① Characteristics and generation of impulse Voltage:-

Parameters of high voltage Impulse:-

for testing high voltage apparatus, several wave shape of the high voltage test impulses are standardised. In addition to switching and lightning impulse voltages with aperiodic waveform, oscillating switching and lightning impulse voltages, which are generated by transportable generators for one site tests, are also standised. Lightning impulse voltages are again subdivided into full and chopped lightning impulse voltages, with the chopping occuring at widely variable times.

Impulse voltages with an approximately linear rise are designated wedge-shaped and those with a very steep front as steep front impulse voltages.

Lightning Impulse voltage:-

The electrical strength of high voltage apparatus against external overvoltages that can appear in power supply systems due to lightning strokes is tested with lightning impulse voltages. One differentiates thereby between full and chopped lightning impulse voltages. A standard full lightning impulse voltage rises to its peak value v in less than a few μseconds

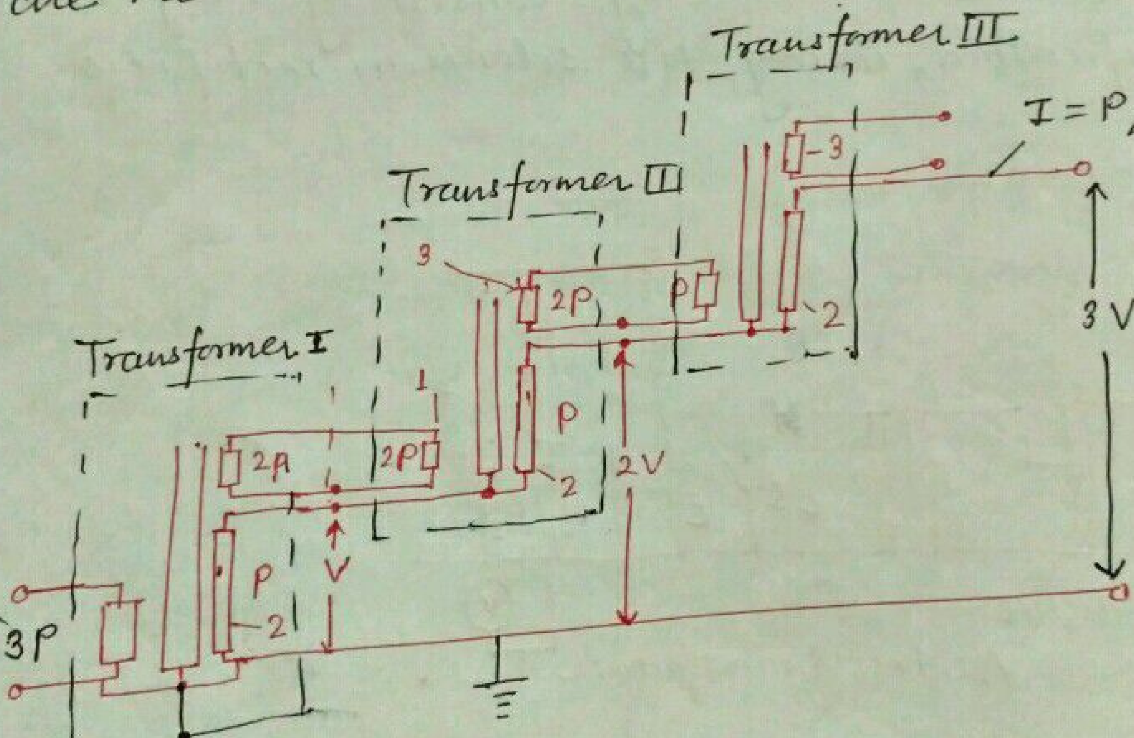
(a) Electrical Design Aspects :-

Electrical design of ac overhead transmiss line involves the following designing asp

1. Power transfer ability i.e. howmuch power be transferred.
2. Transient stability limit and dynamic perfo nce studies.
3. Choice of rated voltage for new transmiss lines.
4. Voltage control and reactive power compensation voltage regulation.
5. Power transfer controllability for tie-lines and ac lines.
6. Choice of conductor, corona rings.
7. Transmission loss and efficiency.
8. Corona, radio interference, TV interference and audible noise.
9. Biological effects of electromagnetic field at working level on the ground, below maximum sag point.
10. Insulation coordination and overvoltage studies, surge arrester protection.
11. Design of insulators, creepage distance, clearance and grading gap.

Test transformers can be used in cascade connections. Each unit has 3 windings: a primary (low voltage), a secondary (high voltage) and a tertiary (low voltage) winding. The tertiary has the same rating as the primary winding.

