Advances in UHV Transmission and Distribution
Prof. B Subba Reddy
Department of High Voltage Engg (Electrical Engineering)
Indian Institute of Science, Bangalore

Lecture – 09
Importance of High Voltage testing and techniques employed

Continuing with the reliability and testing aspects for the insulation, we have two types of a High Voltage testing techniques.

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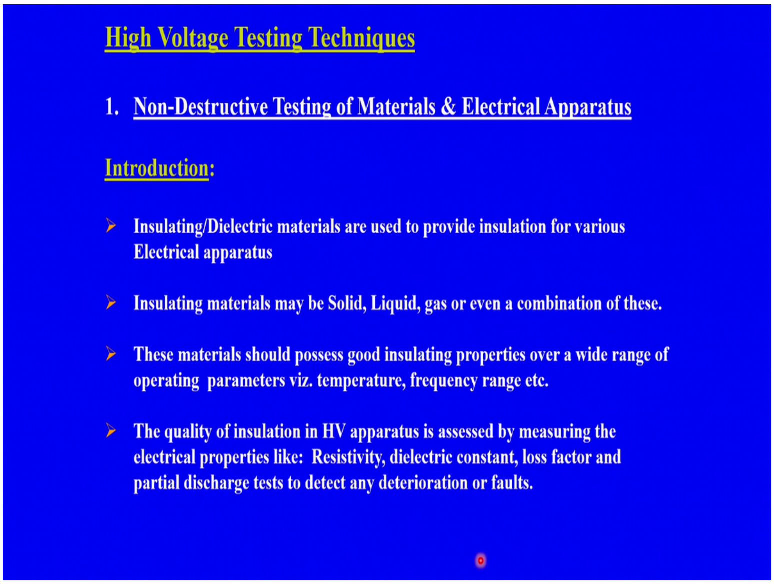

One is the Non-destructive type for particularly for the materials and electrical apparatus, another being the type testing for various equipments. So, the non-destructive testing of materials are basically use to provide the insulation for various electrical apparatus. Insulating materials, which are used for the transmission may be of a solid like insulators, a liquid used for transformer oil, gas; gas may be sulphuric (Refer Time: 01:03) in case of s of 6; related switch gear or even a combination of these.

These materials should possess good insulating properties over a wide range of operating parameters; namely temperature, frequency, range etcetera. The quality of insulation particularly in any high voltage apparatus is assessed by measuring the electrical properties like the resistivity, a dielectric constant, loss factor or tan delta, partial discharge to deduct any deterioration or faults exist in the materials.

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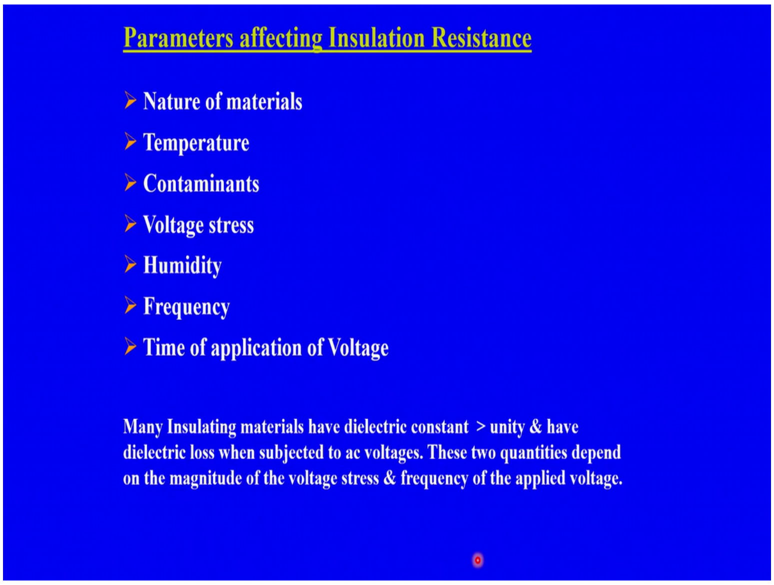

So, the parameters which could affect the insulation or resistance in the; are the nature of materials which are being employed for the insulation. The temperature at the operating of the material; in the field, any contaminants, the voltage stress or the voltage at which the material is subjected; the voltage stress, the environmental conditions like the humidity and the frequency of the voltage applied voltage; that is the AC or DC and the time of application of voltage, how long the material has to sustain over a field of application of voltage.

