LIGHTNING
AND
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LIGHTNING AND LIGHTNING PROTECTION

The results of research conducted in France in recent years by Franklin France and Meteorage Franklin have led to a significant breakthrough in the knowledge and understanding of the lightning phenomen . This knowhow helped develop better protection and preventionn devices , but lightning retains many of its mysteries and will remain , both for researchers and manufactures , a focus of fascination and awe. The ideal answer to the question of what lighting realy is can provided by quoting P.G. Lairent who wrote in ١٩٥٠ .

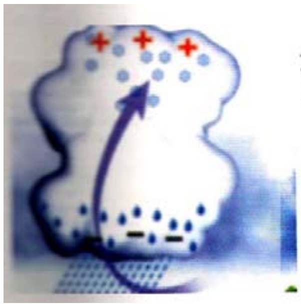
Lightning is an important event which no one can avoid from its danger , but also it can be observed easily . It possesses millions of volts , capabile of shattering insulating obstacles but flows through small diameter conductors. Since it is curious during its descent to explore neigbouring metal structures and conductors , when rightly or wrongly, It hopes to find an easier outlet, It wiser to pyave its way with approparicate interconnection than to bar its way with obstacles that are inffective .

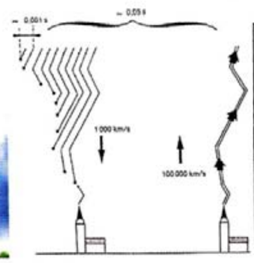
Lightning explores the surrounding space supplies to a sort of sensitivity that it procuses from the electrical field that it propagates, and this same field means of breaking through inslator by applying its electrical force . The essential idea behind every protection system is to avoid forces can be brought into play .

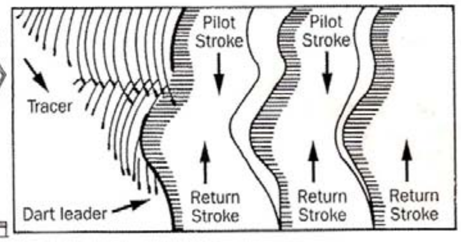
The storm cloud

Lightning is produced by cumulo-nimbus storm clouds . The upper part of the cloud is made up of positively charged ice crystals while the base contains negatively charged water droplets. This separation of charges is caused by atmospheric turbulence . A highly intense electrical field is created between the charges , and when this field reaches its breakdown point , an electrical discharge occurs, either as lightning flashes between clouds or cloud zones or as lightning between the cloud and the groun .

During fine weather , the electrical field on the ground is around ١٠٠v/m . As the storm(negative storm) approaches , this becomes a positive value possibly reaching ١٠ to ٢٥ kv /m . The potential difference between the cloud and the ground is then of some several tens of megavolts as shown bellow .







The Effects of Lightning

The main effects of lightning are as follows :

١-Thermal effects :-

These effects are linked to the quantity of charges involved lightning strikes. For materials with high resistivity , they cuase various melting points at the places of impact . On poorly conducting a large amount of energy is released in the form of heat . The moister they contain causes a sudden overpressure that may result in explosion .

٢- Effects due to arching :-

The resistivity of the soil makes earthing resistant and therefore unables to prevent a sudden rise in the facilitys potential when lightning current passes through it . This creats differences in potential between the various metal parts . Earthing and connections between the metal parts must therefore be carefully designed and connected to down conductors .

٣- Electrodynamic effects :-

These effects are produced if part of the path along which the lightning current travels is within the magnetic field of another part . This may produce repulsion and attraction forceswhen lightning travels through conductors close to eactors close to each other .

٤- Electrochmical effects :-

These are nigligbile and have no effect on the earthing compared with stray current in the soli .

٥- Acoustic effects (thunder) :-

Thunder is due to the sudden pressure rise (٢ to ٣ atmoshernes) in the discharge channel subject to electrodynamic forces during the lightning strike . The propagation of the spectral componention produced by the shock wave is at right angles to the chanel for the higher frequencies but omni directional for lower frequencies . The results is a series of rumbling and crackling sounds that vary according to the distance of the observer from the lightning channels and the direction taken by the channels .

٦- Induction effects :-

Pace voltage dispersion of lightning currents in the soil depends on the nature of the terrain . A heterogeneous soil may create dangerous differences of potential between two neighbouring points .

Discharge Penomenon

From the cloud base generally charged a low luminous discharge known as the tracer , is released . This makes its way to the ground in leaps of some tens of meters . It is in fact series of discharge each taking the route ionized by the previos discharge with an interruption of ٤٠ to ١٠٠ us (average speed of progression of ٠.٥ to ١ m/us)
As it approaches the ground , the highly charged tip of the tracer causes the electric field vertically below it to increase considerably ,possibly eaching values of ٤٠٠ to ٥٠٠ kv/m .