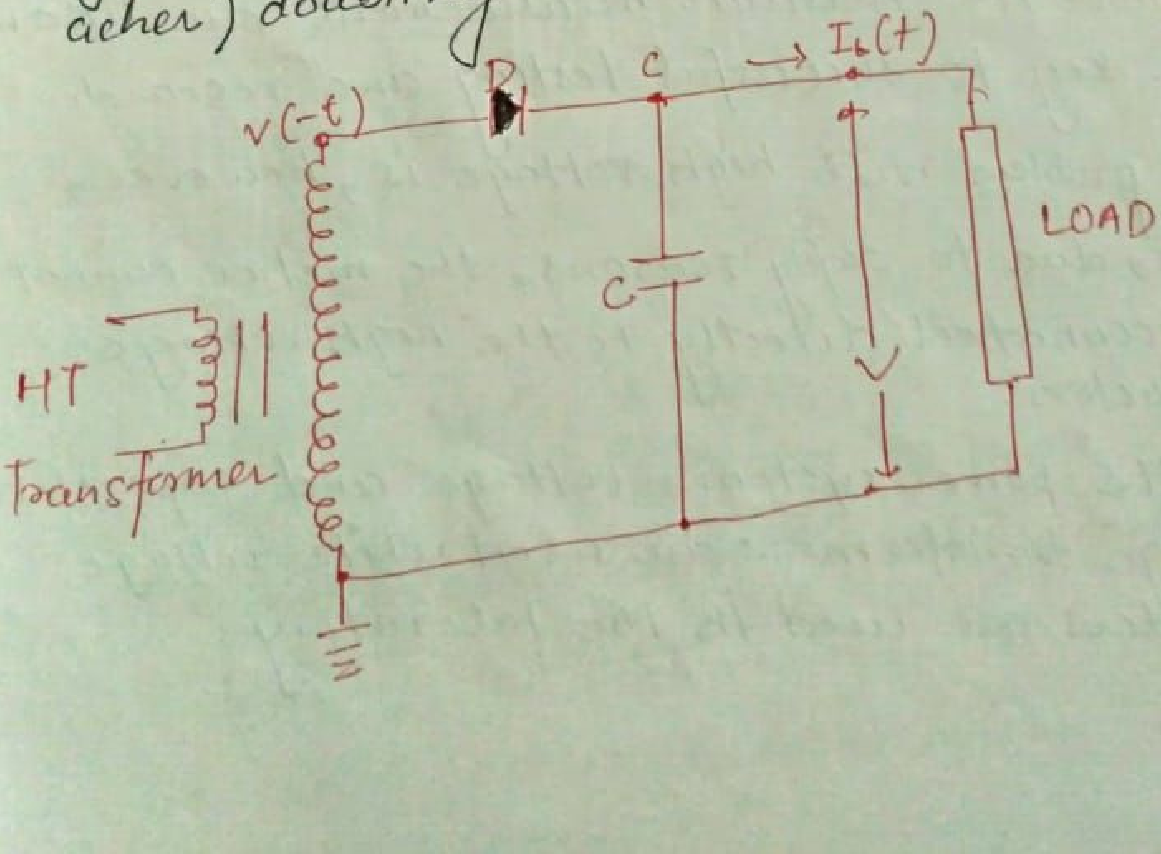
Tertiary winding is used to supply the primary of the next unit. The tanks of the second and third units are insulated for high voltage and are mounted on insulators.

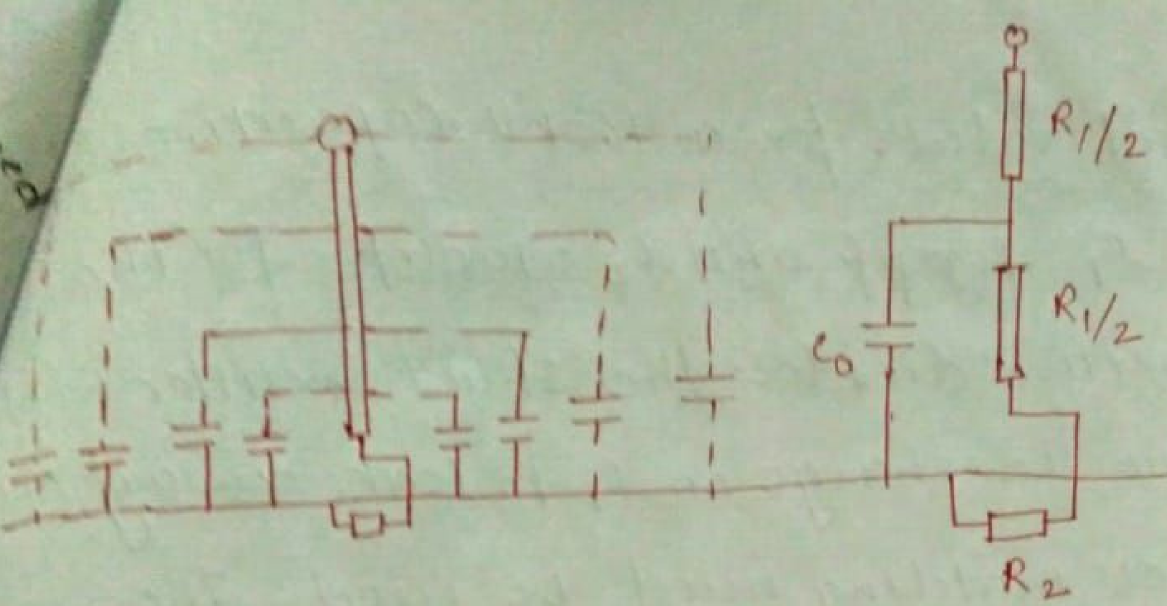


The method when performing AC tests is to increase the voltage gradually until flashover occurs. The voltage just before flashover is the flashover voltage