So, we have many insulating materials have different; have dielectric constant usually greater than unity and have a dielectric loss when subjected to AC voltages. So, these two quantities particularly depend on the magnitude of the voltage stress and the frequency of applied voltage, so two important factors to be noted here.

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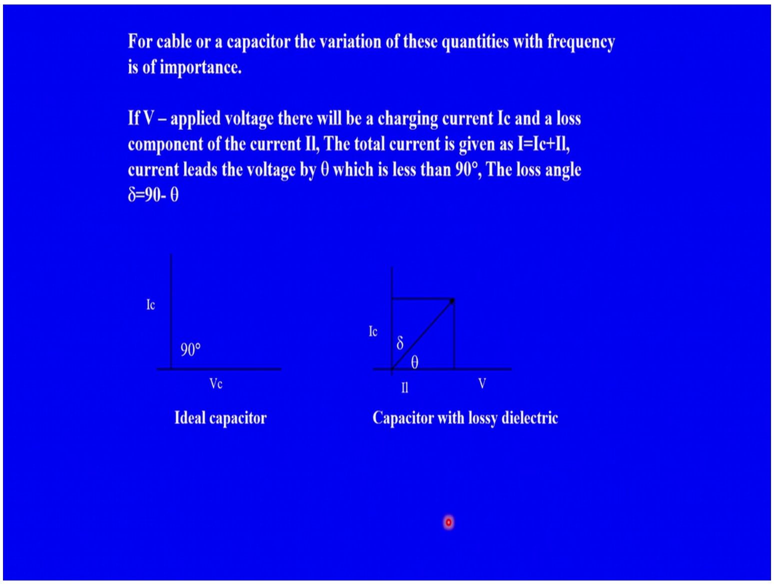

So, for a capacitor or a cable; the variation of the quantities, the applied frequency and the voltage is of importance. So, if in case considering a viewing the applied voltage there will be a charging current; consider here the charging current which is shown here I s, I c charging current for I c and a loss component of the current; the loss component of the current is Il; Il is shown here; Il is a loss component.

The total current is given by the charging current plus the loss component; that is I is equal to Ic plus Il; the current leads the voltage as you see here. The current leads the voltage by a 0, a theta which is less than 90 degrees here you can see here, it is less than 90 degrees. The loss angle that is the delta which is shown here is the difference that is a 90 minus theta, this gives the loss angle for any a capacitor having a lossy dielectrics. This is an ideal capacitor, in ideal capacitor there will be a no loss component existing for a capacitor with a lossy dielectric, this is how or component or a loss component do exist.

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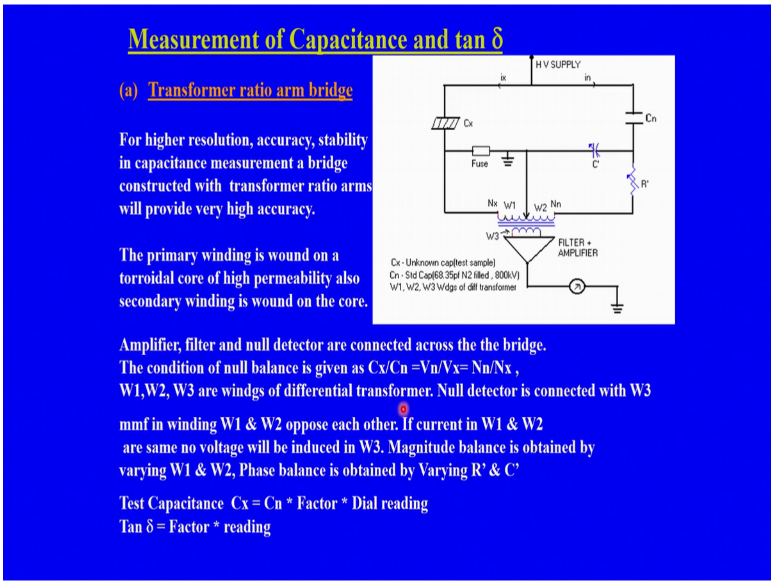

