Advances in UHV Transmission and Distribution
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Lecture – 36
Measurements of High Voltages (cont)

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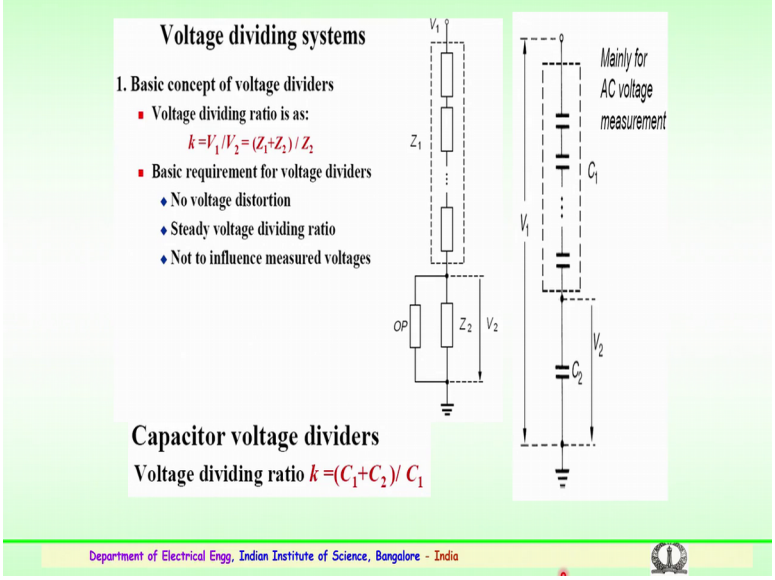

So, the next is the voltage dividers which are generally used after the initial use of sphere gap assembly, the requirements or the further improvements in the measuring aspects for the AC or a DC have been got, and these systems have come into the place where its being used in the laboratories.

So, voltage divider or voltage dividing systems are in place in a high voltage laboratories for the proper measurement of a voltages. So, basic concept of voltage dividers a simple nature, where the voltage dividing ratio say voltage V 1 is applied here, the resistance or the impedance which is shown here will be of two components, the larger high voltage a side of the arm what we call Z 1 consists of number of resistors in series and it will be a very high value.

The and the secondary or the low voltage arm what to be call as Z 2 the impedance Z 2 it could be of a lesser value in comparison to the total resistance value very less in comparison to the value. So, we typically obtain the voltage at V 1 which is given which is to be measured could be measured across the Z 2, where V 2 could be obtained and

with the proper a dividing a ratio that is the ratio is calculated as V 1 by V 2 is equal to Z 1 this entire resistance or plus Z 2 this value divided by Z 2.

So, this gives you the divider ratio. So, the whatever voltage which you see here multiplied by the k, will give you the actual voltage which is being seen across the voltage divider. So, this is important. So, the basic requirement for voltage dividers is that no voltage distortion should be there during the measurement, and there should be steady voltage dividing ratio and this should not influence the measured voltages.

So, similarly resistance voltage dividers you have seen here, and capacitive voltage dividers also been used. So, for the mainly for the AC measurement similar in construction you have a number of units which is known as the high voltage arm or C 1, and the C 2 will be higher capacitance value.

So, the dividing ratio for the capacitor will be C 1 plus C 2 divided by C 1. Because C 1 will be in series number of capacitance series will bring down the value of the entire capacitance whereas, the second voltage arm will be of higher rating.

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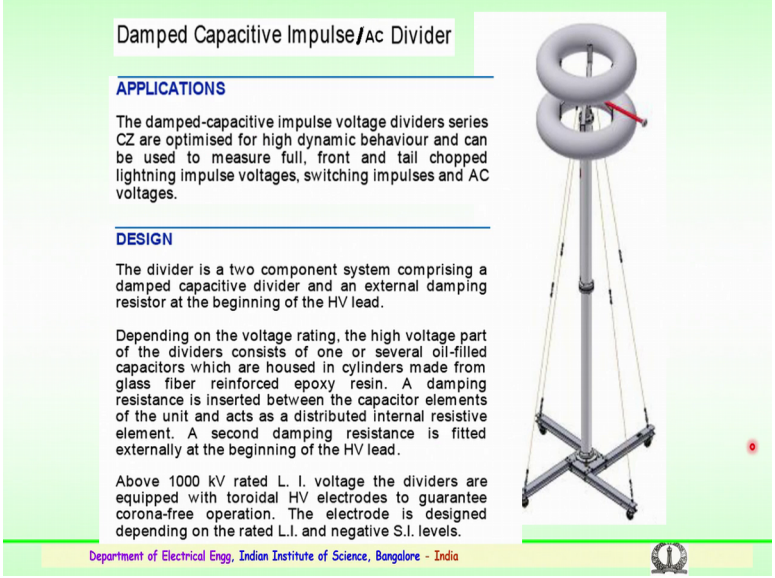

The third type of dividers are known as the damped capacitive it could be impulse or AC dividers. So, it could be used for AC measurement are also for the impulse current and impulse not current impulse voltages or AC applications. So, the application of the damped capacitive impulse voltage dividers are optimized for high dynamic behaviour

and these can be used to measure either the full waveform or the fronted or the tail or chopped lightning impulse voltages, switching impulse voltages or the AC voltages.