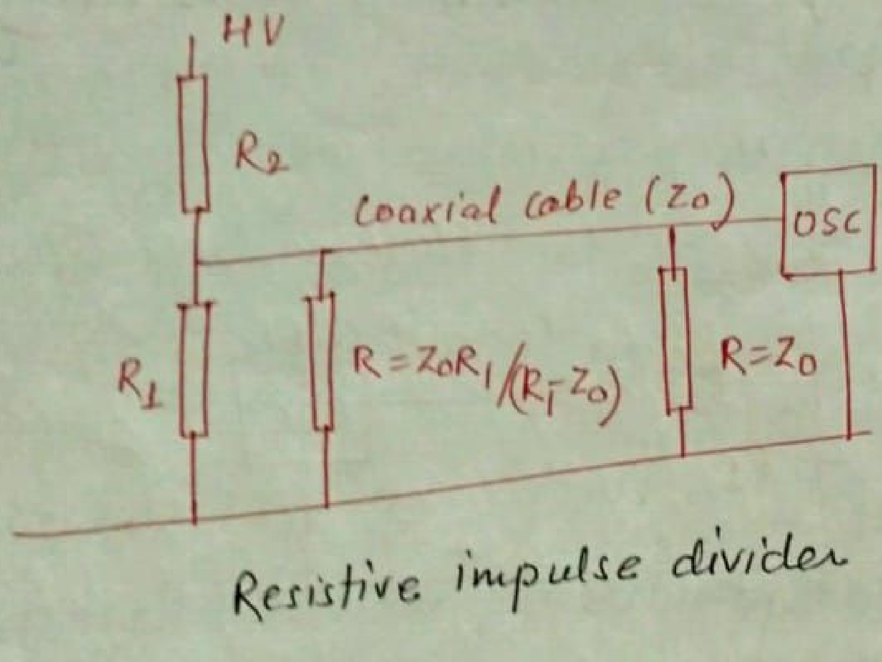
An AC high voltage test transformer is again supplied via a vauiac and a rectifier is used together with a filter capacitor C to limit the ripple to acceptable values. The earthing switch Es is a safety feature and closes automatically when the power is switched off to discharge the capacitor C. Note that the peak inverse voltage required of the rectifier is 2Vm.

Doubling and multiplier circuits (as used in TV's and household appliances) are also used to obtain an even higher voltage. A typical Cockcroft-walton (in Germany: Grein acher) doubling circuit.





Note that the coaxial cable must be terminated in its characteristic impedance at both ends,



Resistive impulse divider

Capacitive Impulse Divider :-

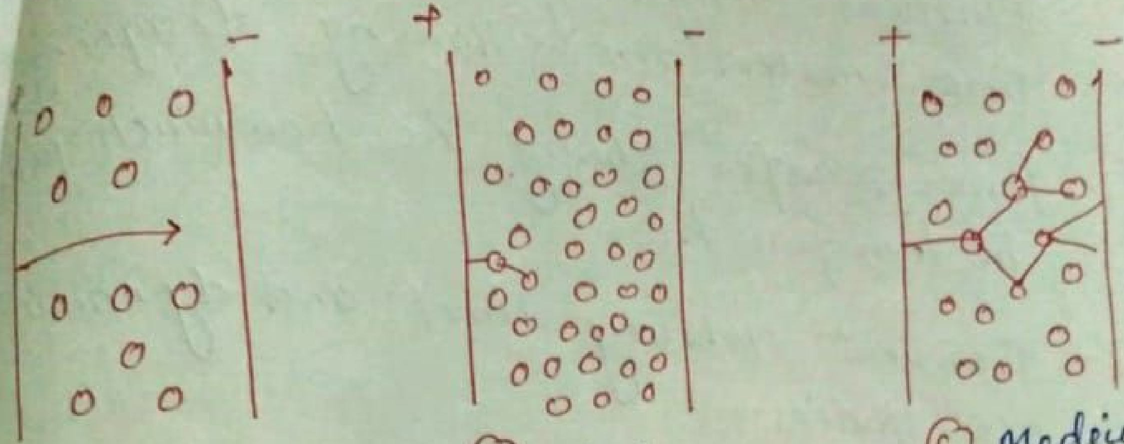
In the case of a capacitive divider the stray capacitances are usually negligible, compared to the capacitance values of the divider.

= 101,3 kPa = 760 mm Hg) and temperature (20°C), breakdown occurs at a field strength of approximately 30 kV/cm. In these gaps the Townsend flashover mechanism prevails.

At lower pressures the gas molecules are less densely packed and the mean free path between collisions is longer. The electrons therefore attain higher speeds before colliding with the gas molecules, resulting in a lower flashover stress for the same gap.

