Advances in UHV Transmission and Distribution
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Lecture – 35
Measurements of High Voltages (cont)

So, good morning. We have discussed about the high voltage generation, which is very important for the testing of high voltage equipments in the laboratory. So, essentially we have looked into the generation of high AC voltages high DC voltages and high impulse voltages both impulse surges of both voltages and currents.

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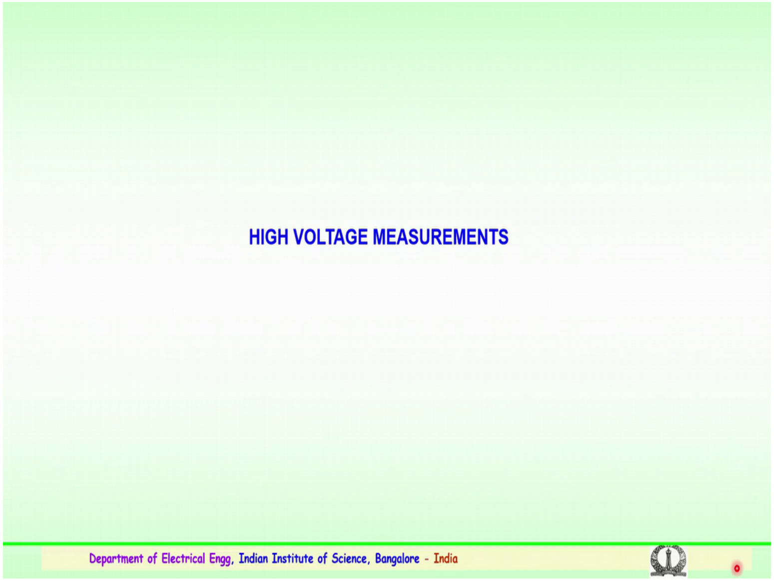

So, these are very essential, so that the available generators could be used for the testing and also proper verification of the equipment which could be installed in the high voltage transmission network or in the substation. So, generation of high voltage is equally important is also the measurements. So, measuring the high voltages, for low voltage you have a several equipment or the oscilloscope or any other measures where you can be used for the measurement. But in case of high voltages and high currents particularly in the range of hundreds of kilo volts and hundreds of kilo amperes, so the measuring equipment plays a very important role in the laboratory. So, we will focus on some of the important measurements which are typically used for the high voltage AC, high voltage DC, high voltage impulse voltage and impulse currents. So, we will focus on some of the important and the importance of the measurement and the equipment or the measuring systems which have been deployed at the high voltage laboratories for the same.

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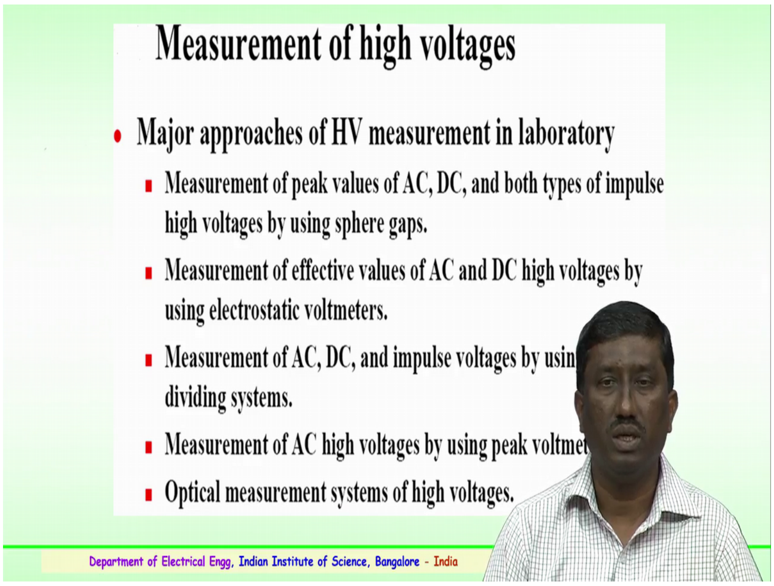

The first and foremost important for measurement of high voltages is to see that any high voltage measurement laboratory should be able to use the devices. So, measurement of peak values, it could be of high voltage AC, HVDC or both type of impulse voltages, this could be done by the use of a sphere gap arrangement. So, the measurement of effective values of HVAC and HVDC is also being done by using electrostatic voltmeters. A measurement of AC and DC and impulse voltages is done by using the dividing systems, it could be resistive dividers or a capacitive divider arrangement. The measurement of AC high voltages could be also measured by using a peak volt meters. And finally, in the recent past optical measurement systems for measurement of high voltages is also being used in the laboratories.