So, for this you require to measure the capacitance and tan delta of equipment or a material or for the verification. So, for the capacitance and tan delta measurement there are several measuring equipments which are being employed. One such equipment being the transformer ratio arm bridge, so for higher resolution; particularly for higher resolution, the accuracy, the stability for the capacitance and measurement a bridge constructed with transformer a ratio arms; will provide a very high accuracy. That is one of the reason the transformer ratio arm bridge is used to measure the capacitance and tan delta.

With primary winding, here you have the windings of the transformer which is shown here; these are the various components Cn being the standard capacitor, then Cx being the capacitor to be a measured or protection is a fuse unit here then R and the capacitance which can be attuned are put as a variable capacitance resister here. Then we have a three windings W 1, W2 and W 3; Cx being the unknown capacitance Cn is the standard capacitance W 1, W2 and W3 are the windings of a differential transformer.

So, we have a filter plus a transformer here again a meter which is connected, so here the primary winding particularly is wound on a toroidal core of high permeability and also the second rewinding is wound on a core of high permeability. The amplifier, the filter and the null detector which is shown here are connected across the bridge. The condition for the balance that is the null balance is simply given by the Cx by Cn is equal to Vn by

Vx that is equal to Nn by Nx. So, Cx is nothing, but the unknown capacitance of the test sample, Cn is the standard capacitance.

So, Vn is a known voltage across that, Vx is the unknown voltage, Nn is the winding of the transformer W1, 2 and Nx is the winding side of W1. So, where W1, W2, W3 are the windings of the differential transformer shown here; the null detector is connected with W3 winding, you can see here. So, the m m f in the winding of W1 and W2 oppose each other, if current in W1 and W2 are same; so, no voltage will be induced in W3 in case both are same. So, the magnitude balance of the voltage is obtained by varying either W1 or W2; and in case for the phase to obtain the phase balance; this could be made by varying the variable resistance and variable capacitance which are in the circuit.

So, for phase balance variation of R and C could be used and for the magnitude balance, we could use W1 and W2 windings. So, the test capacitance that is a capacitance or a unknown capacitance which is being connected, which is to be found can be a estimated with a standard capacitor; that is a Cn into the factor, the multiplication factor where exactly the multiplying factor for the; which is being in the set into the reading; that is a reading which we have obtained. Now, during the measurement with the adjustments of W1, W2 and R and C.

So, these dial readings which are appearing on the transformer ratio bridge will help to get the test capacitance. Similarly, tan delta, the loss delta factor could be measured with actual multiplication factor into the reading which is being obtained on the meter after the null detector has been achieved. So, this is how a simple method of measurement of capacitance and tan delta for the equipment is carried out in the laboratories. There are several other bridges which also will help in measuring the capacitance and tan delta.