At very low pressures, such as used in vacuum contactors, the gas atoms are so far apart that the collision probability is low, with the result that ionization and flashover takes place at a much higher value. The ionization coefficient α is an indication of the ionization probability of a gas and depends on the applied field strength E and the gas pressure p. This dependence can be

$E_a = 30 + 1.35/d$



(a) Low pressure (few collision low ionization

(b) High pressure (low kinetic energy: low ionization

(c) Medium pressure (optimal: high ionization)

Paschen's law indicates that there exists a relationship between the flashover voltage, the gap length and the gas density.

Consideration for design of EHV lines under steady state conditions:-

EHV lines design under steady state condition depends upon three main aspects.

(a) Electrical design aspects
(b) Mechanical design aspects
(c) Thermal design aspects.

ightning phenomenon and overvoltage overhead shielding wire.

protective relaying of transmission lines.

Busbar layout in substations.

Electrical tests.

Safety

- Reliability, availability etc.

Mechanical and structural Design Aspects:-

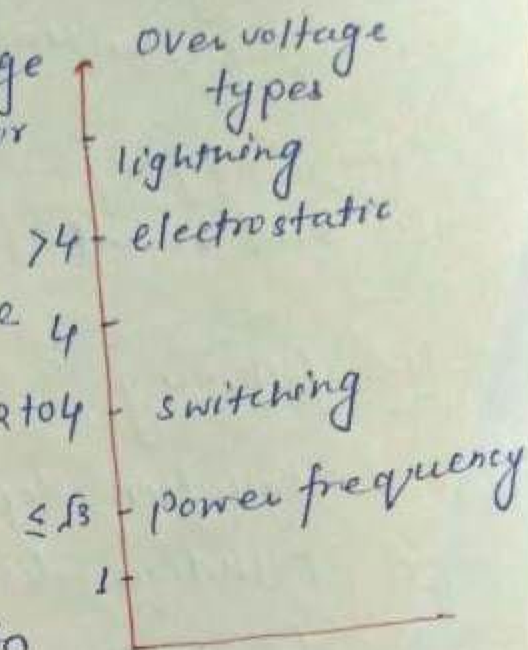
The transmission line involves civil, mechanical and structural design aspects as follows.

1. Structure design; choice of configuration of towers, insulators and conductors.
2. Mechanical loading calculations.
3. Conductor configuration and hardware.
4. Insulators.
5. Line hardware
6. Design of overhead shielding wire.
7. foundation, anchoring and spacers and

... calculation.

finition :-

The purpose of insulation coordination is to determine the necessary and sufficient insulation characteristics of the various network components in order to obtain uniform withstand to normal voltages and to overvoltages of various origins. its final objective is to ensure safe, optimized distribution of electrical power.



By optimised is meant finding the best possible economic balance between the various parameters depending on this coordination:

Depending on this coordination:

1. Cost of insulation.
2. Cost of protective devices.
3. Cost of failures. (operating loss and repairs) in view of their probability.

Impulse Measurement:-

Impulse wave can be measured and displayed on an oscilloscope, using resistive or capacitive dividers.

Resistive Impulse Dividers:-

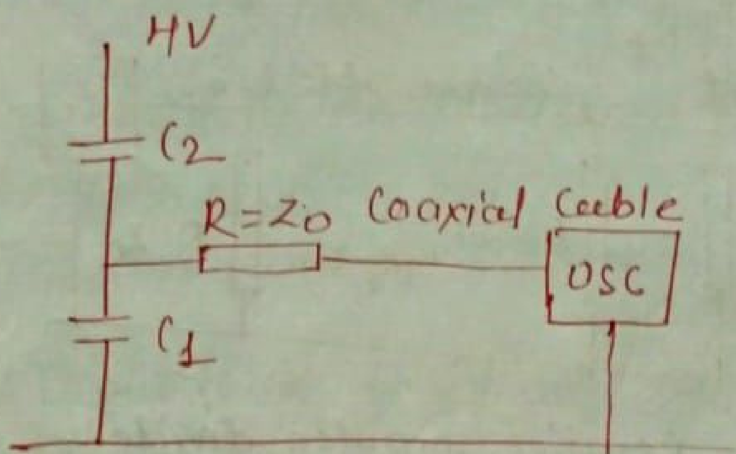
A resistive divider has distributed stray capacitance to ground that may effect the accuracy of high frequency measurements. this stray capacitance can be approximated by an equivalent capacitor C_e, connected to the centre of the resistive column.

$C_e = C$ and time constant of the divider is

$$\tau = \frac{1}{6} R_1 C_e$$

The total capacitance to ground of vertical structures such as dividers, are estimated at 15 to 20 pf/m height. Thus, a 1 MV divider, having a height of 3m and a resistance of 20KΩ would have a time constant of approximately 200ns, only just adequate for a 1.2/50 μs wave.

Typical values for a 100kV capacitive di[vider] are $C_1 = 100pf$ and $C_2 = 100nf$ for the Capacitive divider. The shunt resistor would allow the charge on C_1 to leak away and series matching must be used. The Resistor $R = Z_0$ and the characteristic impedance of the cable forms a divider to halve the impulse when it travels along the line.

