such a way two arrangement simultaneously that is 3 and 3 insulators could be experimented and two different solutions intentionally two different conductivities as a experiment is for a long duration of time to listen the time.

So, two different tanks have been used and the studies could be conducted for do different contamination, this was the idea the fabrication has been carried out, and important is during the high voltage contact this is the dipping period where the insulator goes dips and this is a dripping period, next comes to the high voltage contact and further cooling or the resting period. During this contact of the high voltage the imported used to measure the leakage current again ah fabrication of the leakage current monitoring device a small current sent along with the necessary protection has been done, to see that during the contact leakage current is measured and that is communicated to the oscilloscope or to the national instrument module where continuous monitoring of discharge activity can be done.

So, this is shows the small current shunt along with the protection, which is used for leakage current monitoring this is specially fabricated spring type of mechanism, where when the insulator comes in contact with the metal structure, this spring action will be see in the it comes in contact with the insulator metal part, and the flow of leakage current is carried out through the cable and seen in across oscilloscope.

So, this arrangement of 40 seconds dipping; 8 second transition and 40 second dripping transition contacting with the high voltage then arresting everything is done using the proximity sensors which are been placed on the white dia from which is shown here. So, whenever the metal comes in a contact the proximity sensor will function, and its sees that the time and the arrangement which is required is meant it, further we have a relay and timer which is set along with the proximity sensor which will be helpful for the continuous experimentation. So, this is a fabrication of the specialty for conducting the aging studies.

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So, experimental studies have been conducted for over a period of time on several types of insulators, you can see the activity initially the samples will be of dry conditions after some period the samples slowly because of the scintillations or the discharges you can see discharges or a scintillations sometimes this scintillations happened near the second shed sometimes near the third sometimes in between shed to shed discharges are also seen. So, this activity is completely random in nature and depends on the salt depends on

the conductivity of the solution and depends upon the drive and red band formation, during the dripping period when it comes with after the dripping period when it comes with the high voltage contact.

So, these phenomena which undergoes for a thousand hours experimentation, after the experimentation we have seen the samples completely eroded completely degraded. So, these are the samples for the AC conditions for normal contaminant and with the acidic composition with two different times. So, we have seen the surface completely eroded and degraded. So, this will help to see that the samples performance losing the hydrophobicity a similar situation if it exceeds in the field, this gives an idea to see how the sample performs over long period of time with the rotating wheel type of arrangement.

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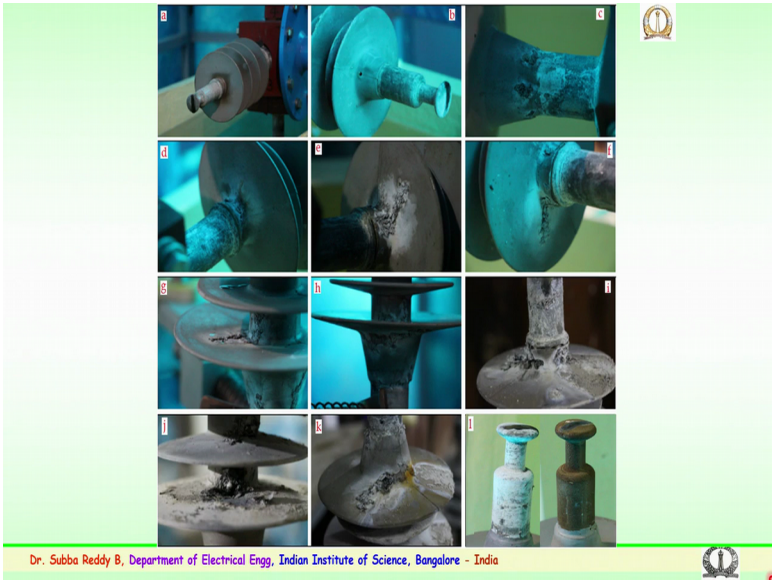

So, further to that not only the surface degradation, some of the places a puncture science have been noticed and the pin or a metal corrosion has happened on many of the samples, and in particularly in acidic treated samples a more degradation more surface rupture and the pin getting corroded have been visible much more in compared to the normal contaminant. So, several of the experimentations have been conducted and evaluated for various types of samples.