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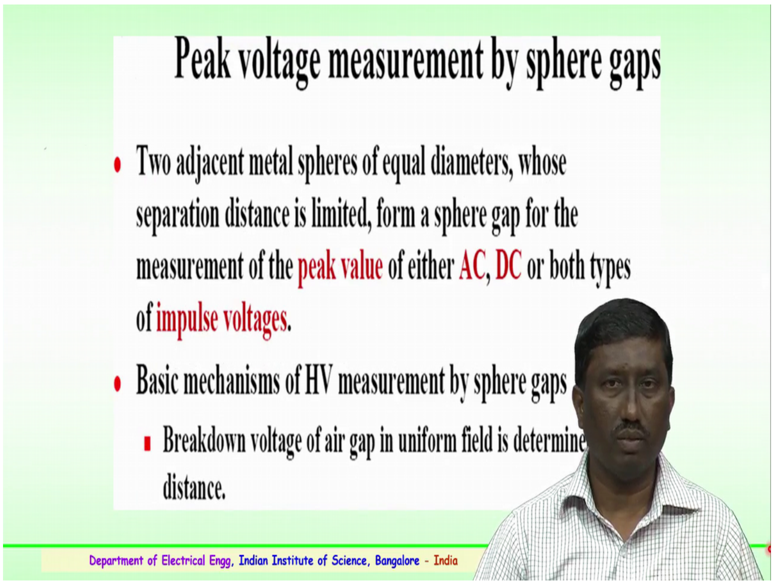

First, we will look into the importance and how the peak voltage is measured by using the sphere gap arrangements. This was one of the important method, which was being used since the high voltages were known and this is a simplest method where it can be used in the laboratory. So, basically consisting of two adjacent metal spheres and placed at a equal diameters. So, these at spheres have to be of the same diameter and arrangement could be of a vertical or horizontal arrangement and the separation distance is limited. So, form a sphere gap for measurement of the peak value, you can either measure AC, DC or both type of impulse voltages using the sphere gap assembly.

So, the basic mechanisms of high voltage measurement by a sphere gaps is done by applying the voltage and the break down voltage of the distance which is maintained between the sphere that is a air gap in uniforms field the sphere gaps spheres are of uniform dimensions and uniform field will be obtained by using the sphere gaps. So, the break down voltage of the air gap in uniform field is again determined by the gap distance. So, the diameters of the sphere and the gap distance play a role in the uniform field breakdown voltage.

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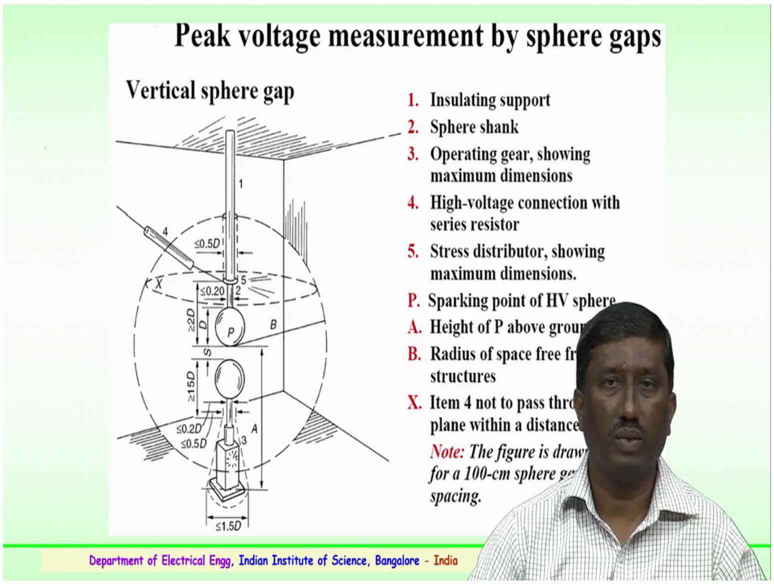

So, this is a typical example of the arrangement of sphere gap, a vertical sphere gap assembly where it is being used for the peak voltage or measurements. So, this assembly consists of the following. You can see the two spheres are here. So, one of the sphere is connected to the ground end which could be a mobile it could be one of the sphere could be on a mobile platform, other is normally fixed. So, the two sphere gap arrangements are fixed to insulating support, you can see that this is the insulating support. The second here you can see the sphere shank the metal sphere, sphere could be of copper, brass or aluminium. So, this sphere shrank again is a metal portion which is connected to the insulating support. So, this is the shrank, this is the insulating support. Third is this arrangement where it is an operating gear showing maximum dimension. So, the distance S between the two spheres can be controlled by using a motorize mechanism in case of the huge spheres. So, this is basically control or an operating gear arrangement for the making the arrangement of a required gap distance.