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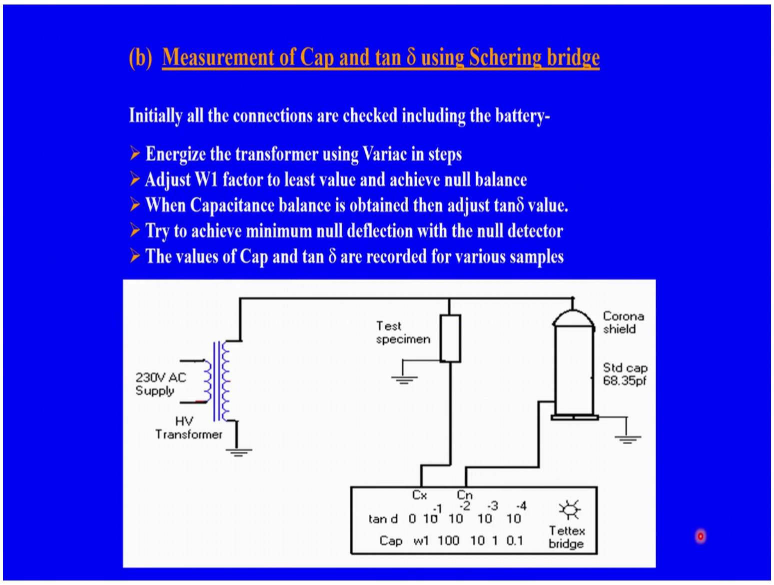

This is again a second type of bridge for like a transformer ratio arm bridge, which is known as a Schering bridge; here transformer high voltage transformer, again the test specimen which is to be measured the capacitance; is to be measured and again is connected here. The Cn being the standard capacitor in here, in present case; the standard capacitor being 68.35 picofarad with a hydrogen filled insulating media.

So, this is employed here for the measurement; so, what is initially all the connections are verified including the battery for the bridge which is a Tettex bridge for a measurement. So, we have to energize the transformer using the (Refer Time: 10:38) stat or a variac in steps and adjust W1 factor, so where W1 is here the tan delta factor is here for the capacitance we have here various readings 100, 10, 1, 0.1 and so on and so forth.

So, we have to adjust a factor to least value and how to achieve a null balance in the meter which is being used. So, when capacitance balance is to obtained; then the adjust tan delta value. First, initially we have to obtain the capacitance balance; further we do the adjustments for the tan delta value. Try to achieve a minimum null deflection, so that is important; with the null detector. The values of capacitance and tan delta could be recorded for various samples or tester specimen in the circuit. This is again the simplest bridge which is used in the laboratories for a measurement of capacitance and tan delta.

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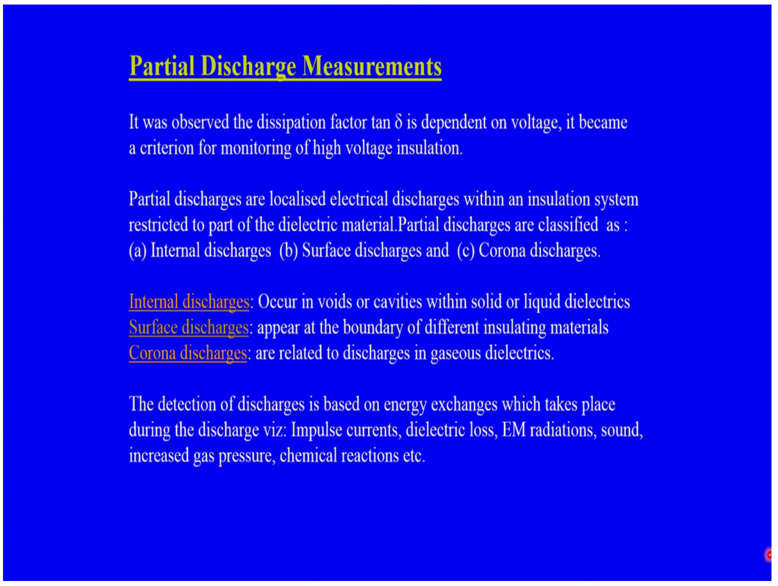

Further, partial discharge measurements is a very important for the cable insulation and many of the equipments like transformer and so on, where this discharges over in the long period on service could deteriorate the insulation of the equipment or the material. So, it was observed that the disputation factor or the tan delta loss component is dependent on voltage. So, it became a criteria for monitoring of high voltage insulation, so taking into consideration, the partial discharges are to be measured.

