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SAFETY ASPECTS OF SUBSTATION EQUIPMENT & ELECTRICAL TRANSMISSION SYSTEMS AGAINST LIGHTNING STROKES

Saju K. K., M. R. Radhakrishna Panicker and Sheena K. M.
Centre for Under Graduate studies in Engineering
Cochin University of Science and Technology
Kochi, Kerala

SYNOPSIS

It is a known fact that tremendous amount of energy is generated in each lightning stroke. Direct impact of this phenomenon can cause extensive damage to man and machinery. Detailed study on lightning have formulated many theories for its formation.

The Progress of any nation depend mainly on generation of Electrical power and its uninterrupted supply for which protective systems have to be incorporated. By means of providing efficient protective systems for substations, electrical equipments and other electrical installations generating and transmitting power most of the damages that can occur due to lightning stroke can easily be avoided.

INTRODUCTION

In earlier periods, lightning was looked upon as the wrath of gods and has inspired and intrigued mankind for a long time. Detailed study on lightning have formulated many theories for its formation. While designing the protection system of electric power systems, safety measures should be taken for protection from lightning.

This paper is presented to highlight the lighting phenomenon, protection of substations, overhead transmission lines & electrical apparatus from lightning.

LIGHTNING PHENOMENON

Lightning phenomenon is a peak discharge in which charge accumulated in the clouds discharge into a neighbouring clouds or to the ground. The electrode separation between cloud to cloud or cloud to ground is very large (can be 10Km or more)

As a result of certain atmospheric conditions that take place during thunder storms charges are accumulated in clouds or portion of clouds and equal and opposite charges are produced on the earth.

As the charges increase, the potential between cloud and earth increases and therefore the potential gradient in the air increases. This potential gradient is usually, more intense at the charge centre in the cloud. When the gradient exceeds the breakdown value of the moist ionised air (» 10kv/cm), an electric streamer with plasma starts towards the ground with a velocity of about 1/10 times that of light, but may progress only about 50m or so before it comes to a halt emitting a bright flash of light. This is due to insufficient build up of electric charge at its head and there by inability to maintain the necessary field gradient for further progress of the streamer.

Other charge centres in the cloud discharge to the charge centre which started the initial streamer thereby initiating subsequence discharge to earth along the original stroke channel. It has been observed that the streamer starts repeating about 100 us after the initial one. Branches may also be formed from the leader stroke. The leader stroke progresses by a series of jumps and is referred to as stepped leader.

The total time required for a stepped leader to reach the ground is about 20ms. Picture of a typical leader stroke is shown in fig.1

In case the charge centre in the cloud can feed enough charge into the initial streamer to maintain the gradient at its tip above the strength of the air, the leader progresses and reaches the ground in the first instance itself.

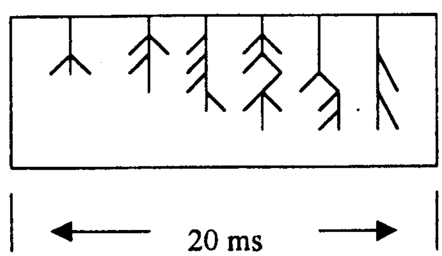


Fig 1

As the leader moves towards the ground, positive charge is directly accumulated under the head of the stroke or canal. By the time the stroke reaches the ground or comes sufficiently near the ground, the electric field intensity on the ground side is sufficiently large and the gradient on the earth surface becomes great. Eventually it becomes sufficiently strong to cause a short upward streamer to rise from the earth and contact is made between the leader and the earth.

The positive charge returns to the cloud neutralising the negative charge and hence a heavy current flows through the path of the order of 1000 to 2,50,000A.

This high current will lead to dangerous over voltages in power systems leading to heavy damages there by emphasizing for good protection system.