So, the high voltage connection is given here with a help of a sphere with a help of series resistor. This high voltage connection is shown it is connected to a metallic end of the shrank. And we have a series resistor this series resistor is important in case of the flash over. The pitting on the resistor spheres is avoided, and also the following flash over during the flash over the current will be limited to the source.

The connection which is made to the high voltage terminal is known as a small ring type of arrangement here this is a stress distributor which is connected between the metallic and the insulating rode which shows higher dimensions than the shrank of the sphere gap. The P is you can see the point P here; P is the sparking point when the voltage is applied the spark occurs between these two points so known as the sparking point in this sphere gap assembly. And distance from the ground this is the ground plane; from the ground plane is a distance A which is fixed or it could be adjusted as per the requirements. So, A shows the height of the P that is point where the sparking could occur from the ground.

So, the radius this B which shows the value from the peak point of the sphere to the outer circumference which is shown here in the dotted line represents the radius of a space this entire space surrounding the sphere gap from external structures. So, it is advisable the external metallic structures should not be near within this in the vicinity of the sphere gap assembly. So, minimum radius of mentioned as per the standard is being followed and this shows the distance which has to be minimum clearance has to be maintained.

Then x you can see the dotted line here I mean a spherical type of arrangement is shown here. This x is the item four, which this connection that is from the high voltage connection through the resistor, it should not pass that is it should not the contact should be form and you should not come in the way of to pass through this plane within a distance so that this again same distance has to be maintained. So, this distance B is equally should be maintained and it should not come in the vicinity of this clearances.

So, this figure peak volt measurement by sphere gap assembly that is vertical sphere gap assembly indicated is for sphere gap of 100 centimeter gap radius at a spacing. So, all this dimensions which have been mentioned or with a reference to the 100 centimeter sphere gap radius. So, very clearly the dimensions have been given this is taken from the standard IS and ISC standard for measurement of peak voltages by sphere gap it is available. It is very clear the distance or the fabrication when it is being done for the sphere gap assembly. The dimensions are being very clear given here the distant the diameter of the shank, the example here the minimum insulator dimension, the dimension of the sphere the distance which has to be maintained and the gap. And also what is a minimum diameter of the spheres which could be used up to a particular voltage. So, these information is very clearly defined in the standards pertain into the sphere gap assembly is used for measurement of both high voltages and high currents.

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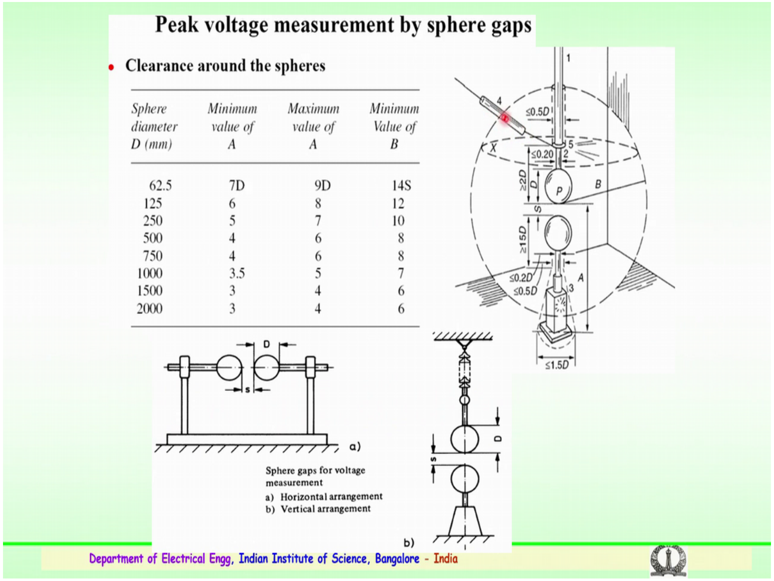

So, what is the minimum clearance. We have seen about the sphere gap assembly, this is vertical sphere gap assembly which we have seen, this is in case of the horizontal. So, sphere gap arrangement could be of horizontal or vertical in nature for the measurements of the voltages and it depends which type of arrangement to be used depending upon the level of voltage which is to be measured. So, here you can see the clearances as per the specifications given the minimum clearances are defined here that a being the clearance from the ground to the point of where the flash over could occur the top surface. The B is the minimum radius for the clearance required.