So, this is what is a partial discharge; so partial discharges are basically the localized electrical discharges within an insulation system because of the electrical stress and they are restricted to part of dielectric material. The partial discharges could be classified as; the internal discharges, internal discharges are the discharges which are occurring inside the insulation or the surface discharges could be on the surface of the (Refer Time: 12:58) material or an equipment and the third being the corona discharges.

So, these are three different types of a; partial discharges which are classified. So what are this, how the internal discharges occur, so internal discharges do occur in particularly in voids or cavities; a small, a blow holes or there is a void in an insulation particularly in solid insulation like the cable or in the transformer there are small void insulating bubbles where the; or because of the insulation on the transformer winding, if there are a voids the discharges could be an internal type of discharges. This could be in solid or liquid dielectrics, so that is a liquid insulating materials. The surface discharges; the surface discharges normally appear at the boundary of different; on the surface of in insulating material. So, these discharges could be again degraded the insulation in the period of service.

The third being the corona discharges, a corona discharges are related to the gaseous dielectrics; particularly the gaseous dielectrics wherever the gaseous media is being used as a insulating a medium. So, gas corona discharges do occur, so these are supposed to be measured and these are to be contained for the better performance of the insulating a materials or the equipment. So, the detection of these discharges internal surface, partial discharge what we call is based on energy exchange which usually takes place during the discharge.

That is namely: impulse, currents, dielectric loss, electromagnetic radiations; maybe because of the sound, increased gas pressure or due to the chemical reactions which are happening like in the equipment of a transformer and so on.

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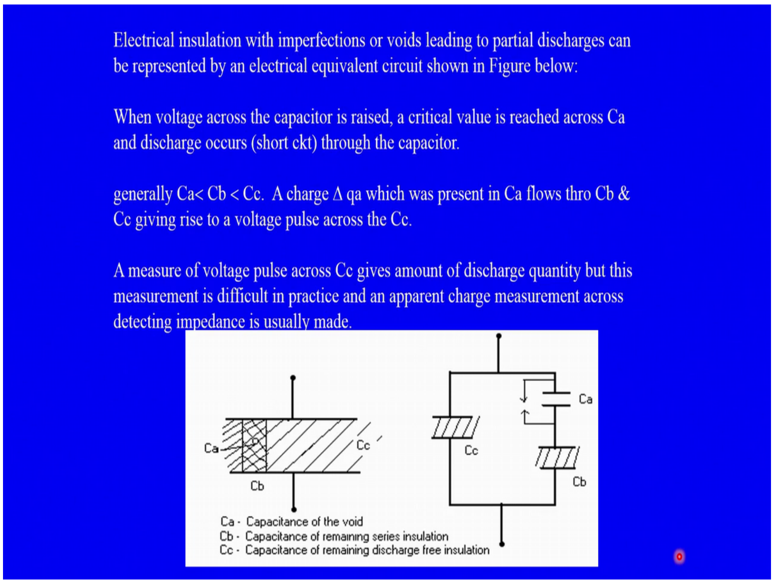

So, these measurements have to be carried out at regular intervals and to check the healthiness of the equipment which is in service. How partial discharges or estimated or calculated, so in electrical insulation with any imperfections; which is not properly done or has containing a voids, this could lead to partial discharges this is; in case of a insulating material could be represented by an equivalent circuit simple equivalent circuit as shown in the figure a below here.

So, this Cc is the Cc, Ca and Cb; Ca is the capacitance of the void which is assumed or any imperfections which are existing in insulating material. Cb being the capacitance which is of the remaining series insulation along with Ca, then Cc is the remaining discharge for a insulation like if you consider is Ca is a small void, where the capacitance of the void; Cb is the total insulation, including the void and surrounding; the Cc being the series insulation of the material. So, this is a represented as a simple equivalent circuit.