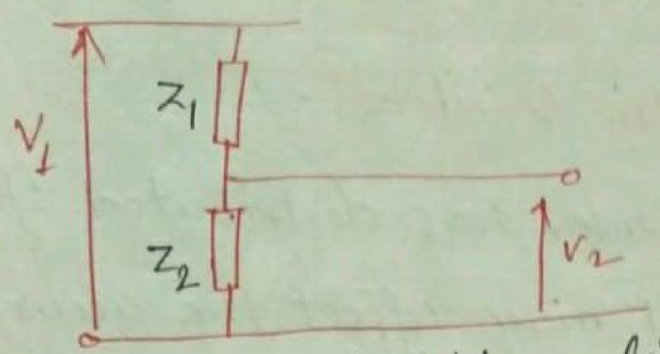


★ sphere Gaps for voltage Measurement :-

flashover of uniform gaps: The effect of pressure and gap length (Paschen's law)

In small uniform gaps it has been found empirically that, at standard pressure.

Voltage dividers:- The operation of voltage dividers depends on the division of voltage across two series impedances, Z_1 and Z_2



General Voltage divider.

$$V_2 = \left(\frac{Z_2}{Z_1 + Z_2}\right) V_1$$

Type of voltage		Nature of the impedances
DC	→	Resistors
AC	→	Resistors or capacitors
Impulse	→	Resistors or capacitors.

for capacitive divider:-

$$V_2 = \frac{C_2}{C_1 + C_2} V_1$$

The voltmeter is directly calibrated in terms of the high voltage.

The sphere gap is used to calibrate the voltage measurement.

Effects of pollution on the performance of transmission lines:-

Climates plays significant role in pollution procedure and resulted electrical breakage.

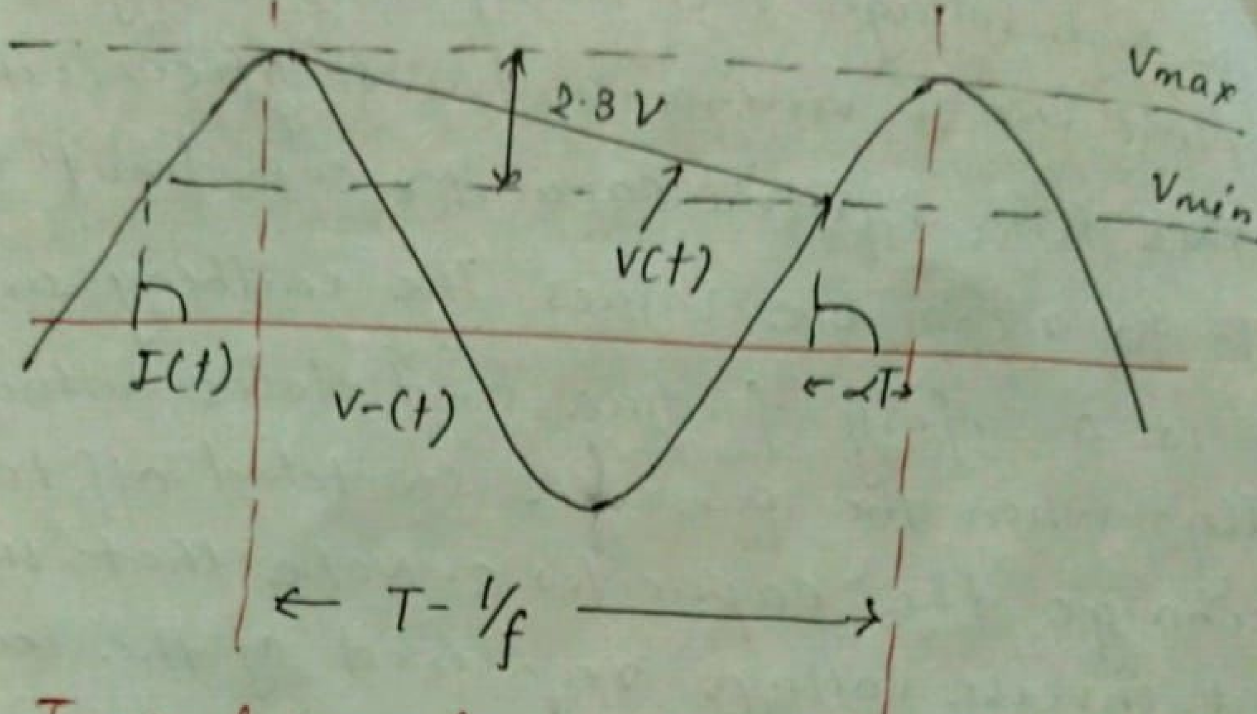
The following are affected by climate :-

1. Pollution deposition on insulation.
2. pollution distribution on insulators surface.
3. durability of pollution condition.
4. pollution despersion amount from resources.

Two kind of pollution can result in insulation electrical breakage in power frequency voltage.

1. pre deposit pollution.
2. instant pollution

- pre deposit pollution can be one of followings: high dissolvable salts ($NaSO_4$, $MgCl_2$ and $NaCl$) Low dissolvable salts (gypsums, suspension ash) or non solvable materials (clay, kaolin, oil) and acid (NOX, SOX)
- Instant pollution includes conductive fog and birds pollution (residue)



Typical waveforms and a typical doubling circuit DC test source.