So, you can see from the table where it gives the diameter in mm these is a sphere diameter that is diameter of sphere in mm ranging from 62.5 to 2000 or 2 meter sphere gap assembly. So, here the minimum value of a that is clearance from the ground has to be maintained in case of 62.5 mm dia spheres a minimum of 7 d. So, 7 into the 62.5 is the minimum clearances to be maintained from the ground, and the maximum is specified as 9 d.

So, anywhere between 7 d and 9 d is the distance which has been given for the A for 62.5 mm dia’s sphere. And minimum value of B, B is a clearance which we mentioned discussed from the point to the minimum clearances is the distance, this distance is again

4 into S. 14S is the gap distance suppose the sphere gap assembly is used for say 2 centimeter gap measurement if the fixed distance is 2 centimeters. So, 2 into 14 will be the minimum clearances as per the standards to be maintained so that no metallic objects or any other interference object for the measurement should not be near the vicinity of that distance.

So, similarly when you increase the sphere diameter, so you can see the values also change. For an example for a 2 meter that is 2000 mm sphere gap assembly the minimum value will be three times of the D that is 2 into 3 - 6 meters. So, the a will be minimum 6 meters from the ground and the maximum value will be 4 into 2 - 8 meters. So, 6 to 8 meters will be 8 meters will be the maximum value which it could be taken or minimum has to be 6 meters. So, this is the clearances required and maintained for the accurate measurements as per the standards, else there could be erroneous results if the deviation is made in the clearances. And the minimum value of B fix for 2 meter is 6 into the again gap distance which used for the measurement.

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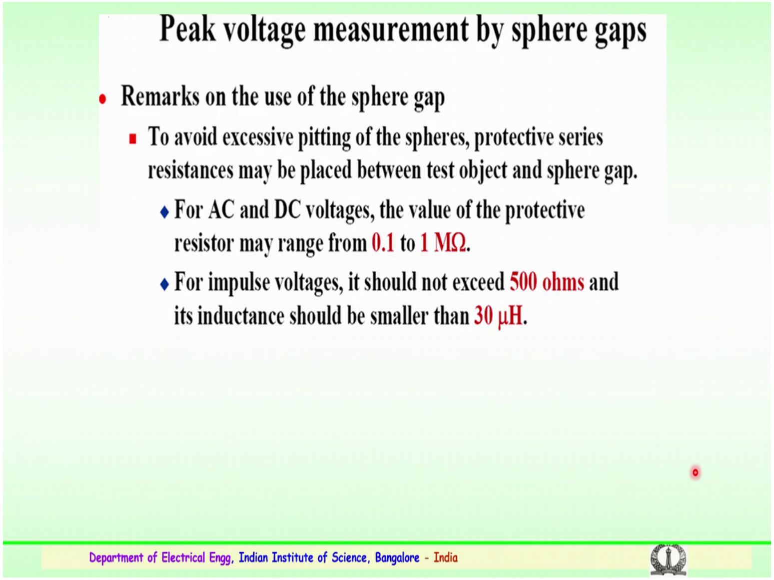

So, peak voltages are measurement was a concept which was initially being used and even till date for the calibration and measurements sphere gaps are also being used in the laboratories high voltage laboratories and the texting laboratories. Few observations on the use of sphere gap, it is advisable to see that excessive pitting on the spheres have to be avoided. During the break down, continuous break down there could be pitting near the edges on this sphere gap. It could be here or here, these have to be properly seen that the pitting never appears, because this again on the values which could be obtained will be a different incase the pitting is excess.

So, there should be a protective series resistor that is intention of going in for the series resistance that is as shown here may be placed between this object and the sphere gap. So, for case of AC or DC voltage measurements typical value for the protective resistor may range anywhere between 0.1 to 1 megohms. So, depending upon the values are depending upon the AC or DC typically the range could be anywhere between 0.1 to 1 mega ohms. For impulse voltages, the specification says or it is to be maintained it should not exceed 500 ohms series resistance. And at inductance particular the it could be the lead inductance or it could be resistance which is being connected should be very small and it is being specified should be less than 39 micro henry.