So, this divider can be of multipurpose use. So, these are again a corona control rings, at a very high voltages the corona could be seen at the metallic ends of the capacitor units or the units which are used for the divider. So, this has to be properly shielded for measurement. So, the corona control rings are used.

So, design basically consists of two components as shown here comprising of a damped capacitive divider and an external damping resistor in the beginning. So, that is very important. So, damped capacitive impulse it is a combination of a capacitive divider with the external damping a resistance at the beginning of the high voltage lead. In case if I am taking the high voltage lead from here, the beginning of the capacitance resistor would be consisting of a small resistor which will be used for damping.

So, depending upon the voltage rating the high voltage part of the divider could consist of one or several units which are oil filled units of capacitors, which are oil filled and are housed in cylinders or insulating cylinders made up of fiber glass or reinforced epoxy resin or any other insulating material.

So, a damping resistance is normally inserted between the capacitor elements of the unit, which acts as a distributed internal resistive element this is to be noted. A second damping resistance is also used and this resistance is fitted externally at the beginning of the high voltage lead here at the beginning of the high voltage lead.

So, normally above 1000 kv that is one million and above rated lightning impulse a voltage the dividers are equipped with the tower del rings. This is the corona control rings or a toroidal rings what we call for voltage level of one mega volt or one million volt and above for lightening and for switching impulses these are generally used. These electrodes are designed depending upon the rated values for lightening impulse and a negative switching impulse level which is a higher in compared to the positive switching levels.

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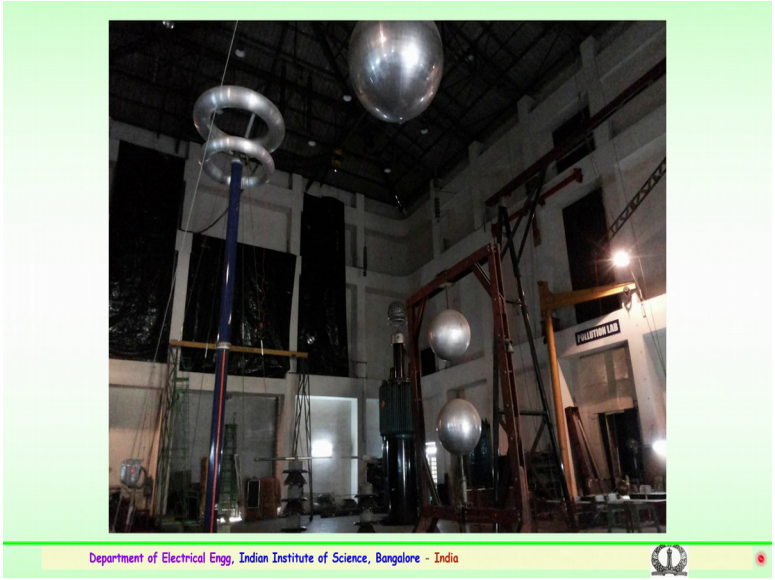

This are this is the damped capacitive impulse AC divider which is being used in our laboratory at the Indian institute of science where for measurement of very high impulse and AC voltages is measured using the divider.

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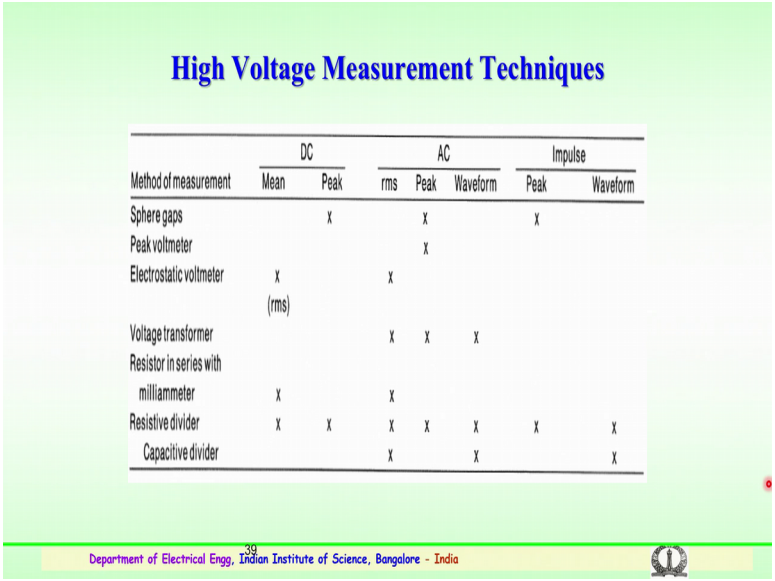

So, voltage measurement techniques various types are available, this table gives the information about the method of measurements either it is an average mean value or

peak value, similarly for this is for DC for AC it could be rms peak incase of impulse again it could be peak or the actual waveform which could be obtained.

So, here you can see this sphere gaps when used for the DC measurement will be given the peak values, similarly for AC peak values and for impulse peak value. So, sphere gaps are used for measurement of peak values. The peak voltmeter or electrostatic voltmeters are also the measuring devices used for high voltage measurements, here these peak voltmeters are basically used for the DC where it gives the var rms value in case of the measured values, and rms value for the AC or impulse electrostatic voltmeter are not used.