Measurement :- Lord Kelvin (William Thomson 1824-1907) wrote, "To measure is to know" and "if you cannot measure it, you cannot improve it" Accurate measurement are likewis the key to successful testing and research. The problem with high voltage is, however, that, due to safety reasons, the meters cannot be connected directly to the high voltage conductors.

On the power system, voltage and capacitive voltage transformers are used while voltage dividers are used in the laboratory.

(c) Thermal Design Aspects:-

The temperature rises of conductor due to ohm losses and solar radiation. Heat is lost due cooling wind, radiation, convection, conduction etc. The thermal balance occurs when heat gained is equal to heat lost. Even during over loads maximum temperatue of conductor should be held below about 75°C for the following reasons:

1. Strength of aluminium conductors reduces rapidly at temperature above 85°C
2. Higher temperature means higher thermal losses to atmosphere. It means higher loss from transmission system.

EHV line Insulation design based upon transient Overvoltages:-

Atmospheric conditions such as wind and rain:

1. wind, by causing inter-conductor clearance gaps to vary, was responsible for arcing;
2. Rain encouraged current leaks to earth.

These problems resulted in:-

1. Use of insulators
2. determination of clearances
3. Earthing of metal frames of devices

shown.

$$\frac{\alpha(E)}{p} = A e^{(-Bp/E)}$$

Where A & B are constant, unique for each gas.

This leads to flashover voltage

$$V_c = B \frac{pd}{\ln(pdA/K)}$$

Paschen's law :- The flashover voltage of a uniform field gap is a function of the product: gap length times gas pressure.

A empirical relationship has been suggested by Sohst and Schroder for uniform gaps with pd values between 10-2 and 5·102 bar cm.

$$V_c = 6.72\sqrt{pd} + 24.36\,pd$$

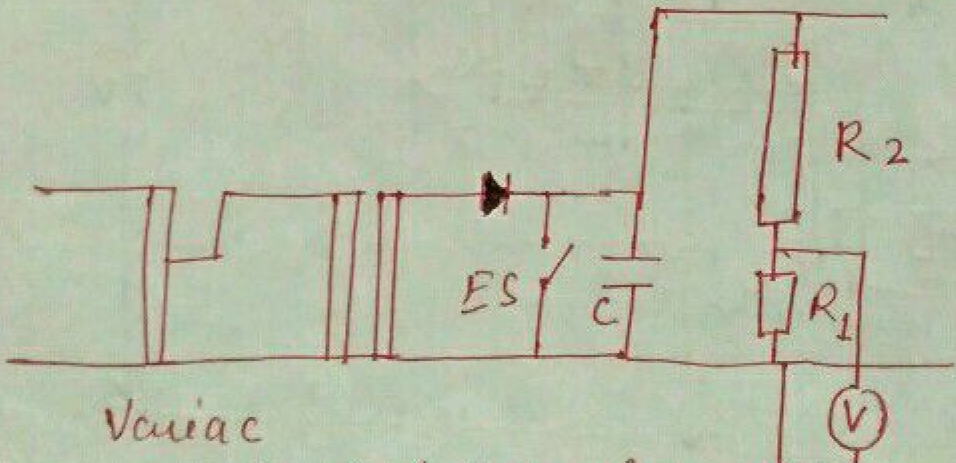
with V_c the flashover voltage in kV (peak) and pd in bar cm.

Another, more simplified empirical formula for the critical stress E_0 in kV/cm is that due to Townsend, with d the gap length in cm.

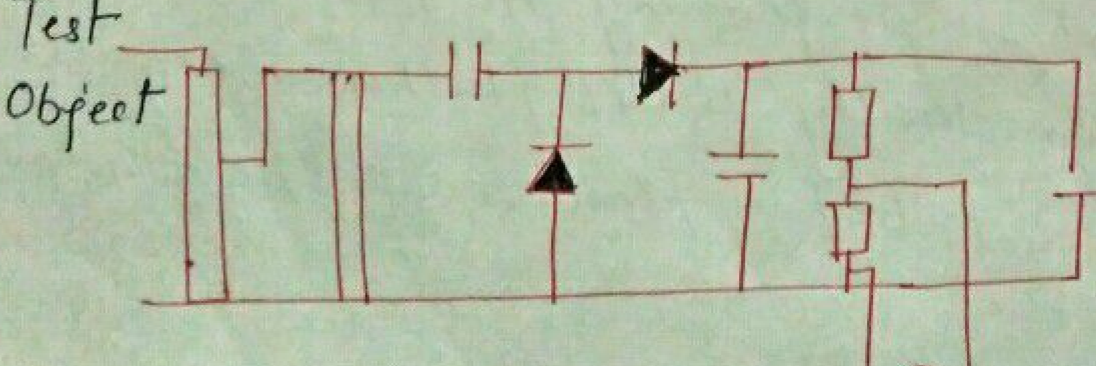
Direct Current (DC)

DC tests are used mainly to do "pressure" on high voltage cables. Although the cable with AC, AC testing is not practical. The high capacitance of the cables necessitates AC test sets with a high kVA rating to be able to supply the capacitive current. In case of DC, once the cable is charged, only the losses have to be supplied.