So, when voltage is applied across the capacitor terminals a critical value is reached across Ca; this small capacitance the critical value is reached and a discharge occurs in this void or what we call a short circuit, the breakdown of the void take place through the small Ca capacitor. So, generally Ca; the capacitance of the void is less than the capacitance surrounding the void which is being mentioned as Cb, would be less than the capacitance of the entire in series which is available.

So, a charge; a small charge quantum a very little charge which is accumulated or when discharge happens in the Ca, which is known as Qa; which was earlier present in Ca, flows through Cb that is from the Ca, it flows through Cb then goes to Cc giving rise to a voltage pulse across Cc, when we measure the voltage pulse across; a small pulse is a generated which is small charge emitting from the void termed as capacitance Ca. So, measure of voltage pulse across Cc; gives amount of discharge quantity which was a present in the void, but this measurement is a difficult in practice.

So, an apparent charge measurement across the detecting impedance is usually a conducted in the laboratory because estimating or directly measuring this, it is not an easy task. So, an apparent measurement charge measurement is normally followed in the laboratories to measure the partial discharges.

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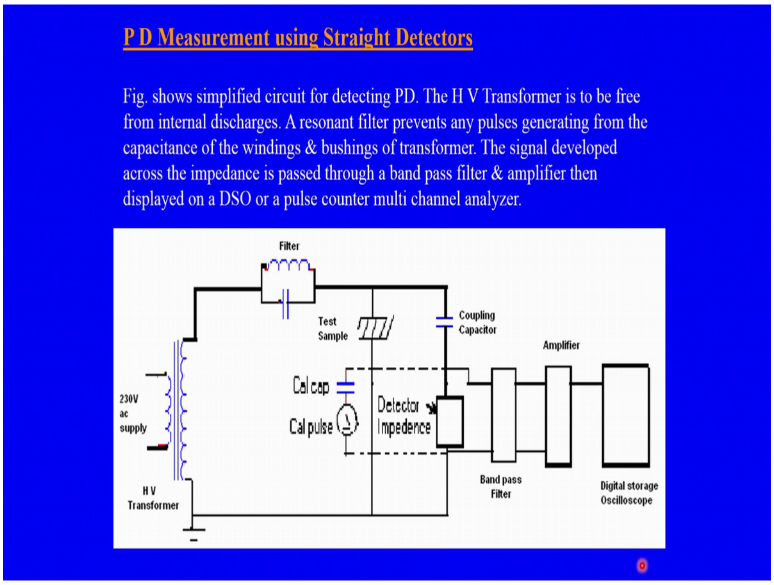

So, how the circuit looks partial discharge measurement, there are different partial discharge detectors which are being employed by the utilities or the laboratories where the equipment is being tested or the partial discharge measurements are being carried out. So, for partial discharge measurement you should have a laboratory without any interference and the circuit details are shown here for the measurement.

You see the transformer; high voltage transformer, you have a filter which is tuned to a particular frequency then this is the test a sample which is to be measured for the partial discharges, it could be a cable, it could be a transformer, it could be any other material where partial discharge has to be tested.

Then you have a calibration capacitor and a calibration pulse arrangement to calibrate the required pulse. Then you have a coupling capacitor at high frequencies, this tries to see the discharges which are from the sample could be a communicated through the detector impedance and further from the detector impedance, this it is connected to the band pass filter, again the signal is amplified and it is being monitored in the digital storage oscilloscope finally.

So, the filter the resonant filter prevents important function of the filter is to prevent any pulses or any discharges generating from the capacitance of the winding, for the high voltage winding. These discharges which are energized at that voltage, should not communicate, should not pass to the sample. So, that is one of the reason where filter blocks the discharges from the transformer and it prevents the pulses or the discharges going towards the test sample and also the bushing of the transformer or the transformer bushing or the windings could lead to the discharges; this has to be prevented. That is one of the reason, where the filter acts as a; to prevent the discharges further communicate into would the sample.