So, then we have pt or potential or voltage transformer which is typically used for the measurement of AC for both rms peak and for the waveform requirement. And we have a methods where we could connect resistors in series with a mille ammeter. So, that system or that arrangement method could be used for measuring the mean or the rms values in case of a DC rms value in incase of AC measurements. So, further we have a resistive divider which we have a just discussed or a capacitive divider or the combination of a damped capacitive type of dividers, these are generally used the measurements of DC AC and an impulse.

So, this dividers are of recent applications and could be used for a very large voltages where the accuracy level also is very high in comparison to the spear gap and other methods.

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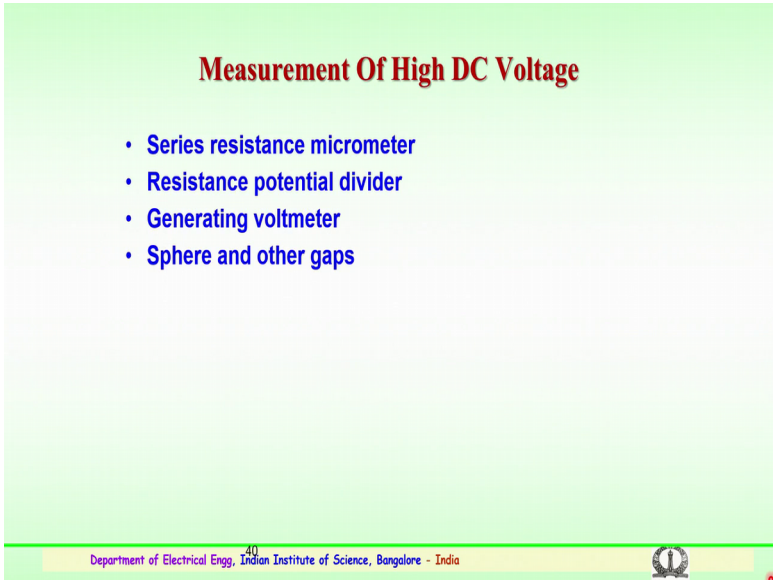

So, for measurement again of related to the high DC voltages, these are the methods which are generally used for the measurement. Series resistance or micrometer method where the number of resistances in series are connected with the help of micro ammeter where the measurements this method is used for measurement of DC.

The second is the resistance potential divider which is being used and third is generating voltmeter and the forth is sphere gap arrangement assembly.

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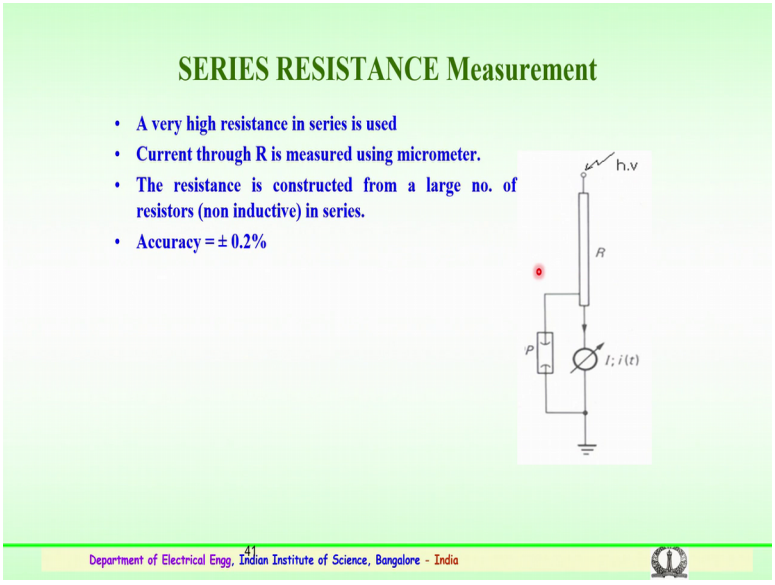

So, series resistance measurement is a simpler arrangement here you can see very high resistance this R is very high resistance is used. So, the current which is flowing through this resistor during the application of the voltage is measured using the micrometer which is a indicator micro ammeter which is used.

So, this resistance is generally constructed with a number of resisters in series and it is advisable to go in for non inductive type of resistors and the inductive affect should be reduced. So, the accuracy by results accuracy of results obtained by using the series resistance method could be between plus and minus 0.2 percent much better accuracy in comparison to the sphere gap assembly where it was three percent plus minus 3 percent.

So, the accuracy is much better in case of the series resistance method.