DC test sets usually consist of half wave rectification, using HV selenium rectifiers.



AC test transformer



Typical doubling circuit for DC tests

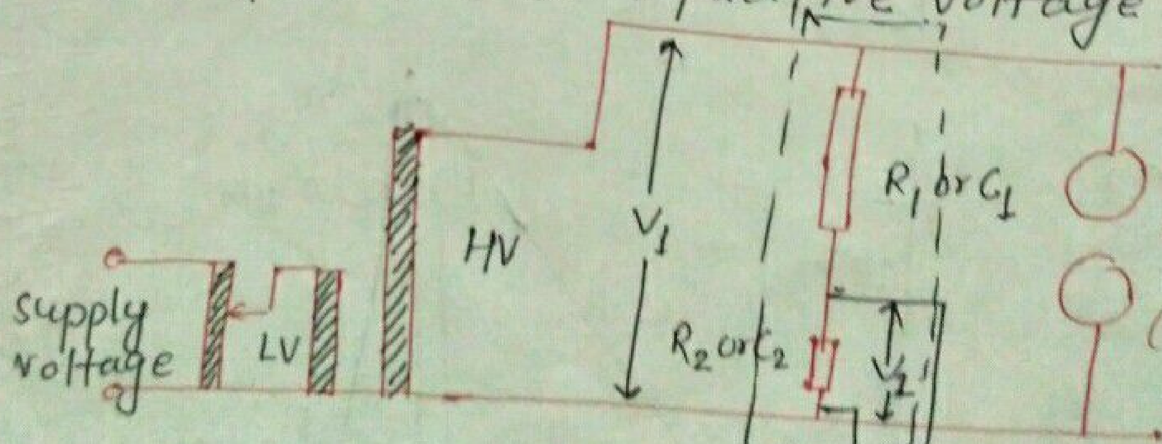
Generation of high AC and DC Voltages:-

In an AC network the equipment is continuously subjected to full power frequency voltage. The equipment should therefore be able to withstand normal frequency voltage, allowing some overvoltage.

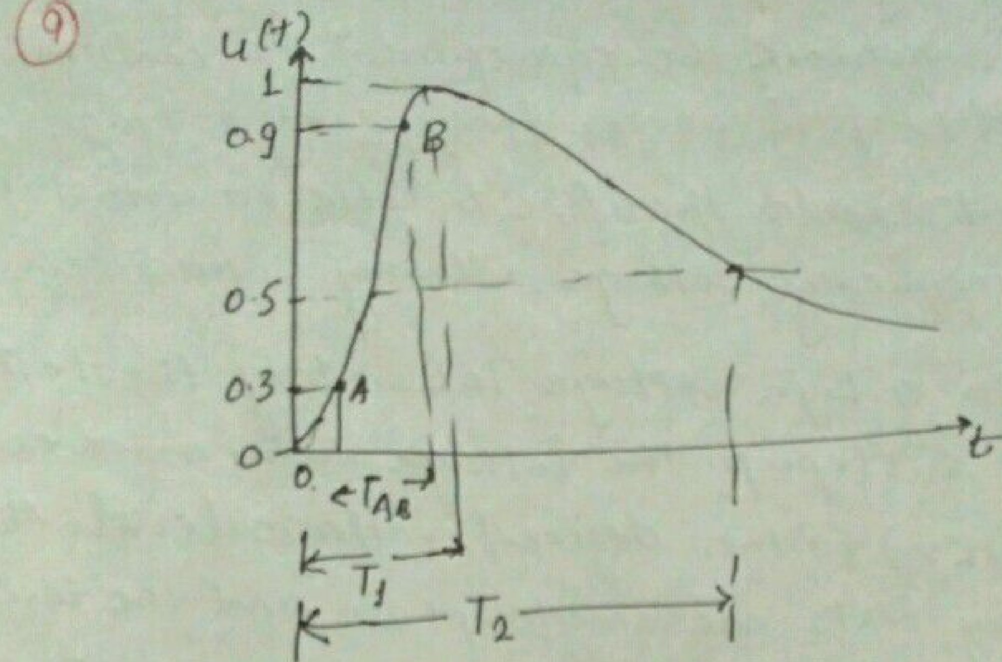
In a high voltage laboratory the test transformers stepup the voltage from a lower voltage (220 V or 11 KV) to the desired voltage level. All laboratory tests are single phase and the low voltage side of the transformer is supplied via a regulating transformer to be able to adjust the magnitude of the output high voltage.

