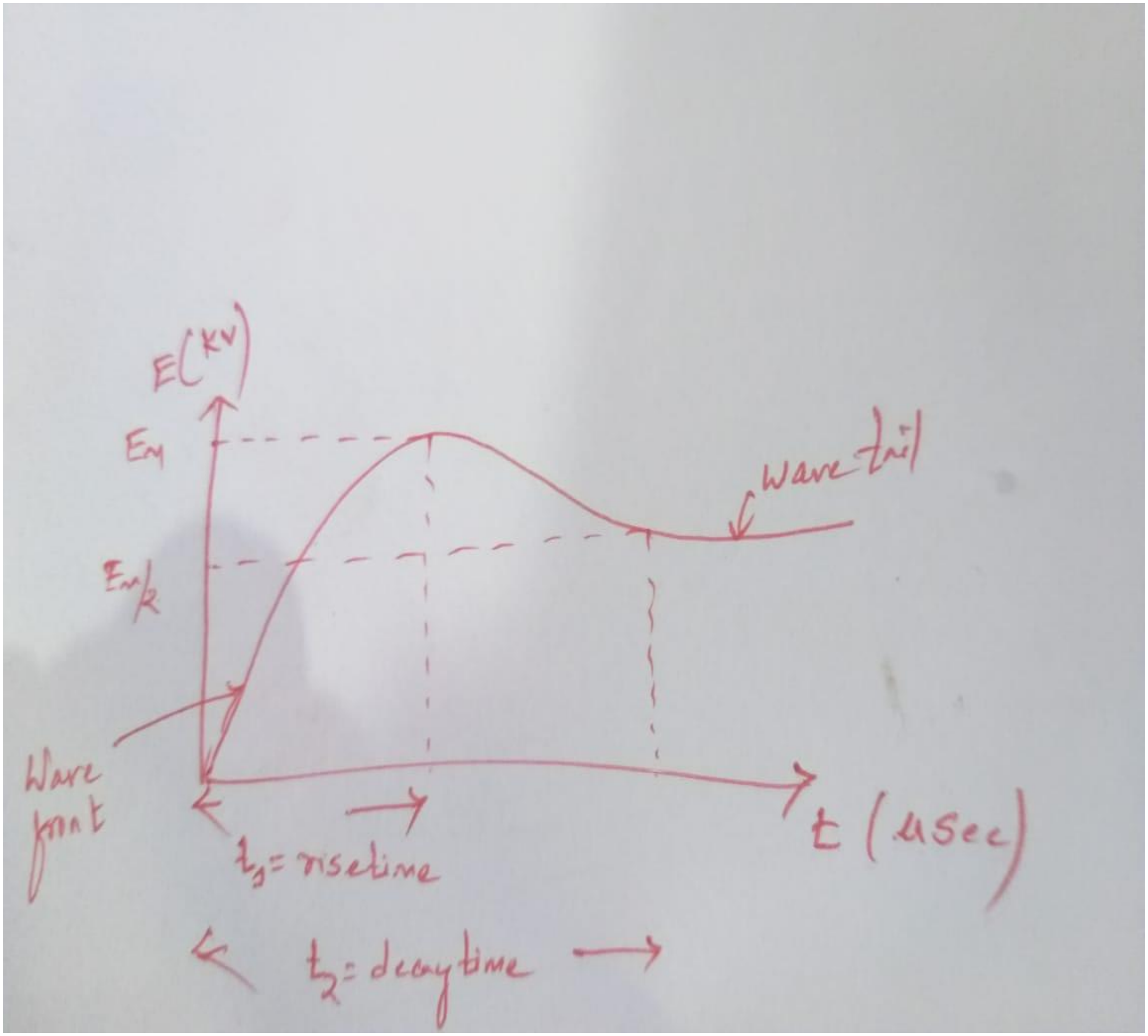
TOPIC-7 by Lect. Aurobindo Ghose(E.E), G.P PURI

The Concept of Surge:

When a lightening surge or internal overvoltage condition strikes the end point of a transmission line it releases charge on the line and depending upon the inductance of the transmission line a voltage wave that is proportional to the charge density and a current wave travel over the line.