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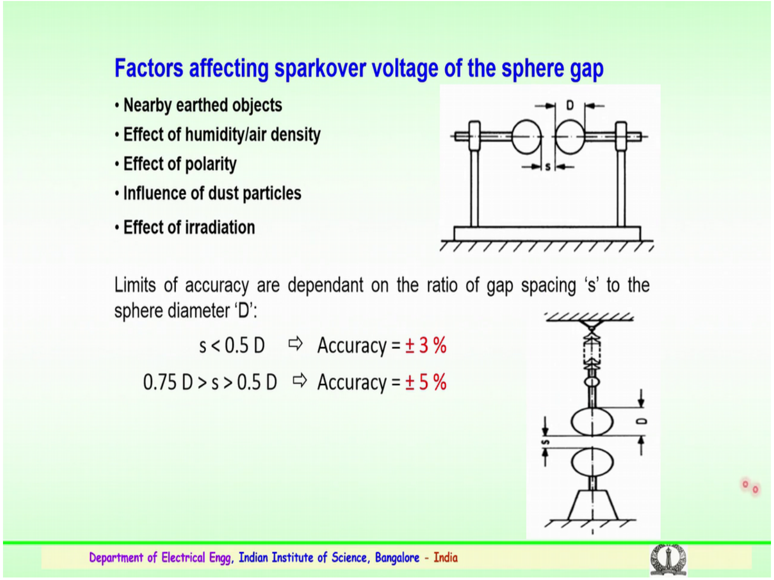

So, what are the factors which could affect the proper measurement of the sparkover voltage by using the sphere gap assembly. Again this has been represented here for the horizontal assembly, D is the diameter of the sphere, S is the distance between the two spheres which is used to measurements. Similarly, for the vertical arrangement D is the diameter, S is the distance between spheres. The factors which could affect the sparkover voltage of the sphere gap assembly are the nearby earthed objects. So, any metallic objects or earthed objects if it is near the vicinity that is a factor B which we were discussing. So, this minimum clearances B from the point of the discharge activity where could happen to the minimum clearances is of at most importance that is a distance into the clearances is very, very important else the readings could be erroneous. So, the any earthed objects or metallic objects or any interference should not be in the vicinity of the specified distance.

The second is a effect of humidity and air density. So, sphere gap measurements have to be taken where humidity should not exceed a certain value this is clearly given in the standard, where it says above 85 percent of the humidity these readings are prone for erroneous. So, repeatability could be not achieved. So, it is always recommended to see that the humidity level and the increase in the air density is of important while using the sphere gap assembly. Then it also affects using the polarity positive or a negative polarity, the results are not very consistent. So, it depends upon the polarity values, there could be minor change in the magnitude of the value the effects. So, the effect of polarity is also been seen.

Then influence of dust particles as these sphere gaps are of open type, here the metallic spheres likely to be influenced by the settlement of the dust particles or on the surface of the spheres. So, these could initiate early breakdown and the results which are obtained may not be the correct values. So, proper cleaning is required on the sphere gap assembly and the final factor which could influence is effect of irradiation. So, irradiation also when influence the sphere gap assembly. So, it is always suggested proper UV radiation at a distance could be used to see that UV radiation will help in uniform or breakdown could happen with the effect of proper irradiation that is one point which is very important.

So, limits of accuracy of the measurement the sphere gap arrangement. So, measurements are values which you get either it in horizontal or a vertical type of arrangement are normally dependent on the ratio of gap spacing that is the this gap spacing that is S between the sphere gap assembly to the diameter of the sphere. And here the error in case the distance between the electrode is less than 0.5 D the diameter of the sphere say 2 centimeter dia sphere in case if it is the distance is maintained and such a way that it is half the diameter. Then the results obtained till half the diameter of the spheres the gap spacing where is equivalent to half the diameter of the sphere that is radius of the sphere in such case the accuracy could be obtained up to plus minus 3 percent.

So, whereas, in case if the distance between S that is gap distance and the diameter of the sphere is of more than 0.75 D or more than greater than 0.5 D then the accuracy will go higher will be again plus or minus 5 percent. So, you may not get very accurate results. So, you will have to be using the sphere gap assembly lesser than the specified 0.5 diameter of the sphere.