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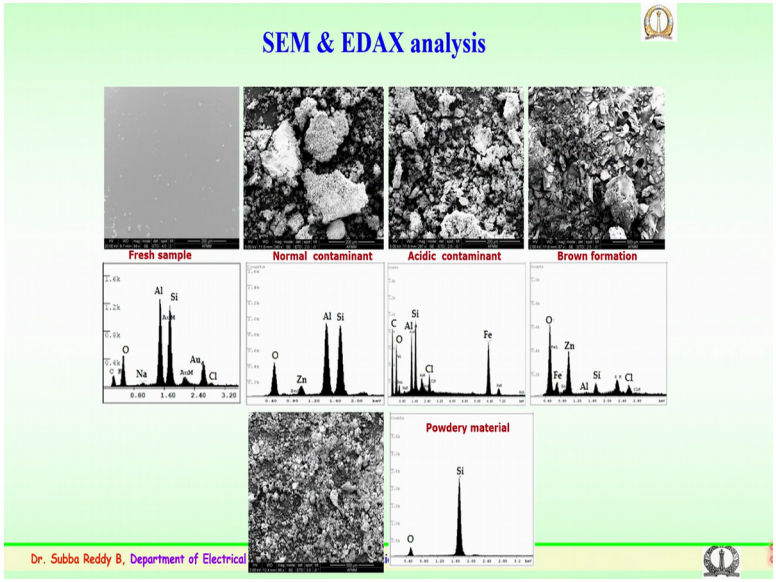

And again we have performed the surface analysis morphological analysis using SEM EDAX, FTIR and other techniques to verify the surface changes on the fresh and the treated samples. So, this show some of the SEM studies conducted for the fresh then it is for the normal contaminants as per the standard, then acidic contaminant as per the acid rain simulation some of the information again from EDAX showed various composition of the metals which have come in existence and some has also been conducted for the surface degradation and the powdery element which is present and it is also been seen how the performance of these for the degradation.

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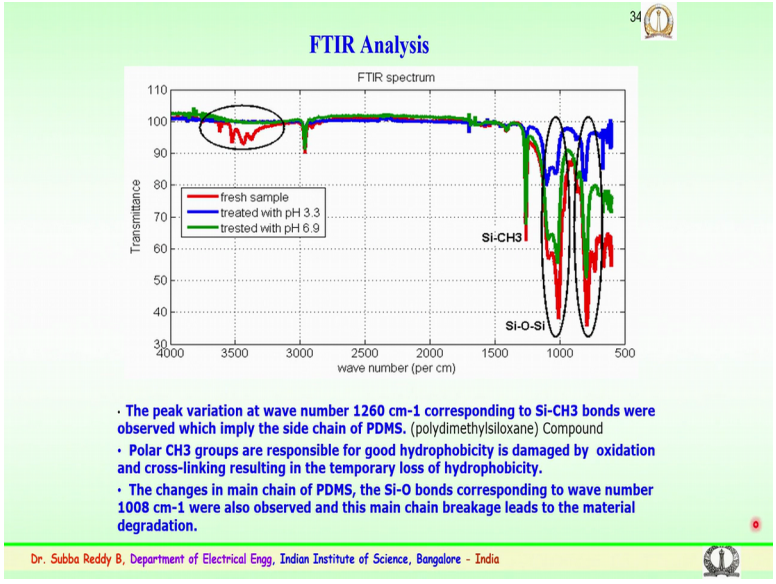

This is an FTIR Fourier transform infrared analysis conducted on different p H values of three and 6.9 along with the fresh the red spectrum indicate the fresh sample the blue indicates the p H value of 3.3 and the green indicates the p H value of 6.9. So, this gives very clear indication the peak variation particular that wave number 12 60 somewhere here you can see the peak of variation 1260, corresponds to Si-CH3 bonds which were applied this imply that the side chain of the PDMS that is a polydimethylsiloxane presence of the compound here this implies that formation of that the second a polar CH3 groups are responsible for the hydrophobicity, this is damaged by the oxidation and cross linking which results in a temporary loss of hydrophobicity the changes in the main chain of PDMS that is a polydimethylsiloxane compound the S i bonds correspond to the wave number of 1800 you can see here this which is encircle here were also observed this mention breakage leads to the material degradation.