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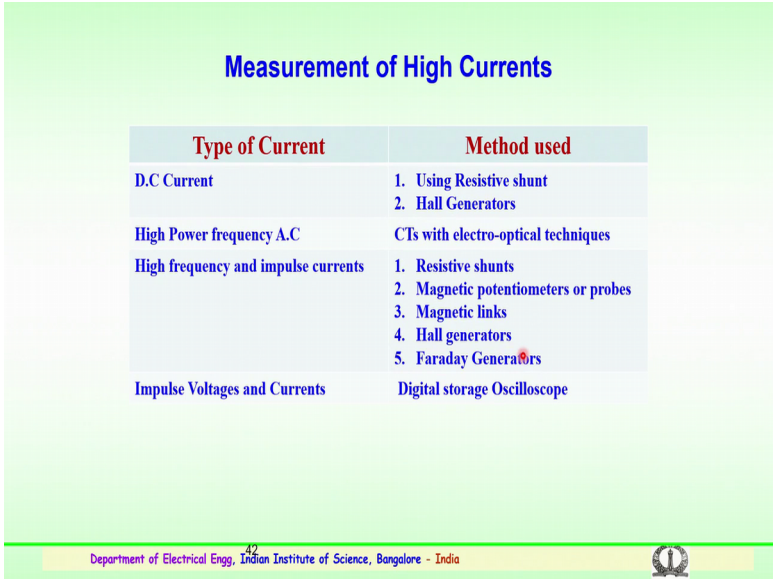

So, measurement of high currents so, type of currents and also the method which are used for high currents particularly. So, for the machine DC current resistive shunts are used hall generators, for high power frequency AC measurements current transformers with electro optical techniques are being followed and measurement have been done for high frequency and impulse currents.

So, we have a resistive shunts which is basically resistance which is connected in parallel with number of parallel options and it is use for measurement. The second is a magnetic potentiometers or the probes which could be used for high impulse currents, a magnetic

links again these are being to used for measurements of high currents, hall generators and faraday generators these are some of the methods which are being used in the for the high frequency the impulse current measurements. For impulse voltages and currents typically for the waveform requirement you can either use cathode oscilloscope or digital recent digital storage oscilloscopes, with necessary dividers so that the waveform can be seen and analyzed.

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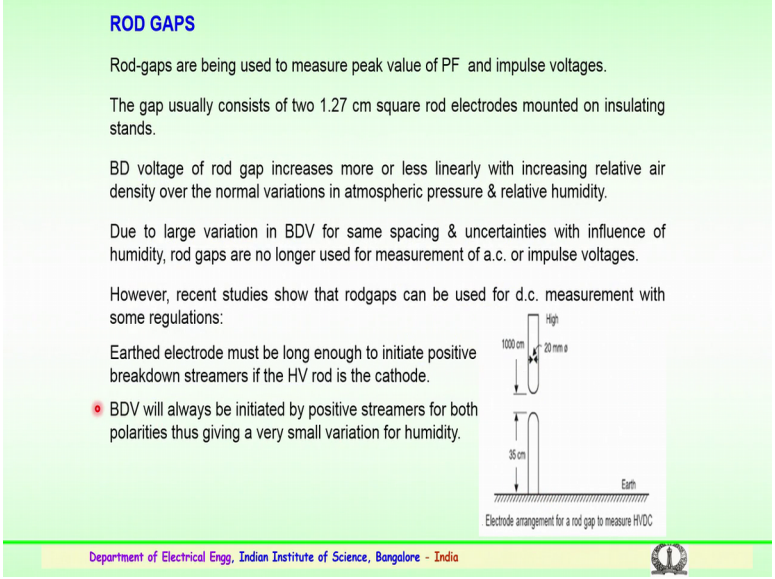

So, the rod gaps also have been introduce like the sphere gaps, we have discussed about the sphere gaps assembly for the measurement of high AC DC or impulse. Similarly rod gaps were also being used for measurement of peak voltages particularly for power frequency and impulse voltages. Here the gap usually consists of to a standard rods of square in diameter this rods a 1.27 centimeter again this is standard dimensions and mounted on a insulating stands as shown here.

Here the breakdown voltage of the rod gap assembly the voltage at a distance which is specified it could be yes or a minimum distance small d, the distance till the breakdown if the breakdown voltage of this rod gap increases more or less linearly with increasing relative air density that is observation over the normal variations in atmospheric pressure and relative humidity and because of the large variation in breakdown voltage from the same spacing. So, there could be difference it using this sphere gap large variation in the breakdown voltage and because of the uncertainties which could influence the like a

humidity on the rod gap which is being discussed are no longer used for measurement of AC or impulse voltages, because these give much more hedonics results and in the accuracy is not very good.

So, that is a reason where these are being this not used for AC or impulse voltages; however, a recent studies show that a rod gaps could be used for DC measurement with some regulations. So, that is being again being lot of experiments being conducted and towards the use of the DC measurement with rod gaps.

So, here one of the rod which is connected to the earth earthed electrode, here earthed electrode must long enough to initiate that is condition to initiate the positive breakdown streamers if the high voltage is a cathode. So, the breakdown voltage will always be initiated by the positive streamers from both the polarities, which give a very small variation in the humidity affect.