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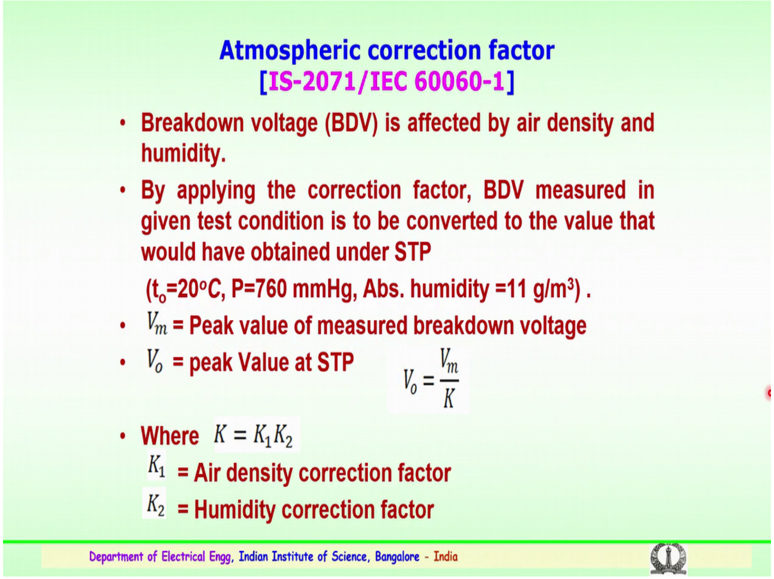

So, for the break down voltages proper and necessary atmospheric corrections have to be made, because this values could differ from the laboratory to laboratory. And hence these breakdown voltages have to be properly corrected to the standard temperature and pressure values which have been given in the standards. So, there are national and International Standard that is 2071 and also IEC 60060 high voltage test standard where very clearly mentions about the correction factors to be used for the break down voltages obtained using the sphere gap assembly. The breakdown of voltage as we know that is affected by air density and also humidity.

By applying the suitable correction factor, the break down voltage measured during the test condition is to be converted, the values have to be converted to that which could have obtained under standard temperature and pressure. So, very important where the value should be converted in with equivalent to the standard temperature and pressure which is mentioned. The standard temperature is 20 degree centigrade - t 0, pressure being 760 mm of mercury hg, and absolute humidity at 11 grams per meter cube these are the standard values, which have been specified. Now, considering V m being the peak value of the measured break down voltage of the sphere gap when the voltage applying the there will be a break down here. So, this break down voltage for a specified gap is the value V m which is known as the measured break down voltage.

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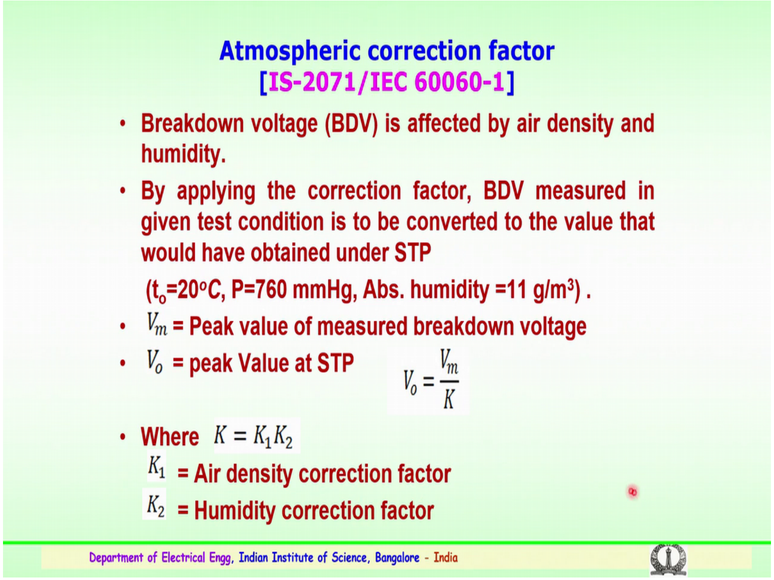

So, the V naught is the peak value to be at standard temperature and pressure. So, we have to convert the values to the standard temperature and pressure for this we have a correction factor to be used, so that value v naught which could be equal to the peak value at standard temperature and pressure is given by V m by K factors. So, V m is the peak value of the measured break down voltage by at factor K. Again this K is equal to K 1 into K 2. What is K 1? K 1 being the air density correction factor and K 2 being the humidity correction factor where we have told that the break down voltage of the sphere gap is effected both by air density and humidity correction factor. So, K 1 is the air density correction, K 2 is the humidity correction factor to be considered.