So, this shows the material degradation and you can see the magnitudes variation with p H values the red indicates for the fresh the green for the treated with p H 6.6 and the blue with the p H 3 has a p H value comes down that is higher acidity, the performance of the chain breakage leads to the material much more degradation. This gives the FTIR analysis which is performed on the sample similar trend was seen for several of the samples which have been experimented.

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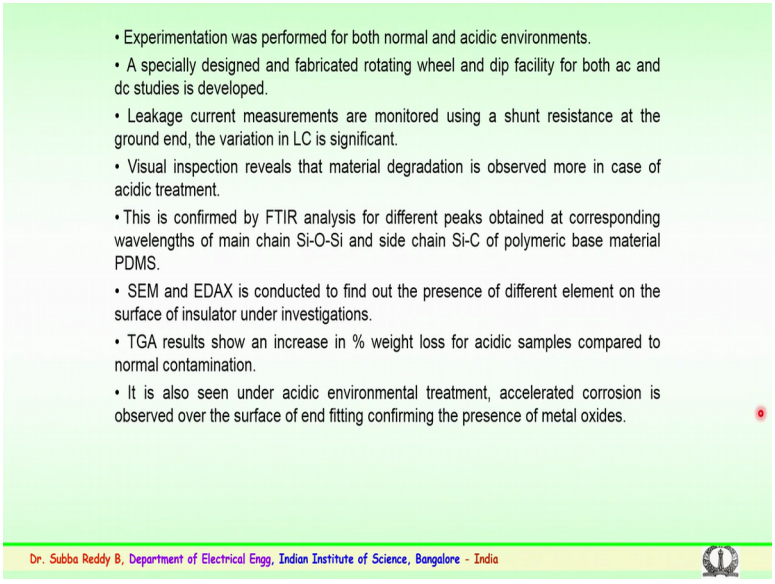

So, experimentation was performed in case for both the normal and acidic environments using the rotating wheel arrangement, especially designed and fabricated wheel and dip facility for both AC and DC studies is developed the leakage current measurements are monitor using especially made shunt resistance box with proper protection at the ground end, and the variation of the leakage current was observed to be a significant. Visual inspection has revealed after the experiment material degradation was observed higher in case of the acidic treatment samples in comparison to the normal samples, this was further conformed by the Fourier transform infrared analysis which was shown that for different peaks corresponding wave lengths the main chain S i O S i and side chain S i C of polymer based material pertaining to the PDMS.

Then the scanning electron microscope and energy dispersive x ray analysis conducted was shown that the presence of different elements on the surface of insulator which were under investigations. The thermo gravity gravimetric analysis results also show the increase in percentage weight loss for acidic sample in comparison to the normal contaminant samples it was also seen under acidic contaminant environment accelerated corrosion the faster corrosion was observed for the surface of end metal fittings this confirms the presence of metal oxides. These are some of the observations important observations during the rotating wheel experimentation which gives an idea of this changes morphological changes and chemical changes which is happening on the insulator and metal parts.

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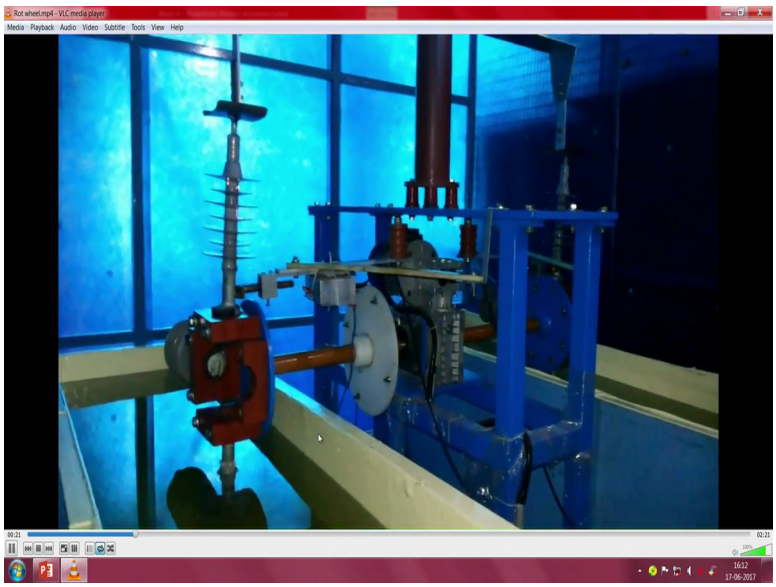