Depending upon the L and C values of the line, the shape of the wave front of the voltage wave will be decided. So, more the L value, a steeper wave front will be available. The value of C of the line to ground impedance of the line, several bushings, insulators etc., decide the shape of the wave front. Moreover, when such an wave front strikes an open ended line, then the reflective wave front shall double up depending upon the amount of charge in the surge impedance.

7.1 Voltage Surge and causes of Over-Voltage: A sudden rise in voltage for a very short duration on the electric power system is known as a voltage surge or transient surge.



7.2 Internal Causes of Over-Voltage: These are primarily due to oscillations set up by the changes in the circuit conditions in the power system. The causes are detailed as follows:

i) Case of an open line: During switching operations of an unloaded line travelling waves set up over-voltages. When the unloaded line is connected to the voltage source, a voltage wave is set up which travels along the line. On reaching the terminal point, it is reflected back to the supply end without the change of sign .This causes voltage doubling effect, thereby internally increased over-voltage.

ii) Case of a loaded line: Suppose a loaded line is interrupted and this will cause a set up of over-voltage of twice the product of natural impedance and instantaneous value of current across the break.

iii) Current Chopping: It results in the production of high voltage transients across the contacts of C.B. When breaking low currents the de-ionizing effect of C.B causes the current to fall abruptly to zero before the natural current zero is reached, thereby causing over-voltage.

iv) Arcing- Ground: Due to unearthed neutral and in case of L-G fault, the line is not put out of action. The zero sequence currents are eliminated resulting in the decrease of interference with communication. However, when the lines are long and operate at high voltages, arcing- ground is witnessed and intermittent arcing takes place with the consequence of high-frequency and over-voltage transients.

v) Resonance: In a power system when inductive reactance is equal to capacitive reactance then impedance is equal to resistance causing power factor to be unity. This condition is termed as resonance condition and at that resonant frequency harmonics of higher order occur which are a cause of transient over-voltage.

7.3 External Causes of Over-Voltage: Lightning is the most important cause of over-voltage externally. Lightning is an electric discharge between cloud and earth, between clouds or between charge centre's of the same cloud. It takes place when clouds are charged to such a high potential with respect to earth that the dielectric strength of air is destroyed and thus creating a huge spark of external over-voltage.

7.4 Mechanism of Lightning Strike: When drops of water are formed, the larger drops become positively charged and the smaller drops become negatively charged. And this cloud upon passing over the earth induces equal and opposite charges on earth. As the charge acquired by the cloud increases, the potential between cloud and earth increases and thus potential gradient increases significantly. Therefore, when the gradient reaches sufficiently so as to cause dielectric breakdown of air and the lightning strikes.

7.5 Types of Lightning Strokes:

i) Direct Stroke: In this type of strike, the lightning discharge is directly from the cloud to the subject equipment e.g. an O.H line. From the line, the current path may be over the insulators down the pole to ground. The cloud will induce a charge of opposite sign (electrostatically induced) on the subject equipment and consequently upon the dielectric breakdown of air, the direct lightning strike occurs.

ii) Indirect Stroke: Let's consider a case study that a positively charged cloud is above the line and induces a negative charge on the line by electrostatic induction. But this negative charge remains on that portion of line which is directly under the cloud and the portions of the line away from the cloud will be positively charged to balance negative charge as discussed. This positive induced charge leaks slowly to earth via the insulators and is termed as Indirect Stroke.