When the ionization threshold of the atmospheric air is reached (٣٠ kv/ cm) at points highly prone to lightning (tree tops, chimneys, lightning conductors, etc) jets released .
Where the field values are are the hightest , this jet with the best triggering

characteristics, or which travels most quickly, will reach the leader. This forms an ionized channel providing the perfect electrical junction between the storm cloud and the ground .. There is a return stroke from ground to the cloud by which it neutralizes its own charge. Within the space of ٠.٢ to ١ seconds, several lightning stokes may be exchanged in continous progression and at a very high propagation speed .

Lightning Protection System

Until recent years, people thought that the installation of a lightning conductor provided a building sufficient protection against lightning . This partial protection is now supplemented by a set of compatible devices designed to protect against direct strikes avoid dangerous differences of potential between neighbor points of the building, prevent induction effects on switch gear and electrical conductors and suppress overvoltages conveyed on network lines .

Lightning Protection

١-Lightning Conductors :-

For these systems tapered rods are pleced at the highest point of the building to be protected . The rods are connected to the ground via shortest way. The protection they provide depends on their installation point and hight above surrounding structure.
Based on the model method provides a reliable calculation of the protection level .

Rods fitted with ionizing devices follow the same rules but the excitation distance is slightly improved (١.٥ to ٣ times) because the arcing delay is reduced .

Their advantage lies in increased efficiency especially where low intensity lightning strikes are concerned, and they have led to a reduction in the height of the rods which was sometimes hardly feasible.

٢- Mesh Method :-

Protection by mesh method involves installing a large mesh Faraday cage on the top of the building and connected to the ground . Small rods (o.٥m) called strike points are installed at all emerging points around the roof meshes (chimneys, roof top structures, etc .)
The choice of the protection system depends on :-

١-The technical possibilities offered by the various procedures. Taking into account (for exemple theat a meshed cage can only protect what it surrounds)

٢-Cost and pehysical properties of the system .

EARTHING

Special care must be given to setting up ground connection given the importants of their role in the efficient operation of lightning conductors standards NF C ١٧-١٠٠ and NF C ١٧-١٠٢ stipulate that each down conductor must have aspecific earthing with different dimensions for cages and roads. The electrical ground or the existing belt is connected to them to provide equipotentially. Finally it is important to keep down conductors earthings well away (٣ to ٥ meters) from any burned metal pipe of electrical conduct and to ensure that ohmic value does not exceed ١٠ ohms with alow wave impedance.

References Standards

Standard NF C ١٧-١٠٠

This standard sets out to the extent of present knowledge and techniques the arrangements required for obtion adequate protection and provides information about the means required to set up this protection its deals with ;

-Franklin rods

-Protection by meshed cage

-Protection by tight

Standard NF C ١٧- ١٠٢

The standard concerns systems using early streamer emission devices .

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-Franklin rods

-Protection by meshed cage

-Protection by tight strands

Standard NF C ١٧- ١٠٢

The standard concerns systems using early streamer emission devices .

Franch Standard

NF C ١٧-١٠٠ Protection of structures against lightning.
NF C ١٧-١٠٢ Protection of structures and open areas by early streamer emission lightning conductors.
UTEC ١٧-١٠٦ Lightning strike counter.
NF C ٦١-٧٤٠ Surge protection devices for LV facilities.
UTEC guide to install LV protection systems.

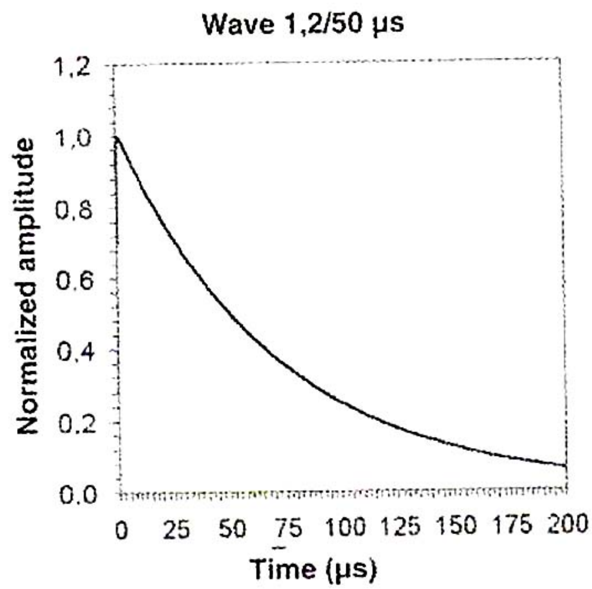
International Standards

IEC ٦١-٦٤٣ (١ and ٢) over voltage protection systems connected to LV distribution networks .