So, we will see how the experiment is fabricated in the laboratory experimentation is done, you can see now the surface is contacted with the high voltage you can see the same discharges scintillations which are happening here. So, this will be here for 40 seconds, after the 40 seconds the insulator most to the cooling period, then again dips in the solution and it come backs to the drip period. So, this experiment is very important experiment you can see the discharge is happening either side of the on the shaft which the insulator are fixed, we have two different tanks. So, one is a normal contaminant other is acidic contaminant, the activity of the insulator or the surface activity because of electric stress after the thing is very clearly seen.

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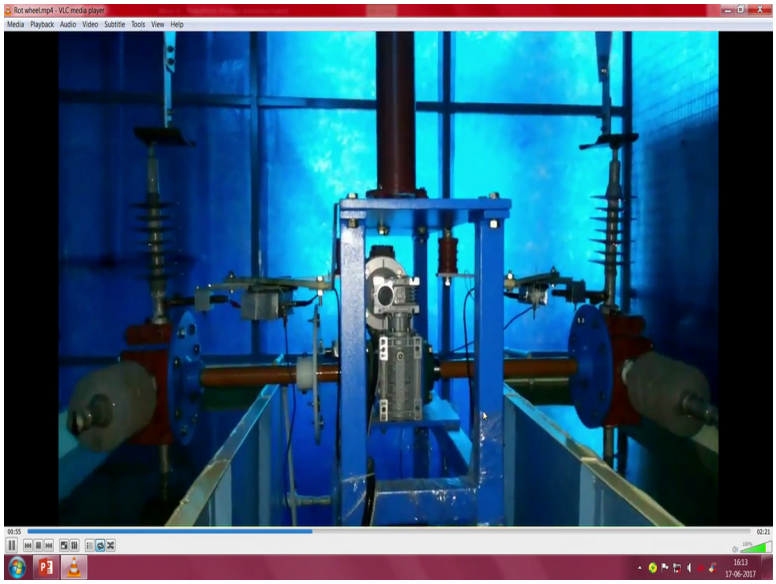

So, this cycle of rotation and the oldest stress which is being seen will be continuously applied for 1000 hours, and the experimentation is being ah conducted and during the experimentation the flow of leakage current on both the sides is measured using the centre box with the protection, employing the digital storage oscilloscope and also national instrument module where you can capture the data for the entire 40 seconds period and during the contact of high voltage.

So, you can see the discharges and after 40 seconds the insulator next in line comes in contact with high voltage, this transition is 8 seconds you can see how the experiment is being carried out. So, initially due to witness you can see the several discharges form because of the wet of the surface. So, later on because of the stress there will be drying

rope and suddenly you see the discharges or the conductivity coming down the leakage current flowing on the surface also comes down. So, this is how the experimentation very important experimentation for the evaluation of the polymer insulators.

So, after the rotating wheel aging experimentation further multiple stress experimentation, multiple stress is an important experimentation which is typically carried out for a very long period of time.

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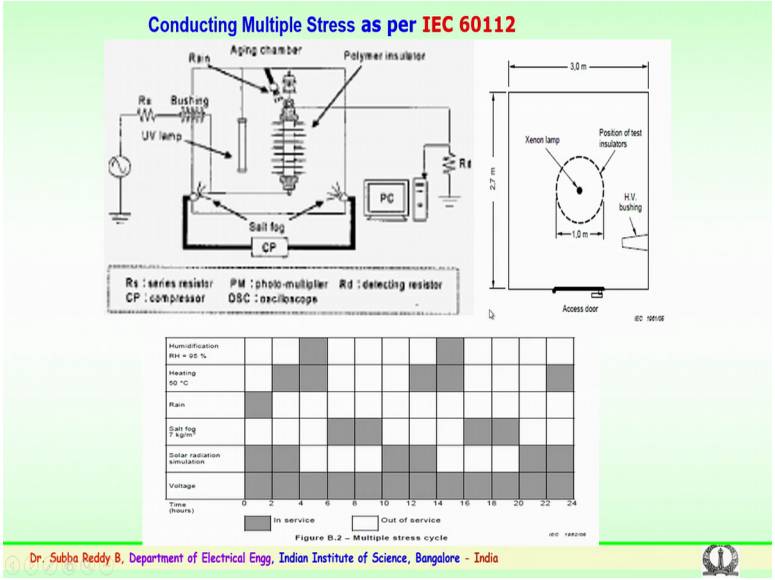