7.6 Harmful effects of Lightning:

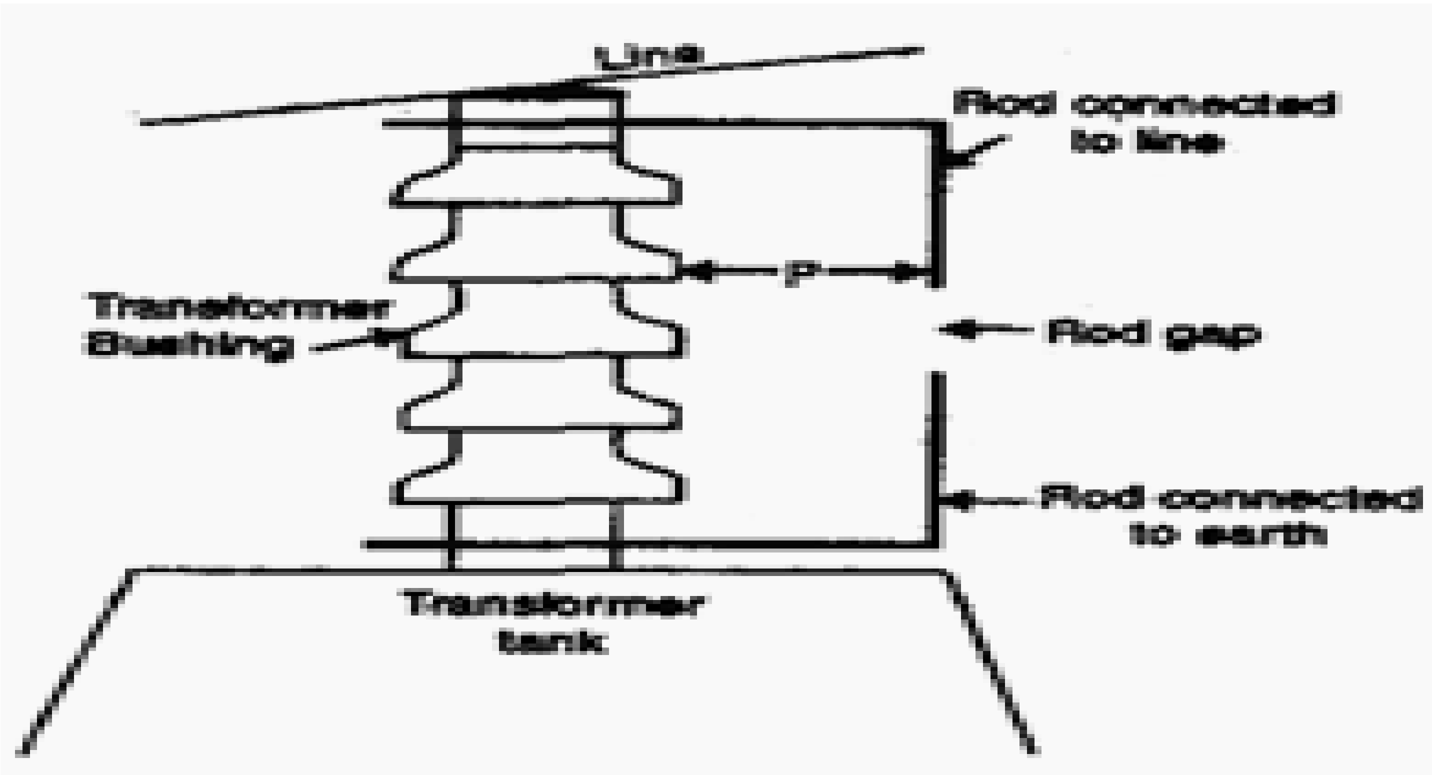
i) The steep-fronted voltage wave on the line produces travelling waves which can shatter the insulations and damage the poles.

ii) The travelling waves upon hitting the windings of a transformer or generator can cause considerable damage because windings have high inductance and inductance opposes the build of charge. This opposition can create very high potential gradient and in turn production of an arc which can breakdown insulation.

iii) If the arc is set up in any other part of the power system, it causes oscillations in the form of voltage surges and high frequency harmonics.

7.7 Surge Diverters or Lightning Arrestors: The surge diverters better known as arrestors basically safe guards the insulation of the terminal apparatus and it ceases to carry current after a discharge.