IEC ٦١-٠٢٤ (١ and ٢) structure protection.
IEC ٦١-٣١٢ Protection by outdoor lightning protection system.

IEC ٦١-٦٦٢ Assessment risks and damages associated to lightning

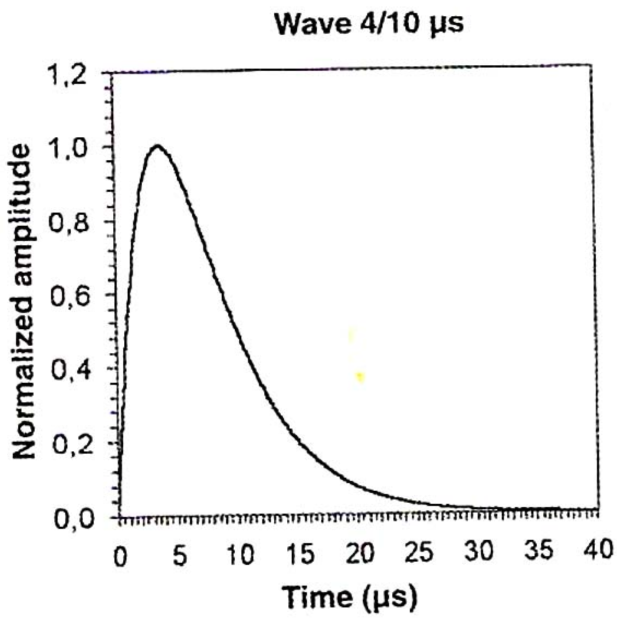
IEC ٦١-٦٦٣ Telecommunication lines.



Reference Lighning Waves

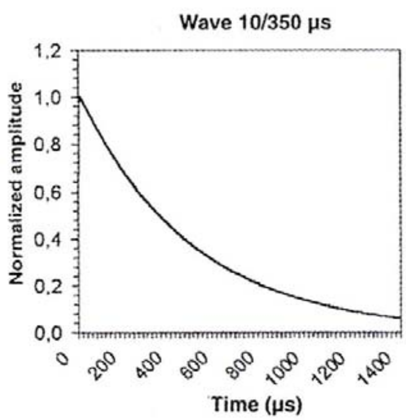
Basic characteristics of lightning currents:-

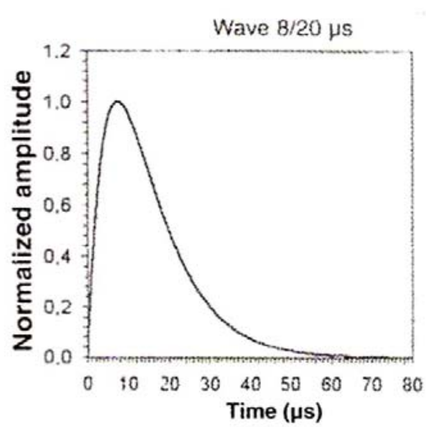
The electrical discharge of lightning generates a current wave whose form depends on geometric parameters (altitude, height and radius) and electrical parameters (electrical field and charge) of the storm cloud . the most widely accepted form of the lightning wave is the bi-exponential form. This is defined by three parameters : the maximum value or peak (amplitude) I max the total rise time TM , and the mid – amplitude tail time TQ .



I(t) = I ٠ (e –t / T ١ – e –t / T ٢)
The constants
di/ dt (t= T M) = O   I(t=T M) =I max   I(t= T Q) = I max / ٢
The experimental measurements carried out on the parameters Imax , TM and TQ of lightning as shown in IEC ٦١٠٢٤ -١-١ reproduced in NF C ٧ – ١٠٢ show that for each of these parameters there is a corresponding distribution function giving for each value of the parameters , the probability of a lightning strike with a value greater than or equal to the quantity it defines . In the laboratory the current wave forms most widely used for testing a

protection devices resistance to lightning are the ١.٢/٥٠ , ٤/١٠ , ٨/٢٠ and ١٠/٣٥٠ ms waves . The ratio of characteristic power conveyed by each of these waves over the square of the corresponding maximum current Imax , is a constant whose value is approximately equal to ٣.٦١٧ ١٠-٥, ٦.٨ ١٠-٦, ١.٣٨ ١٠-٥ and ٢.٥٣ ١٠-٤J/W respectively .
For the same characteristic energy , it is possible to determine the ratio between the peak current of these waves . The table below give the coefficient by which the maximum current of the waves shown in the first column having the same characteristic energy .





Lightning Protection Requirement Level Determination

(According to the German Standard ٥٧١٨٥)

Before the lightning protection systems is installed for any establishment, first the protection level mest by determined.