As per initially standards mention the experimentation has to be carried out for 5000 hours. So, this is a rigorous experimentation or analysis which is done for the insulator polymer insulator, you should have a specially built chamber aware the simulation of several parameters have to be carried out the humidity, the temperature, the rain simulation, the salt fog for the pollution the solar radiation that is a u v radiation, and the voltage. So, these are 6 parameters to be applied to the insulator simultaneously at an interval to see the performance over a period of time.

So, how this experimentation is performed in the laboratory again it inverse lot of effort to fabricate such a facility and conduct the experimentation monitor the experimentation, then monitor the surface of the insulator continuously then evaluate the surface. So, it is ah rigorous task for the engineers for conducting the experimentation the cycle shows as follows here, this cycle which is here or this describes for a 24 hour period of electric

stress. So, depending upon the number of hours say 1000 or 5000 hours this is continuously repeated with a break off as mentioned in the standard.

So, the voltage stress is continuously applied for 24 hours in a day, then when it comes to solar radiation. So, solar radiation is simulated for totally each block here is 2 hours. So, 4 into 3 blocks that is12 hours is a simulation of solar radiation with a gap interval of as shown here the dark blocks show the stress which is applied the white block show the stress is not applied. So, the entire dark block which is shown here is electric stress which is applied on insulator 24 hours, the solar radiation is applied 4 hours gap of 6 again 4 gap of 6 then comes the salt fog the salt fog is applied totally for 8 hours, you can see when the salt fog is applied for 4 hours there is a gap, again there is a 4 hour application of salt fog similarly the rain. Rain composition is applied only 4 two hours in a day as shown here further temperature the temperature is a totally 4 10 hours. So, ten hours is a 4 hours continuous a gap of 12 hours again 4 hours gap of 12 hours and 2 hours. So, this is the application of temperature and humidity humidity is totally for 4 hours it is applied a at 2 hours with a gap of 8 and again 2 hours. This is how the cycle has been explained in the standard as per 6011 which is to be followed for evaluating the multi stress or multiple stress arrangement for the insulators continuously. Apart from this the temperature we are supposed to use a junon lamp or a u v lamp for the simulation of u v radiation, that is a solar radiation is to be applied using the xenon arc lamp. So, this cycle is a very difficult task to be simulated in the laboratory worldwide there are only few laboratories where this facility is available and experimentation is being done.

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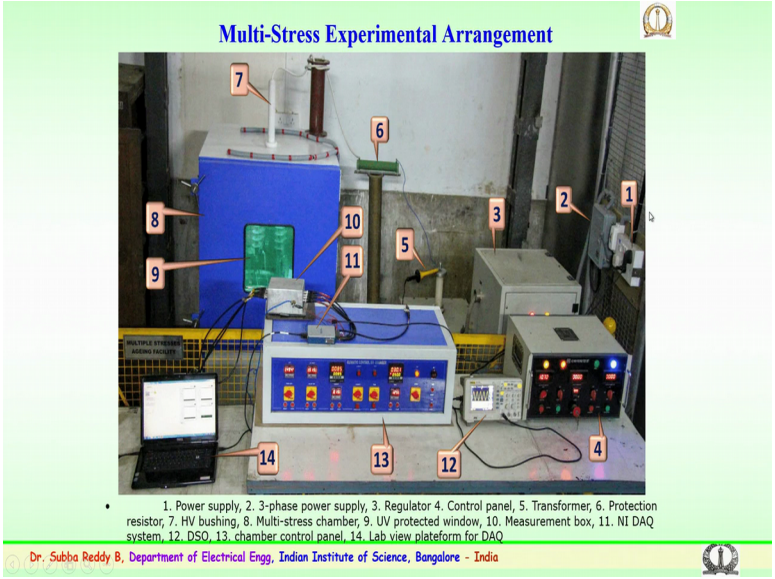

So, in the laboratory here we have tried to simulate the experimental arrangement for a multi stress environment, considering 4 important parameters and the experimental setup is as follows you can see the control arrangement here you can see the oscilloscope the control arrangement for the transformer, this is the regulator cum control arrangement a transformer resister for protection in case of the flash over, and this is a multi stress chamber which has been fabricated for the experimentation. The multi stress chamber consists of the parameters which can be accommodated is the temperature, the humidity, the u v, and the continuous electric stress to the electric supply the high voltage supply is taken through the silicon cable and bushing here.