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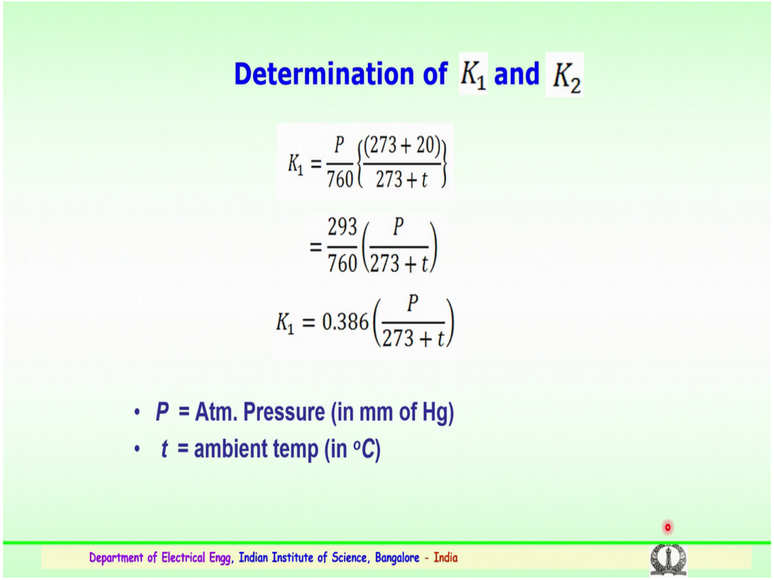

So, how to determine the K 1 and K 2, it is very clearly given in the standard six zero dash one that is IEC 600601 or is 2071. Where K 1 could be calculated as K 1 is equal to P is the pressure divided by 760 to the standard atmospheric pressure into 273 by 20 by 273 by 20 degree by t temperature at the lab conditions. So, this will be equal to 293 by 760 into P by 273 plus 2 t, where K 1 will be equal to 0.386 into pressure by 273 plus t, where t being the ambient temperature, P being the atmospheric pressure in mm of mercury mm Hg. So, this is how the K 1 is being calculated.

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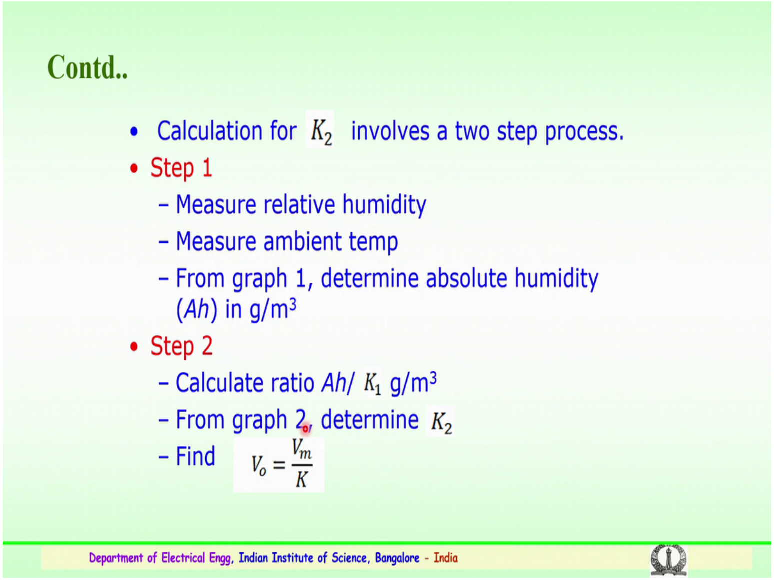

Further, calculation for K 2 is very important this involves two steps that is two step process for calculation of K 2. The step one is to measure the relative humidity. How to do that, we will discuss about it. So, first step consists of measuring the relative humidity then measure the ambient temperature of the experimentation performed.

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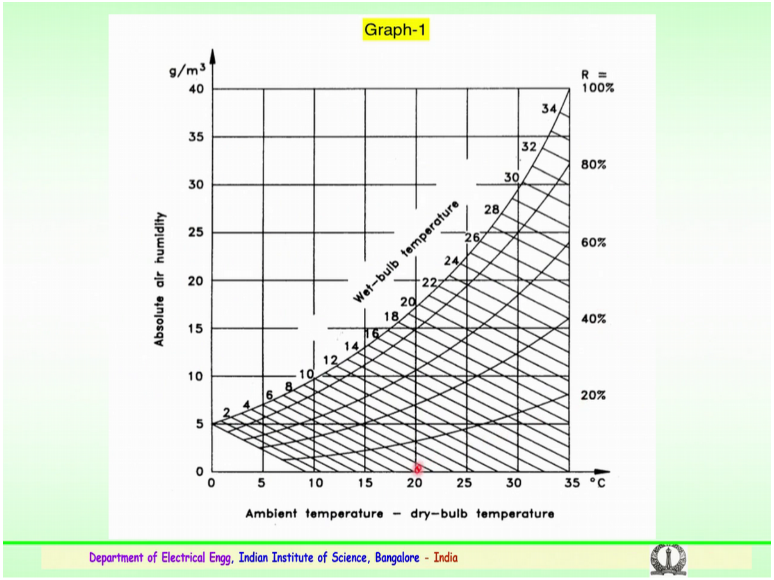