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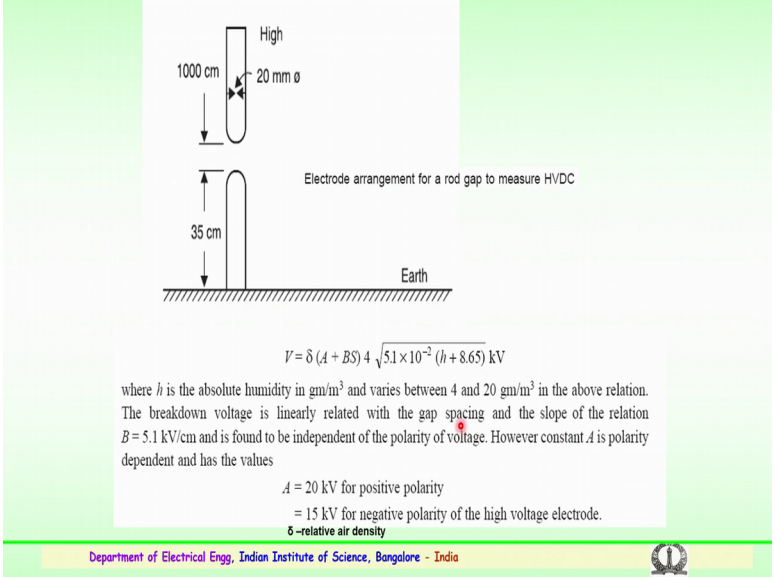

So, this is the typical arrangement as I shown for the rod gap here the voltage could be calculated as delta into A plus BS of 4 in to the square root of 5.1 into 10 to the power of minus 2 into h plus 8.65 kV where h is the absolute humidity in grams per miter cube and this vary between 4 to 20 grams per meter cube.

So, the breakdown voltage is linearly related with the gap spacing that is the gap spacing of the rods and the slope of the relation which is b is equal to 5.1 kV per centimeter is

found to be independent of the polarity of voltage. So however, the constant A which is shown in the equation depends and which is depended and has the values which are given here A could be equal to 20 kilovolts for positive polarity or it could be 15 kV per negative polarity of the high voltage electrodes which are used and delta being the air density relative air density fact.

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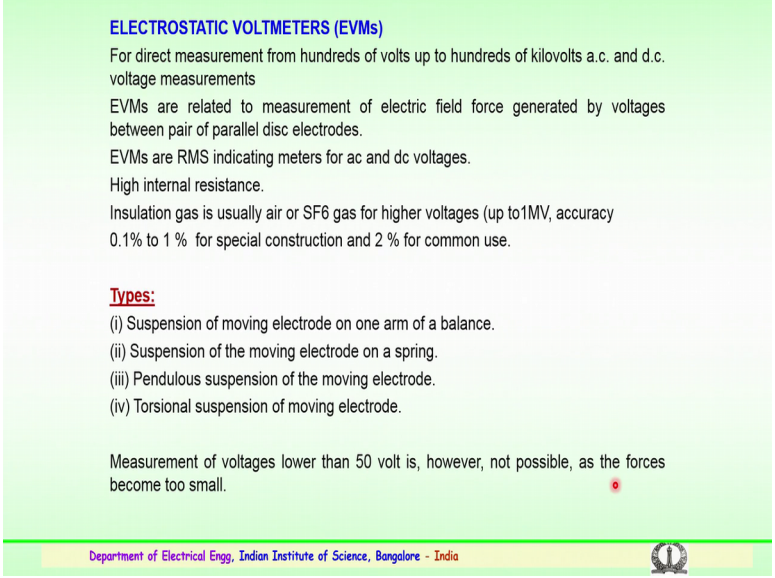

The next measurements for the high voltages AC and DC is electrostatic voltmeters, this electrostatic voltmeters are used for direct measurements ranging from 100s of volts up to 100s of kilovolts for AC and DC applications. So, electrostatic voltmeters are related to the measurement of electric field force which is generated by the voltages between pair of parallel disc electrodes. So, electrostatic voltmeters are basically the values which are obtained are in terms of RMS value, and these are indicating meters for AC and DC voltages. And this have a very high internal resistance and the insulation gas used is usually sulfur hexafluoride sf 6 gas or air in case of very high voltages sf 6 is normally employed up to one million volte.

And the accuracy which could be obtained by using the electrostatic voltmeters could be between 0.1 percent to 1 percent for special contraction and incase of normal construction it could be 2 percent accuracy could be seen. So, here there are the four types of electrostatic voltmeters which are being used one is the suspension or a moving electrode on one arm of a balance.

The second is the suspension of the moving electrode on a spring; the third is the pendulous suspension of the moving electrode and fourth is a torsional suspension of the moving electrode. So, measurement of voltages lower than 50 volts is very difficult it is not possible as the forces become too small and the values for lesser than 50 volts will be very difficult to measure with the help of electrostatic voltmeters.

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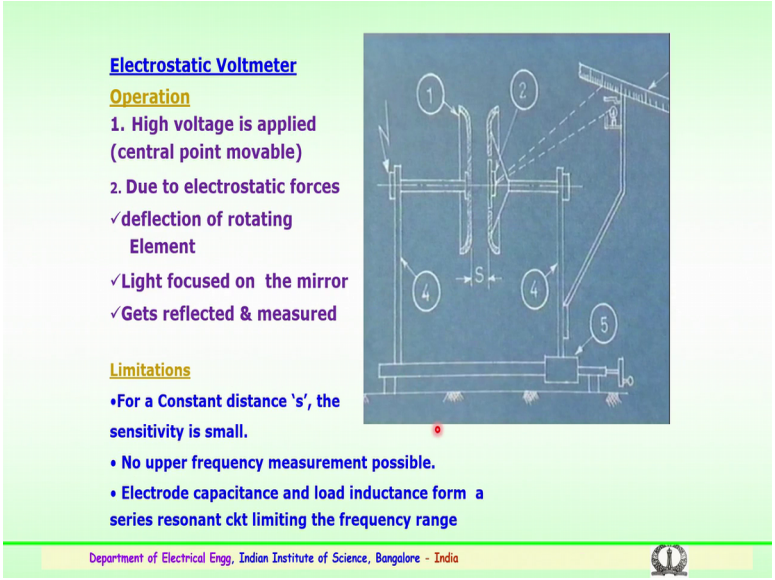