So, inside 2.5 by 2.5 feet is the chamber, you can see the insulators 4 insulators of 11 k v are being energized at a voltage known voltage of 10 kilovolts as per the standard depending upon the 3 page length of the insulators used. So, we have a power supply a 3 phase power supply then a regulator the control panel transformer protection, bushing, multi stress arrangement u v protected window to see the sample energized and the measurement the box and data acquisition system with the lab you platform for data analyzing facility.

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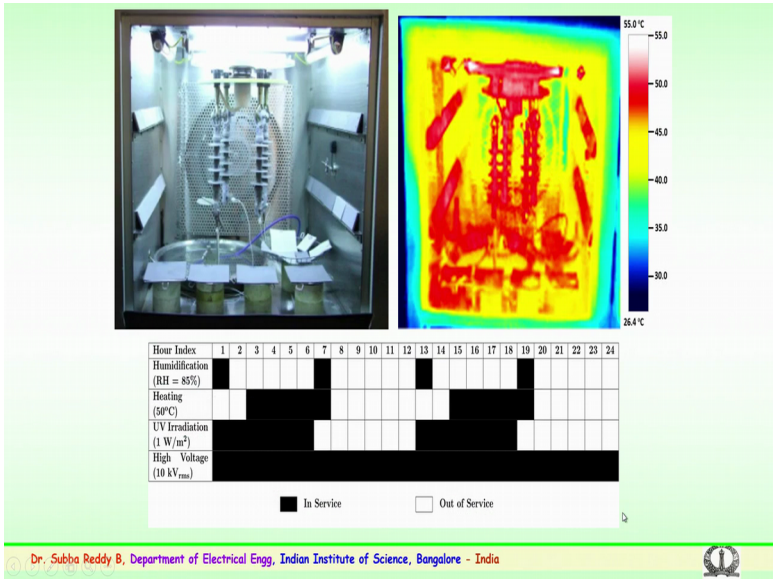

Again here we have a try to modify the cycle, which was as per the standard. So, has 4 parameters have been considered in the present study, the experimental arrangement is shown here we have put up 4 insulators in the chamber, this shows the thermal imaging at equally distributed temperature on the samples with the thermal image imager of a test on make. The cycle which has been adopted for the present experiment is as follows which has shown for 24 hours. So, here we have applied the electrical stress for 24 hours the entire combination you can see here. The ultraviolet radiation we have used 4 specially made u l u v lamps ultraviolet voltage ultra violet lamps which as an output of one watt per metre square this ultraviolet is applied for a period of 6 hours continuously with a gap of 6, and further 6 hours then hitting the temperature we have applied 50 degrees for a period of 4 hours with a gap, again 4 hours. Similarly humidity we have 85 plus minus 90 degrees humidity has been made for 4 hours as shown here. This cycle is not exactly pertaining to the standards we have a deviation in the standard and this is what we have followed for the experimental or research pertaining to this polymer insulators.

So, this chamber shows the multi stress arrangement which has been fabricated in the laboratory. So, where 4 parameters have been used humidity heating u v radiation high voltage and the experiments have been performed for a period of 1000 hours. So, at regular intervals the measurement of leakage current you can show see the leakage current measurements have been the connections have been taken through a Teflon wires

and connected to a shunt box and the measurements have been carried out you can see the shunt box, which is fixed here the measurements from the chamber through the silicon Teflon cable comes here and from the shunt box it is being connected to the measuring oscilloscope or to the national instrument data analyzing systems. So, this is how the measurement of leakage current at regular intervals is being carried out.