Based on studies it has been found that
25% of all strokes are below 10KA
86% of all strokes are below 50KA
11% of all strokes are between 50 and 100KA
2% of all strokes are between 100 and 150KA
0.5% of all strokes are above 150KA
Highest measured current is 400KA

PROTECTION PRINCIPLES

While dealing with protection against lightning strokes it should be borne in mind that lightning cannot be prevented, it can only be intercepted or diverted to a path which has to be well designed and constructed so as to avoid damage. Even this method will provide only 99.5-99.9% protection. 100% protection can be provided only by enclosing the object in a complete metal (or metal mesh) encapsulation. A person in a metal topped closed automobile is safe from lightning stroke injury.

The fundamental theory of lightning protection is based on the fact that lightning strikes the tallest structure having the least resistance through which charge can discharged to the earth.

PROTECTION AGAINST LIGHTNING FOR POWER SYSTEMS

Protection of power systems against lightning is designed for protecting.

1) Overhead transmission lines from direct strokes
2) Electrical apparatus from travelling waves.
3) Power station and substation from direct strokes.

1) Protection of overhead Transmission lines from direct stroke

Transmission lines are drawn from one transmission tower to another at a very great height. As such providing a taller structure than the tower is out of question due to work and cost implications.

The most common method adopted is by shielding the lines by means of ground wires. Ground wire is a conductor, running parallel to the main conductor of the transmission line supported on the same tower and earth at every, equally and regularly spaced towers. The ground wire shields the transmission line conductor from induced charges from clouds as well as from a lightning discharge. Fig shows an arrangement of ground wire on a transmission tower.

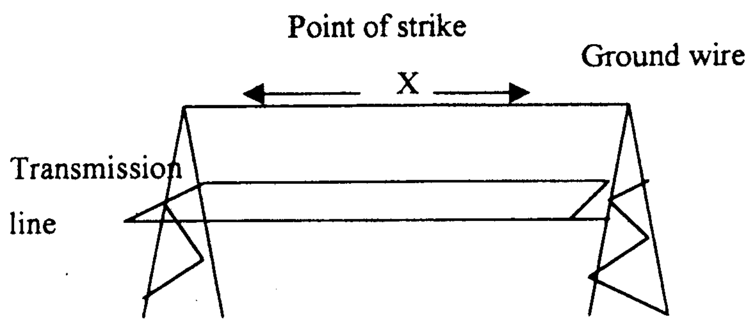


Fig 2

As can be seen during a stroke the ground wire will be struck and current flows in both directions from the point of strike . Since the wire is grounded by means of a low resistance path, the charge gets discharged to the earth thereby protecting the live wires. Other methods used for protection of transmission lines from direct stroke is by using protector tube.

2) **Protection of electrical apparatus against travelling waves**

Indirect strokes may result from Electromagnetically induced current due to lightning discharge in the immediate vicinity of the line or result from Electrostatically induced charges on the conductor due to the presence of charge clouds.

The fig 3 shows negatively charged cloud over a conductor which is at height h above the ground. The charges induced on the conductor are + Q and – Q having a magnitude Q= CV where C= capacitance between conductor and earth and V= EH, E being the field gradient.

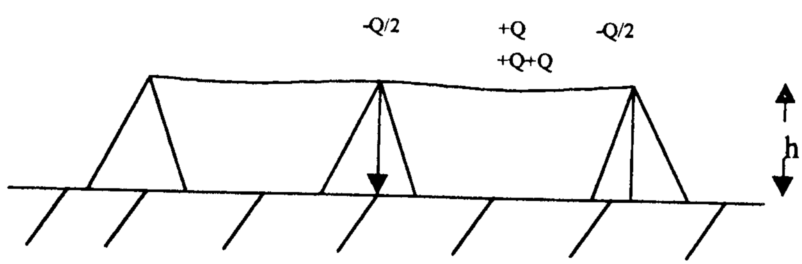


Fig 3

Negative charge leaks slowly to earth via the insulator. The bound positive Charge on the line is released in the from of travelling waves in both directions , when the cloud discharge to earth or another cloud, or passes away. This voltage waves can reach the terminal equipment installed in the substations and damage the same.