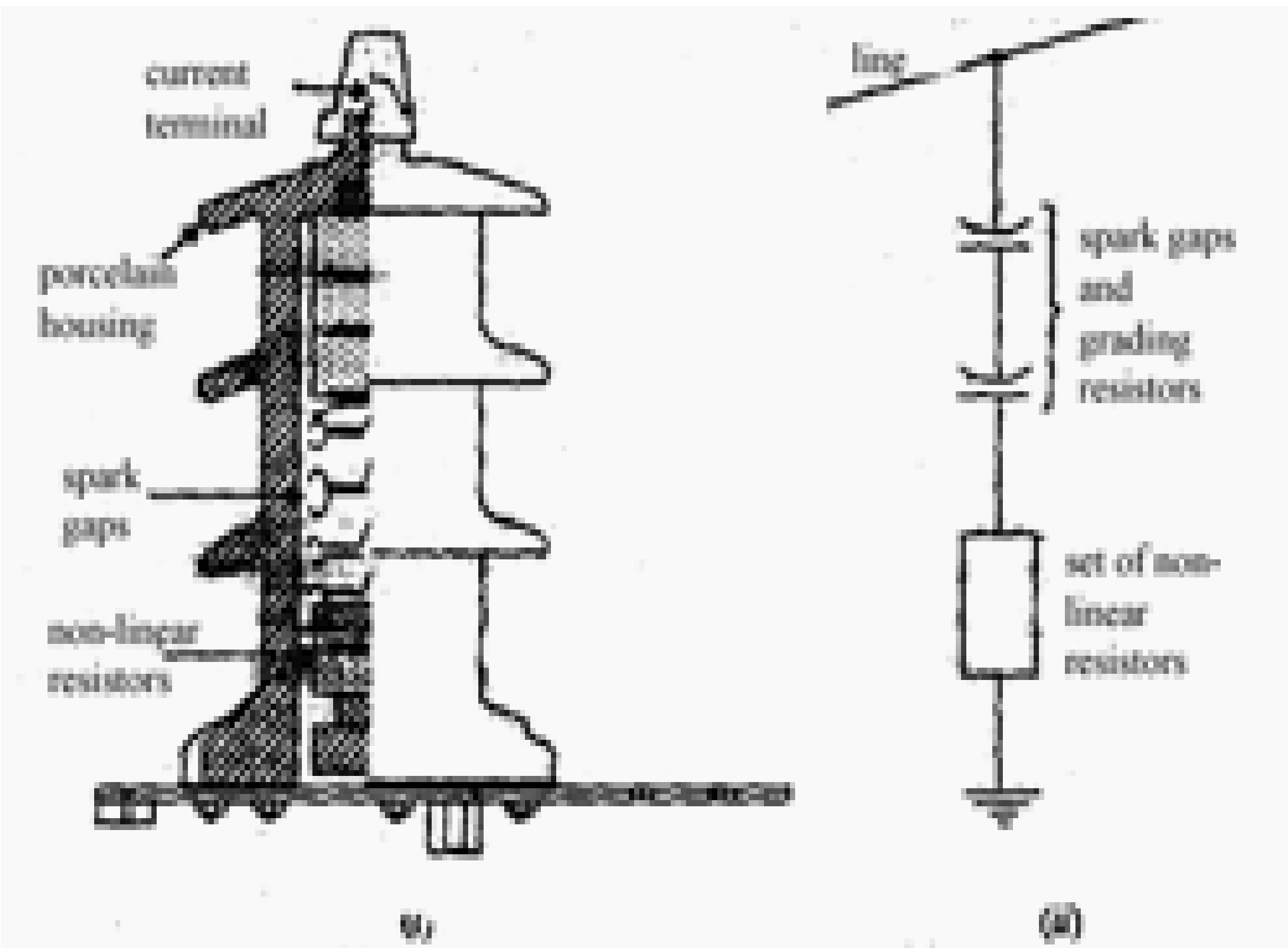
7.8 TYPES OF LIGHTNING ARRESTER



A.)Rod Gap Arrest*er*: This type of arrester is for lower voltage application. When the surge exceeds the designed value of the gap an arc is initiated. A small square rod of size 1 cm^2 bent at right angles and connected between the line and earth as shown in the figure above. The distance between the rod and the insulator should not be less than the gap length so that the arc could reach the insulator and damage it. When the surge voltage reaches the design value of the gap an arc appears in the gap providing an ionized path between it and ground.

B).Horn Gap Arrester: It consists of horn shape metal rods separated by a small air gap. The horns are so constructed that the gap between them gradually increases towards the top as depicted in the figure below. The horns are mounted on insulators. One of the horns is connected to the line through a resistance R and a choke coil L. The other end of the horn is solidly grounded. The resistance helps in limiting the current flow to a small value. The choke coil is so designed that it offers small reactance to the power frequency but a high reactance during transient frequency. Thus it does not allow the transient to enter into the apparatus to be protected. The gap between the horns are so designed that the normal power frequency supply voltage is not sufficient to cause a spark across gaps.