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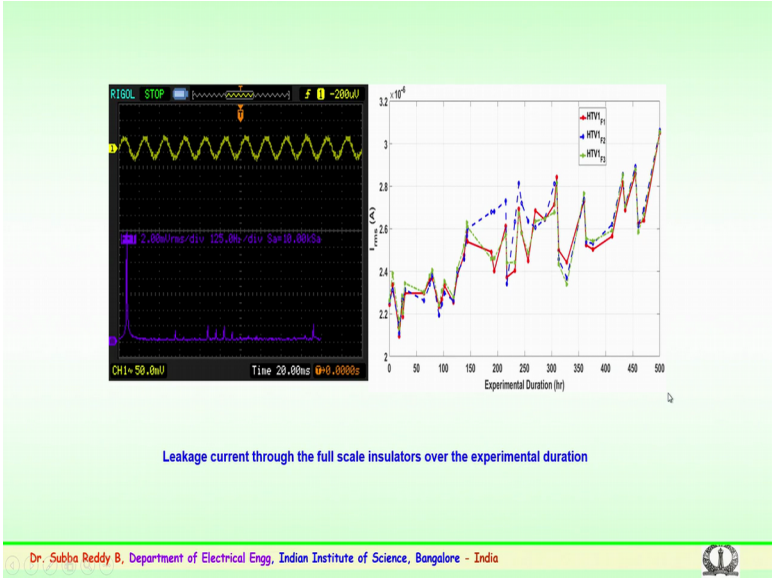

So, experiments have been perform this is a typical leakage current wave form which shows here has been for a particular one sample, this shows the ah the frequency component involved in that at that junction which is form through the which is got from the oscilloscope, the over the period of time this typically gives the experimental duration for 500 hours.

So, further experimentation was still carried out for 1000 hours, it shows that the current which is here it will be in terms of a micro amps verses the experimental duration that is the period in hours, you can see that the initially the current for all the samples the all the 4 samples keep slow and over the period of 5 more than around 150 or above 150 or 100 hours you can see the slowly the increase in the current is observed and further after 500 hours it was also seen we have tried to conduct the experiment for 1000 hours further increase has been observed.

So, this shows that for the multi stress the leakage current trice to increase for a period of time, and also the surface degradation studies analysis where the conducted after 500 and

1000 hours it was seen that the performance of the rubber particularly silicone rubber the behavior for surface changes and hydrophobicity changes are also monitor at regular intervals.

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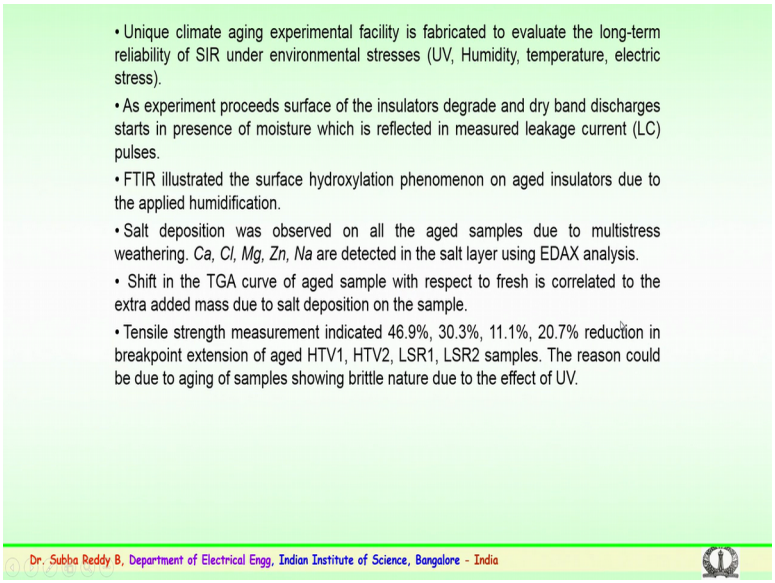

So, for this as mentioned a unique climatic aging experimental facilities fabricated particularly to evaluate the long term reliability of silicon rubber insulators, under the different environmental stresses as mentioned ultraviolet, humidity temperature, and electric stress in the present experimentation. The experiment it was seen that as experiment proceeds the surface of the insulators, degrade and there were instances were small drive band and wet band formations were discharges were observed a particularly in the presence of moisture, this was reflected during the measurement of a leakage current pulses were during the monitoring of leakage current measurements.