So, this is the typical arrangement of the electrostatic voltmeter which consists of an assembly, consisting of a as mentioned the two arms of the electrostatic plate type of arrangements here. So, you have a indicating scale a small mirror which is here because of the electrostatic forces which we developed this mirror reflects, and this is indicated in the scale this is how the simplest measurement is being done by using electrostatic voltmeter.

So, operation the high voltage is applied to the central point of the movable electrode here. So, due to the electrostatic forces the deflection this deflection here of the rotating element rotating element happens, and the light which is focused on the mirror the mirror is kept here gets reflected; here it gets reflected and this scale gives the measurement of the values which for a particular voltage, the deflection is obtained and that is been given in the measuring dial shunt.

So, these have some limitations. So, limitations are for a constant distance say this is being s here for a constant distance and the sensitivity could be very small, and no upper

frequency measurements are possible here that is point to be considered. In the third being the electrode capacitance the electrode which are used capacitance and the load inductance form a series or resonants circuit. So, limiting the frequency range, that is the point. So, it could cause resonance in the circuit and at the values at a limits the frequency range.

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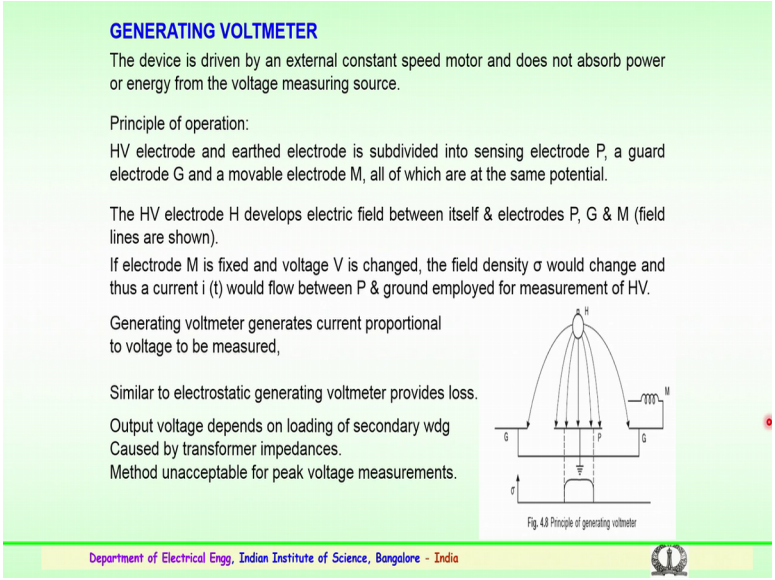

Third is the generating voltmeter again this is a device a which is a driven by the external constant a speed motor and does not observe any power or energy from the voltage measuring source, that is the important part of the generating voltmeter. So, principle operation being here the high voltage electrode and the earthed electrode here it is a earthed electrode is subdivided into sensing electrode which is as shown here which is known as P and a guard electrode here it is a guard electrode both the ends, and a moveable electrode M here you can see the movable electrode M.

So, P is the sensing electrode, guard electrode and the moveable electrode as shown all of which are at the same potential. So, when the high voltage electrode develops electric field between itself that is a P G that is a guard electrode and the moveable electrode, the field lines has as shown here these are the field lines which are shown. If electrode M here M is fixed and the voltage which is applied is changed varied and the field intensity that is the sigma which is shown here in the y axis, this field intensity would change you can see the variations acting depending upon the voltage level and a current I of t will

flow between the P that is a P and the grounded. This from here to here there will be a flow of a current and which is used for measurement of high voltages.

So, generating voltmeters generate current proportional to the voltage to be measured. So, this has to be kept in a considered. So, similarly to electrostatic generating voltmeter provide a loss here also loss are observed, output voltage again depends on the loading of the secondary winding which is caused by the transformer impedance. So, depends on the transformer type of transformer which is employed for the generating voltmeters and this method it could not be used for peak voltage measurements it cannot be used for peak.