DAMAGE CAN BE CAUSED AS BELOW

1. External flash- over damaging insulator or adjacent apparatus
2. Internal flash-over damaging main insulation of the apparatus to earth.
3. Internal flash -over damaging secondary insulation between parts of the apparatus eg: inter turn insulation of a transformer.

PROTECTIVE DEVICE

The most common protective device is the lightning arrestor which is connected between line and earth at the substation. When a voltage wave reaches the arrestor, it sparks over at a certain pre-fixed voltage and provides a conducting path of relativity low impedance between the line and earth. The resulting current flow to earth through the surge impedance of the line limits the amplitude of the line to earth overvoltage known as residual or discharge voltage to a value which will safeguard the insulation of the protected equipment.

Thus it is important to provide protection device at the substations to prevent transformer and other equipment from being subjected to high voltage waves.

PROTECTION OF POWERSTATION AND SUBSTATIONS AGAINST DIRECT STROKE

Power stations are usually housed in buildings thereby are sufficently protected from direct strokes whereas substations are located outdoors and require adequate lightning protection.

An electric substation has a variety of high value equipments like current transformers, potential transformers, power transformers etc which are highly susceptible to damage by lightning. Lightning arrestor installed in the substation can only protect the equipments against travelling waves and not from direct strokes.

It is not practical to cover the entire substation by means of metal sheet or wire mesh for protecting against direct strokes.

The most practical method is the circular sided protection zone using masts or overhead wires or both may be used.

The protection using overhead wires follows the same principle as the protection of transmission lines shielding wire.

Lightning masts are pipes usually made of m.s. with a sharply pointed end and has a height greater the height of the equipment of the s/s. The mast is firmly grounded to the grounding network of the s/s. The mast thereby provides a low resistance path for discharge of any charge to the earth.

The protection principle is based on the general conditions that a direct stroke strikes the object at the highest point having the lowest resistance. For a single rod or mast the protection radius is given by r = 1.5H (1 - h/0.8H) and

r = 0.75H (1- h/H) for the distance of the equipment less than 2/3 H and more than 2/3 H respectively where H is the total height of the mast and r & h are the distance of the equipment from the mast and the height of the equipment. Therefore the height of the mast required for protection of any equipment can be calculated if the distance of the equipment from the mast and the height of the equipment is known. More masts of shorter heights can be installed for protecting a larger area as the zone of protection will be enhanced appreciably.

For designing the lightning masts for a s/s the area of the s/s is divided in to a number of circles. Mast are located at any triangle which will be circumscribed by these circles. The height of the mast above the height of the equipment is calculated empirically in relation to each circumscribing circle and the active height of the mast is found to be d/ 8 where d is the diameter of the circumscribing circle.

<u>Calculation of height of the mast for portion of s/s as shown in figure 4</u>

Masts LM,LM_2 LM_3 are located within the circle which covers the area for protection. The three masts form DABC with the circle circumscribing it.

The diameter of the circle is measured (D) = 25.01m

Active height of the mast or the height of the mast above the height

of the tallest equipment is D/8 = 25.01/8 = 3.13m = h2

Total height of each mast will be h1+ h2 =h=6.8+3.13= 9.93m

Where h1= 6.8 is the maximum height of the s/s equipment.

CONCLUSION

The paper so far discussed the lightning phenomenon and the protection of Electrical power systems from lightning strokes giving emphasis on protection of substations using lightning mass (spikes) against direct strokes. The generation of Electrical power and its uninterrupted supply is of prime importance now a days for the further growth of any nation . Lightning creates many hardship to man ,machine and resources. Keraunic level of a particular region is the number of days in a year, in which thunder is heard, averaged over a number of years. Many places in Kerala have a high Keraunic level of above 60 compared the the normal of 30. As such adequate protective measures from lightning strokes are to be taken before finalising the location and installation of the sub stations.