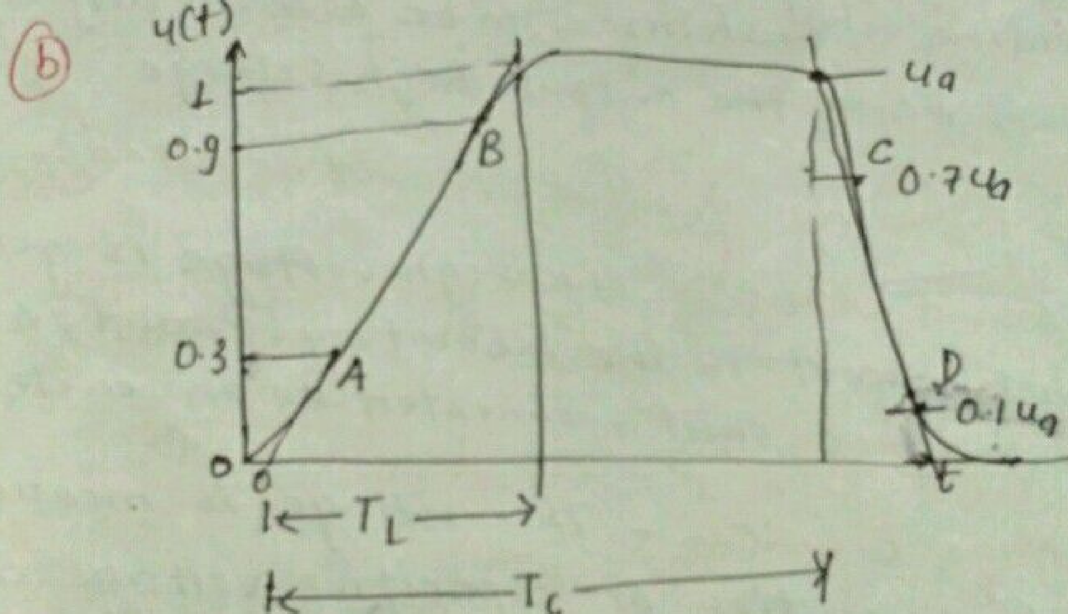
The following features should be noted:-

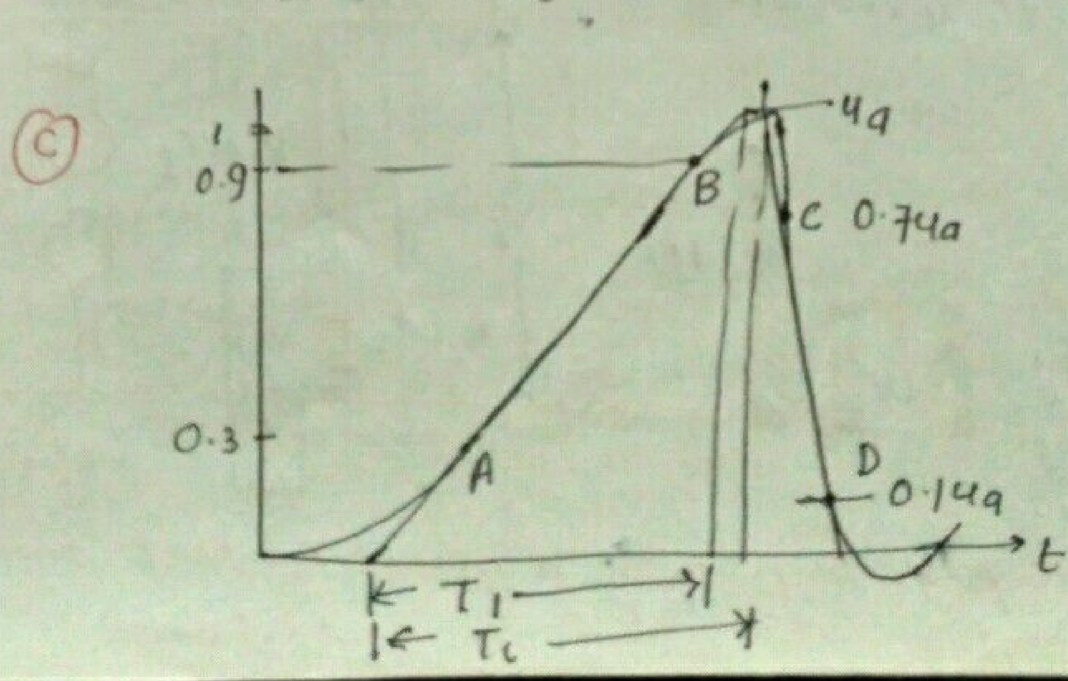
- Ground plane:- The high voltage is generated with respect to the laboratory ground, a low impedance sheet, connected to an earth electrode.
- Voltage Divider:- The voltage is measured with a resistive or capacitive voltage divider.



Schematic diagram of a typical AC test transformer and its connection.







Example of lightning impulse voltages with aperiodic waveform (a) full lightning impulse voltage (b) lightning impulse voltage chopped on the tail (c) lightning impulse voltage chopped on the front

The rising part of the impulse voltage is referred to as the front, the maximum as the peak and the decreasing part as the tail.

chopping of a lightning impulse voltage in the test field is done by a chopping gap, where by one differentiates between 'chopping on the tail' at the peak and on the front.

The standard chopped lightning impulse voltage has a time to chopping between 2 μs and 5 μs.

The various lightning impulse voltages are identified in the test specifications by the following time parameters.

- front time T_1 and Time to half value T_2 for full lightning impulse voltage.
- front time T_1 and time to chopping T_c for standard chopped impulse voltages ($2\mu s \leq T_c \leq 5\mu s$)