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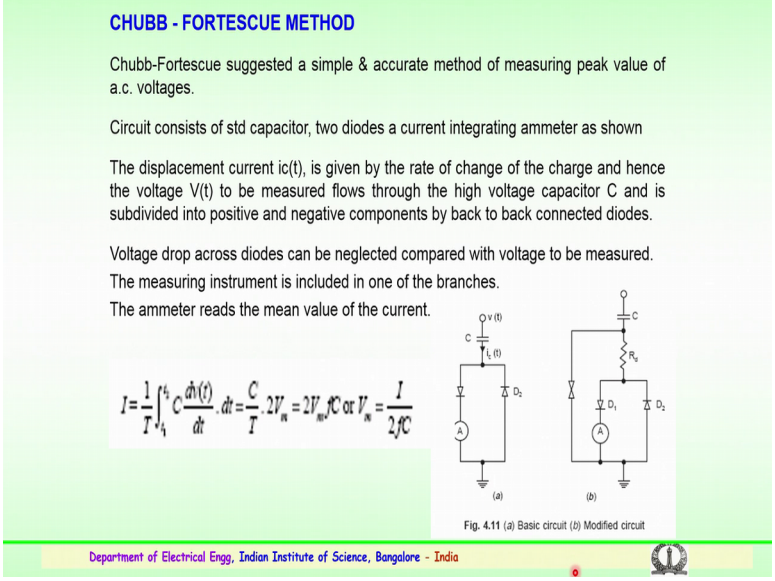

The important and very economical method of measuring the values is Chubb and Fortescue method a famous method; chubb and fortescue suggested a simple and most accurate higher accurate method for measuring peak value of AC voltages, this is in comparison to the sphere gap and other methods this is much more accurate.

So, this basically circuit consists of a stranded capacitor as shown here, two diodes which are connected here and the current integrating ammeter. Ammeter is again shown here. So, the displacement current particularly the I C of T from the capacitor when voltages is applied is given by the rate of change of the charge, and hence the voltage v of t which is to be measured flows through this high voltage capacitor and is divided into

positive and negative components through the help of this back to back connected diodes.

And the voltage drop across these two diodes could be neglected because it is very very small which comparison to the measured voltages. So, the measuring instrument that is a ammeter is included in one of the branches and this ammeter reads the average or a mean value of the current which is passing through there. So, this average value of the current is given by 1 by T integral of T 1 l to T, 2 C dV by dt into dt which is equivalent to C by T into 2 Vm that is equal to 2 V m f is a frequency C or Vm is equal to I by 2 f C is a value which is to measured.

So, this is the modified circuit using a small a resistance after the capacitor, the diodes being the same with the protection fuse unit why it is important here we will just see about the point.

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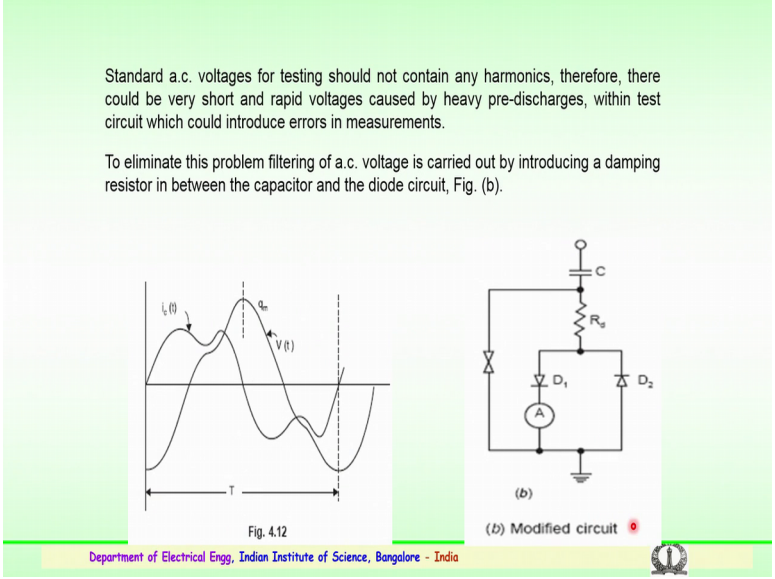

So, for standard AC voltages for testing should not contain any harmonics therefore, there could be very short and rapid raise of voltages which can cause a heavy pre discharges, within the test circuit which could introduce error in the measurement.

So, to eliminate these disturbances or pre a discharge, a filtering of the AC voltage is carried out by introducing a small a damping a resistor in between the capacitor and the diode circuit which is the shown here. So, this is the Chubb and Fortescue arrangement

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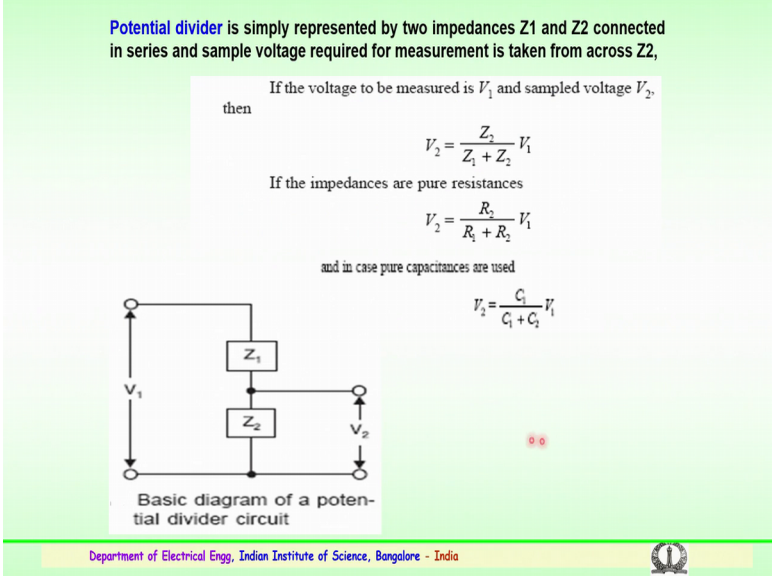

Then simplest divider is the potential divider, and this is the simply represented by two impedances or two resistance is which are shown Z 1 and Z 2 voltage is applied here Z 1 being the very high value Z 2 being the lower value in comparison to the Z 1 that is a resistance could be very low here it is very high.