The signal developed across the impedance; across this impedance when the measurements is been carried out, this is further passed through the band pass, filter, amplifier and then displayed on the (Refer Time: 21:17) or pulse counter, digital storage oscilloscope or a multi channel analyzer. So, several of this combinations could be used to accurately measure the discharges which are happening in the sample which is under test or under measurement.

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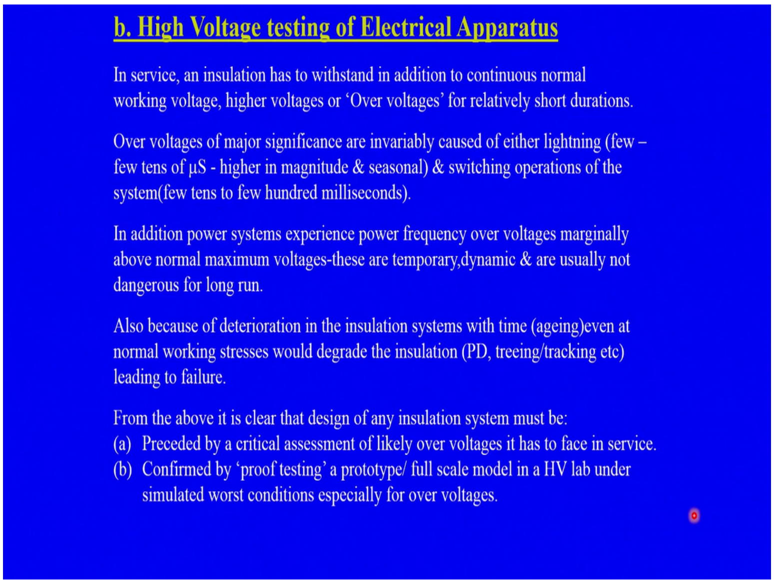

So, that was about the non-destructive type of measurements which are to be carried out for the insulation. We look into the high voltage testing of various apparatus, this is essential as in service an insulation has to withstand in addition to continuous normal voltages, sometimes higher voltages or over voltages for a short durations.

So, over voltages of major significance are invariably caused either due to lighting which could exist for a period of few 10's of microseconds, higher in magnitude and it could be seasonal only a monsoon season so on and switching operations of the system could lead to switching surges. This switching surges; could be of few 10's to few 100's of milliseconds, so these are the over voltages which are likely to cause the insulation to withstand or to see that it has to be withstand to these surges.

So, in addition apart from this lightning and switching surges; power system could experience, normal power frequency that is a 50 hertz; over voltages marginally, above normal maximum voltages, this could be temporary; this may be because of dynamic some problems related to the network and are also usually not dangerous for a long run, this could exist for few cycles where the over voltages could go up.

So also because of deterioration in the insulation, so not only power frequency slightly switching, it is because the insulation will be continuously in the service. So, this could deteriorate over a period of time or what we call it as a ageing; even under normal working stresses without effecting the lightning or a switching surges. So, under normal working conditions because ageing with time; the insulation could deteriorate and they would degrade the insulation, this could degrade the insulation where the phenomenal like the partial discharges, treeing or tracking could be a; you could come across such, on the insulating a materials, this could further lead to the failure of insulation.

So, for proper measurements; these have to be taken care and the insulation has to be verified at regular intervals. So from the above, it is clear that design of any insulation system must be preceded by a critical assessment of lightly over voltages, could be lightning switching or related power frequency voltages. It has to face in service, this should be confirmed; the insulation should be confirmed by proof testing or some cases of prototype and or full scale model. So, depending upon the confirmation which is to be carried out in any high voltage laboratory under the simulated worst conditions; especially particularly for over voltages has to be carried out.