Further the FTIR are the Fourier transform infrared spectroscopy, studies illustrate the surface hydroxylation particularly for the phenomenon on the aged insulators of 500 or 1000 hours, this may be due to the humidification which has been applied on the sample it is also observed the salt deposition was all the aged samples due to multi stress weathering like C a, C l magnesium, zinc, N a are this for all detected in the salt layer using the energy dispersive x ray analysis over the period of time this were prominent after 2000 hours, and when the thermo gravimetric analysis was done it was observed there was a shift in the curve particularly for the aged samples in comparison to the fresh

this is correlated to the extra added mask due to the salt deposition which we have observed on the samples.

Further mechanical strength was measured for the samples for flat and samples which were also placed inside the chamber during the experimentation, and the tensile strength was measured the tensile strength indicated the 46 30.3 11.1 20 reduction in the breakpoint extension. So, it was shown that decrease in this percentage was observed for the aged samples like HTV 1, HTV 2 or the high temperature volca sample two different samples, liquid silicon rubber one and liquid silicon two all 4 different samples experimentations is carried out and it was found that the decreasing tensile strength was observed.

The reason again could be due to the aging of samples which show over a period of time the brittle nature this could be because of the effect of the ultraviolet radiations on the sample. So, multi stress experimentation gives an idea for the long duration performance of the polymer insulators because of the effect of u v effect of humidity, because of effect of temperature, because of effect of electric stress rain and many factors. So, this experimentation as insulators are organic in nature is very important to be conducted no doubt the arrangement of this facility is not an easy task a request lot of effort to be made and lot of experience is required to conduct this.

So, very few laboratories across the world have the facility to conduct a full fledged multi stress experimentation to find out the performance of the samples which is an indicator or estimating the long performance of insulators in the field.

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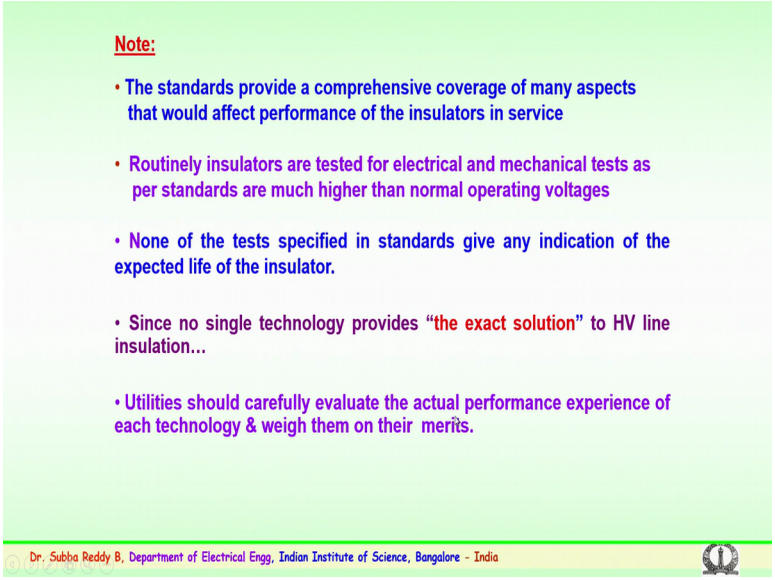

So, coming to the point after the reliability and testing of these samples for various experimentation, the standards which are being used standards which are being recognized for the evaluation, do provide a comprehensive coverage of many aspects that would affect the performance of insulators in service. So, this standard maybe for the ceramic glass or the polymer insulators in service routinely insulators are normally tested for reliability, for electrical and mechanical aspects this with reference to the standards and normally are carried out at slightly higher than the normal operating voltages. To mention, but none of the test whatever the tests which are being prescribed in the standard or specified in the standard give an indication of the expected life of the insulator. So, the reliability experimentation or the standard testings which are carried out in the laboratories or in the industry and do not give the exact life expectation of any insulator in service.

So, since no single technology could provide the exact solution to the high voltage line insulation, the utilities or the power suppliers should carefully evaluate the actual performance experience of the about technologies, it maybe a ceramic or a (Refer Time: 36:40) or a glass or a polymer or a newer type of technologies which are being adopted have to look into the performance experience of each technology away them on the merits, and then try to adopt a for the actual required performance. So, this is the important note to be taken into consideration.