C. ***Valve Type arrester***: This type of arrestor has a non linear resistor in series with the spark gap as shown below. In traditional arresters, the characteristic of the gap spark over voltage versus the surge front time does not match well with the strength versus front characteristics of most of the insulators. Thus it is difficult to coordinate the protective device with the system voltage for which it is used. To resolve this non linear resistors are used in series with the gap to limit the power follow current after an arrester discharge operation. These arresters are used for higher voltage application. Both the assemblies of spark gap and non linear resistor are housed inside a tight porcelain container.



7.9 Surge Absorbers: Inductor metal shields absorb low energy surges. This device is appropriate for short duration surges as it can reduce only the steepness of the wave-front. Such devices are not cost effective for higher transient surges.

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8.1 Static Relays.

8.1.2 Advantages of static relays

- Due to the amplification of energizing signals obtainable, the sources need only provide low power. Therefore the size of the associated current and voltage transformers could be reduced.
- Improved accuracy and selectivity.
- Fast operation of relays and hence fast clearance of faults.
- Flexibility of circuitry would allow new and improved characteristics.
- The relays would be unaffected by the number of operations.

8.1.3 Basic circuits employed

- Timers
- Phase comparators
- Amplitude Comparator
- Level detectors
- Integrators
- Polarity detectors

- Integration of Digital Systems

8.2 Over-current Relays

- Protection against excess current was naturally the earliest protection systems to evolve.
- From this basic principle has been evolved the graded over current system, a discriminate fault protection.
- “over-current” protection is different from “over load protection”.
- Overload protection makes use of relays that operate in a time related in some degree to the thermal capability of the plant to be protected.
- Over current protection, on the other hand, is directed entirely to the clearance of the faults, although with the settings usually adopted some measure of overload protection is obtained.
- In terms of the general torque equation the over-current relay has both constants K_2 and K_3 equal to zero. Therefore, the equation becomes

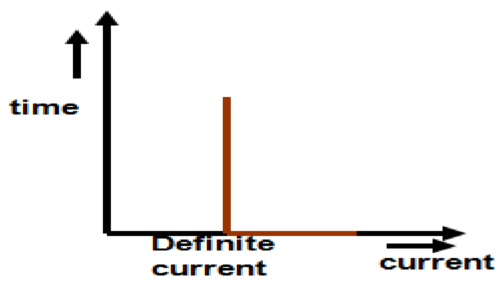
$$T = K_1 I^2 + K_4$$

8.2.1 Types of over current relays

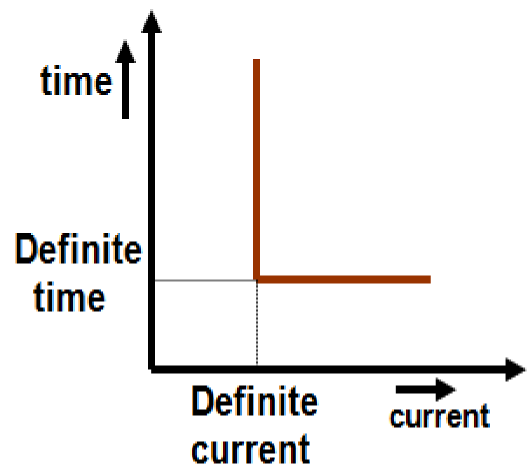
- Based on the relay operating characteristics , over-current relays can be classified into three groups
  - Definite current or instantaneous
  - Definite time
  - Inverse time

DEFINITE-CURRENT RELAYS

- This type of relay operates instantaneously when the current reaches a predetermined value.



DEFINITE TIME CURRENT RELAYS



- This type of relay operates after a definite time when the current reaches a pre- determined value.

8.3 INVERSE TIME RELAYS

- The fundamental property of these relays is that they operate in a time that is inversely proportional to the fault current. Inverse time relays are generally classified in accordance with their characteristic curve that indicates the speed of operation.

- Inverse-time relays are also referred as inverse definite minimum time or IDMT over-current relays

- This type of relay operates after a definite time when the current reaches a pre- determined value.

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