So, this potential divider is connected in a series and sample voltage required for measurement could be tapped from across the Z 2 which is taken across the. So, in case of the voltage is to be measured that is the voltage which is a applied V 1, the sample voltage that is the V 2 here voltage of trend across the Z 2 could be got by using V 2 is equal to Z 2 that is a by Z 1 plus Z 2 in to V 1, and if the impedances are pure resistances whatever Z 1 if it is only resistors then the V 2 is given by the formalae R2 divided by R1 plus R2 into V 1.

So, this is how the ratio or value could be obtained and if case of instead of using the resistors if capacitors are used. So, incase of pure capacitance then V 2 will be equivalent to C 1 that is a lower capacitor by C 1 by C 1 plus C 2 into V1.

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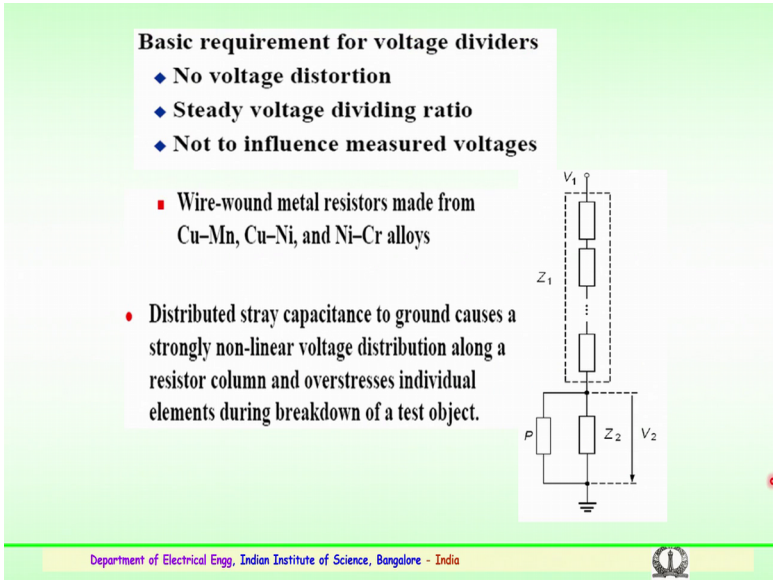

So, basic requirement for voltage dividers which are used for measurement importance is no voltage distortion should happen, there should be study voltage dividing ratio and they should not influence the measured voltages for that a wire wound or a metal resistors made from copper magnesium or copper nickel or nickel chromium alloys are generally used. And here the distributed stray capacitances, stray capacitances from the divider to the metallic object to the tower to the ground, or any other source have to be avoided. So, this stray capacitance ground causes strongly non-linear voltage distribution along the resistor column and the over stress individual element that is a number of unit which are connected will be overstress.

So, we have to eliminate we have to reduce this and suitably the distribution should be uniform.

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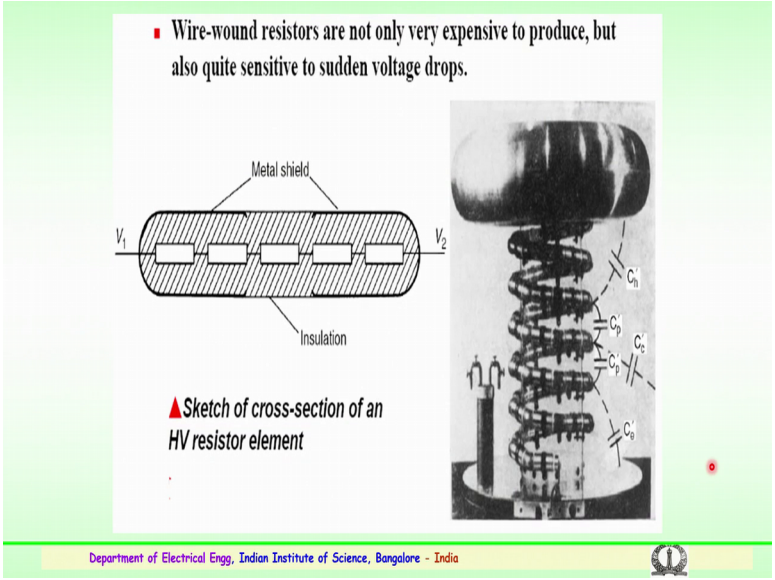

So, for that wire wound resistors are not only expensive to be used to produce, but also quite sensitive to sudden voltages, that is the reason it is being tried with using the metal shield where this is a cross section of one of the high voltage resistor element number of resistors and where it is a resistor divider is built in such a way that the stray capacitances have to taken care you can see the stray capacitance from the ground are between the units and between the metallic objects that is the top most of the conductor. So, these have to be eliminated so that the divider gives the accurate values.