So, going to the graph one in the standard, we could determine the absolute humidity that is in grams per meter cube absolute humidity grams per meter cube that is measure the relative humidity. This is the graph one which is been given in the standard where it gives the values absolute here humidity in grams per meter cube in the y-axis and you can see the ambient temperature that is a dry bulb temperature in the x-axis. So, depending upon the values considering both wet bulb temperature, and the dry bulb temperature. You can see here for an example if it is 20 degree and dry temperature and wet bulb is 18 degrees, you can go through this and see here this corresponds to say sixteen grams per meter cube example.

So, similarly the values are calculated from the graph and this gives grams per meter cube this is a value of absolute humidity is obtained. Now, after that the step two is calculate absolute humidity by K 1 grams per meter cube. So, again we have to refer graph two to determine the K 2. So, how do we do that?

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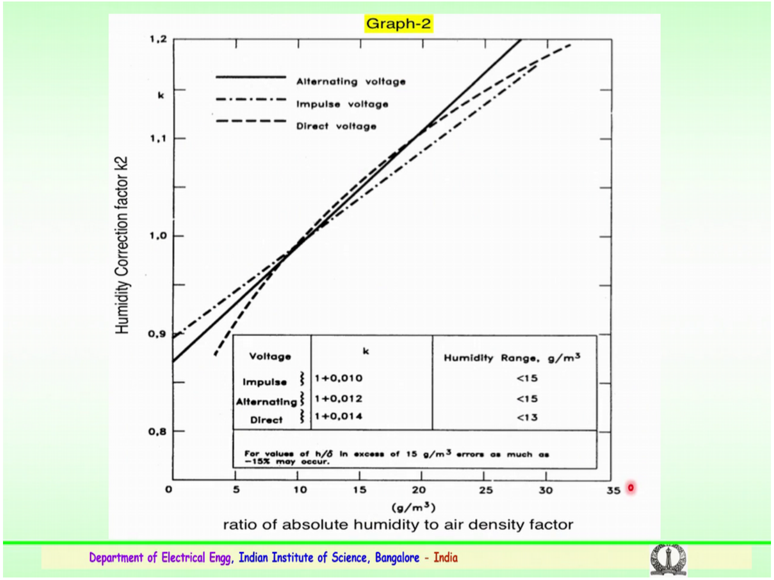

So, this is the K 2 where the humidity correction factor for K 2 is done. It gives the ratio of absolute humidity to air density in the x-axis and humidity correction factor on the y-axis. So, ratio of absolute humidity to air density is first calculated that is absolute humidity by the relative humidity is calculated. From the graph, you can determine the K 2. From here this ratio verses the humidity correction factor suitability. So, in case if it is 15 grams per meter cube. So, 15 grams per meter cube here it corresponds to say 1.04 or 1.05 is the correction factor for K 2. These three curves shown here. The dark line is for the alternating current voltages reference of that. And in case experiment are performed with impulse voltages, you can see at dot and the dash this line represents the curve which is to be referred for impulse. And in case of DC voltages, this is the curve to be referred.

So, in case of DC a particular value say 15 gram per meter cube for DC measurement of the sphere gap use than we have to focus on the DC curve where we get the values suitable to the DC level and further the correction factor for K 2 is obtained. This is how the factors K 1 and K 2 are obtained. So, finally, going back. So, we have to determine the voltage V naught is equal to V m by k. So, the k being K 1 and K 2 K 2 we have found out K 1 and K, 2 now through the graphs. So, we can calculate the values which have been obtained. So, final voltage in equivalent with the standard conditions could be obtained is equivalent to the measured value by the factor K. So, very important for the measurements, the correction factor incorporating the correction factor to the standard temperature and pressure values is very important while using the sphere gap assembly.