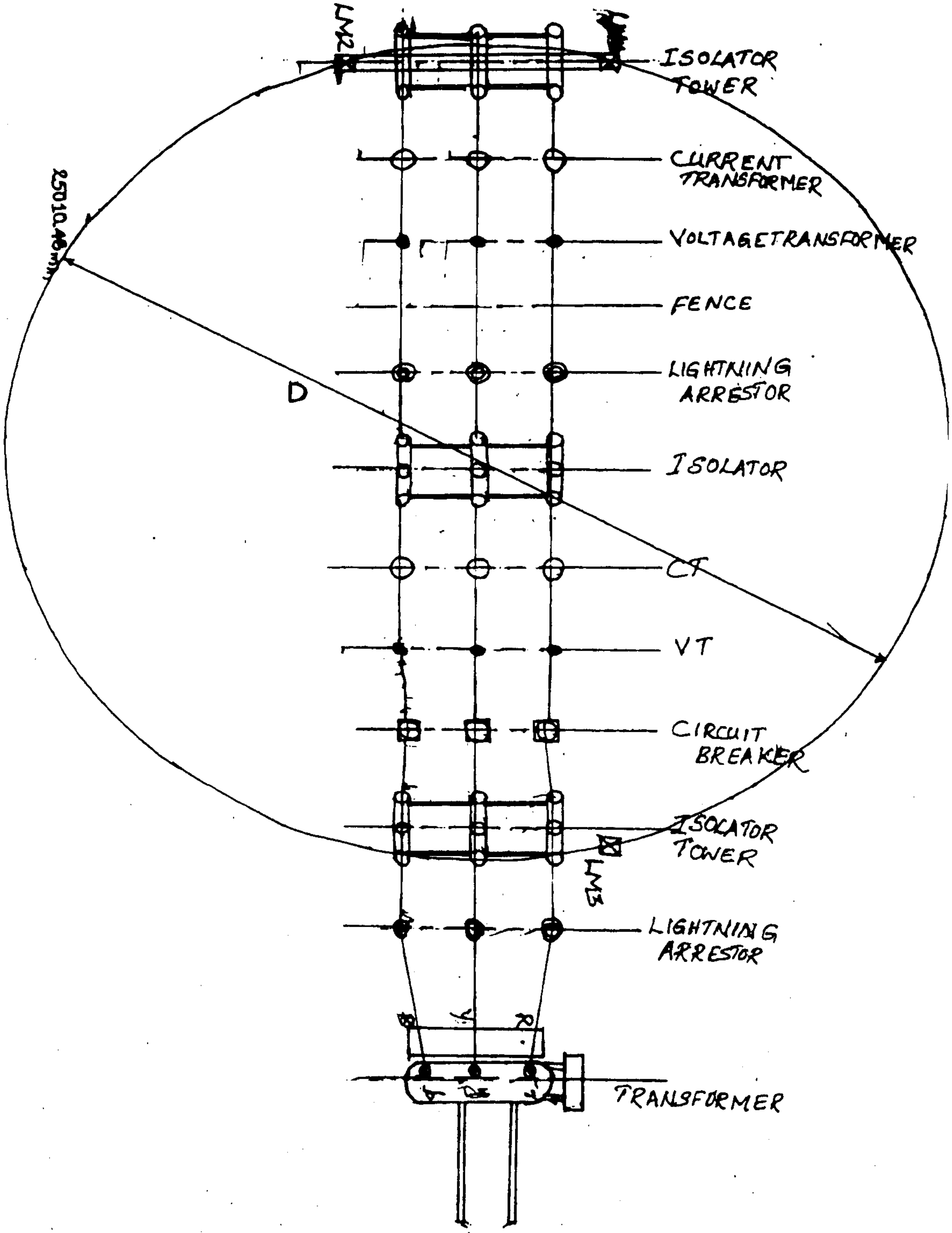
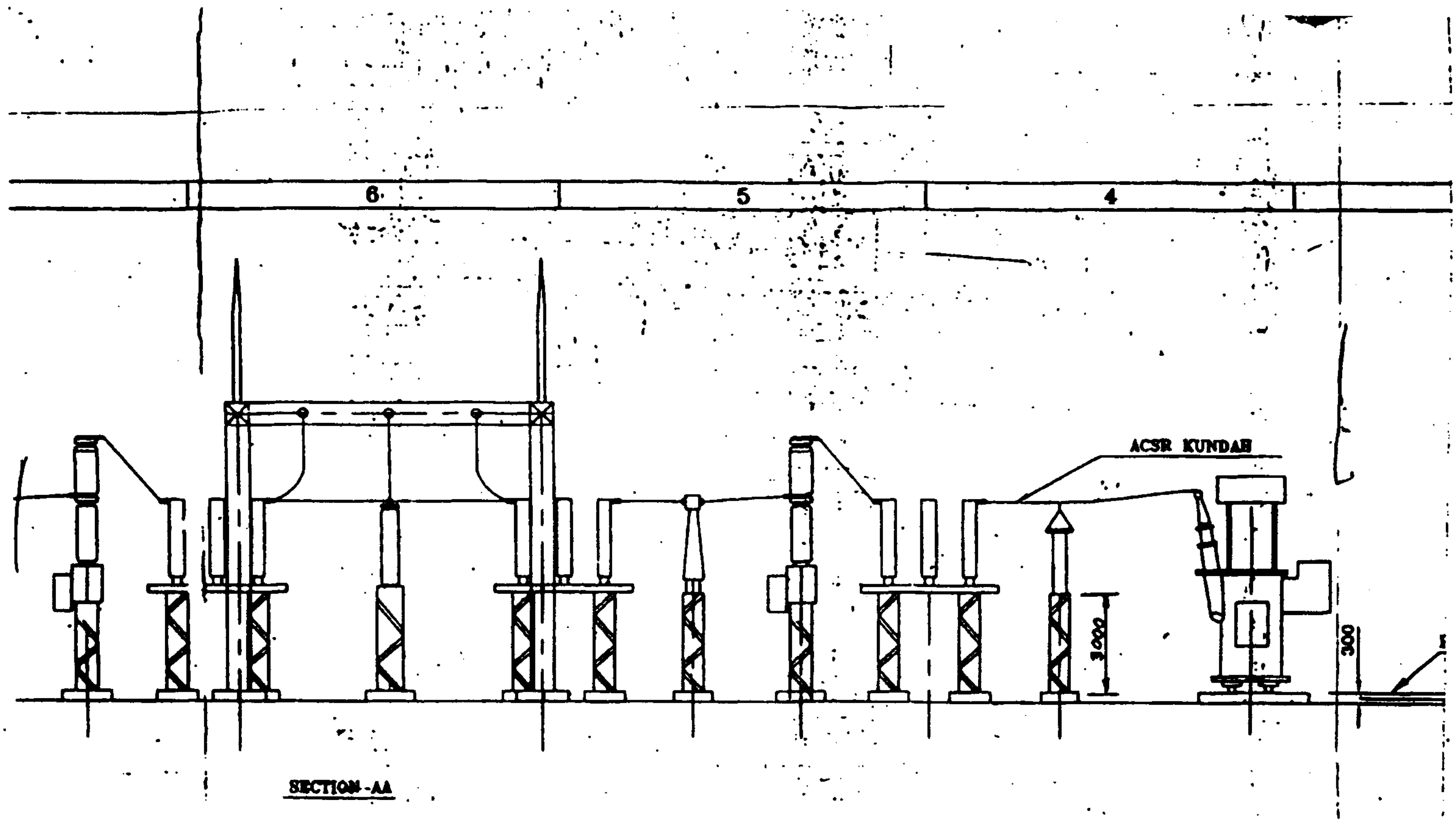

LM2
ISOLATOR TOWER
CURRENT TRANSFORMER
VOLTAGETRANSFORMER
FENCE
LIGHTNING ARRESTOR
D
ISOLATOR
CT
VT
CIRCUIT BREAKER
ISOLATOR TOWER
LM3
LIGHTNING ARRESTOR
TRANSFORMER

Fig 4


6
5
4
ACSR KUNDAH
3000
300
SECTION-AA

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