Choosing Protection level by calculation

First equivalent collection area ,Ae is calculated

a; Maximum width of structure

b ; Maximum length of structure

H ; Maximum heigh of structure

Ae = a.b + ٦. H. (a + b) + ٩.π.H٢

Lightning flash density is determine

Nd = Ng .Ae . Ce . ١٠

Ng is accepted approximately ٢ or Td value determineted from the annual chart of thunderstorm days and then calculated

Ng = ٠.٠٤ . Td ١.٢٥

Nc the annual frequency of lightning that can damages structure , is calculated .

Nc = A . B . C

A = A١ . A٢ . A٣ . A٤

B = B١ . B٢ . B٣ . B٤

C = C١ . C٢ . C٣

Nd ≤ =Nc if Nd≤ =Nc protection is optional

Nd ≥ Nc E= ١- (Nc / Nd)

Activity	Level protection
o.٩٨ ≤ E	level ١ A M
٠.٩٥ ≤ E ≤ ٠.٩٨	level ٢
٠.٩٠ ≤ E ≤ ٠.٩٥	level ٣
٠.٨٠ ≤ E ≤ ٠.٩٠	level ٤
٠ ≤ E ≤ ٠.٨٠	level ٥
E ≤ ٠	The protection is not necessary

Selection Table of A,B,C, Protection Factors for Level Calculation
1

Environment coefficient	Ce
Surrounded by structures or trees of the same higher environment	o.٢٥
Surrounded by smaller structures	٠.٥
Isolated : no other structures withen adistance equal to ٣h	١
Isolated on top of hill	٢

Structures wall coefficient	A١
covered metallic surface	٥

Concrete with electrical continuity	٤
Common concrete	٠.٥
Wooden or flammable	٠.١

R٠٠f plating coefficent	A٢
Steel	٤
Concrete	٢
Prefabricated	٠.٥
Wooden	٠.١

Roof platting coefficient	A٣
Concrete	٤
Sheet iron	٢
Tile	١
Pvc platting	٠.٥

Coefficient of equipment on the roof	A٤
nothing	١
Earthed antennas and metals	٠.٦
Electrical equipment	٠.٢

Panic coefficient	B١
No panic danger	١
Medium panic danger	٠.١
Serious panic danger	٠.٠١

Fire Coefficient	B٢
No flammabile , no catching fire	١
Flammabile	٠.٢
Explosion danger	٠.١
Flammabile , explosive	٠.٠١
Nuclear establishment	٠.٠٠١

Structure equipment coefficient	B٣
Very simple equipment	١
Precious equipment	٠.٢
Especially precious equipment	٠.١
Very precious equipment	٠.٠١

Fire deflating coefficient	B٤
Automatic fire deflating sys.	١٠
Reducing fire	٥
Fire protection	٢
No precaution	١

Environment damage coefficient	C١
None	١
Moderately	٠.٥
High	٠.١
Very high	٠.٠١

Substructure service coefficient	C٢
No interruption	١
Partial interruption	٠.١
Exactly interruption	٠.٠١

Other damage coefficient	C٣
Few	١
Moderately	٠.٥
High	٠.١
Very high	٠.٠١

Lightning Risk Assessment
(According to the France Standard NF C ١٧-١٠٠ and NF C ١٧-١٠٢)

Defintion of Lightning Risk

The risk of lightning is the annual probability of damage by direct or indirect lightning strike at the given place . Standard NF C ١٧ -١٠٠ and NF C ١٧ – ١٠٢ describe the methods for calculating the lightning risk and the choice of protection level for an outdoor lightning protection system . The evaluation of lightning risk is summarized below .

The lightning risk is assessed using varios criteria for the determining the protection need and required protection level (efficiency of protection) . The evalution of lightning risk takes into account the lightning risk and the following factors :-

-Environment of the building (coefficient C١)
-Type of construction (coefficient C٢)
-Structure content (coefficient C٣)
-Structure occupancy (coefficient C٤)
-Consequence of a lightning strike (coefficient C٥) .For any lightning protection system , the protection level of the devices set up must be determineted .

Firstly Nd has be calculated . This is the average annual frequency of direct lightning strikes on a structure .

Nd = Ng . Ae .C١ . ١٠ (where Ae is the equivalent collection area of the structure considered)

Ae = L x W + ٦H .(L + W) + ٩πH

Example : A building of length L=٥٠ m width w=٢٠m and height H = ٣٠ m

Ae = ٥٠ x ٢٠ + ٦ x ٣٠ x(٥٠ x ٢٠) + ٩. Π. ٣٠

Ae = ٣٩٠٤٦ m٢

Then Nc is calculated. This is the lightning frequency accepted by the studied structure

Nc = C٢ . C٣ . C٤ . C٥

The efficiency of the protection to be installed is expressed by the following equation : E = ١ – (Nc / Nd)

Lightning Conductor Technical Specification

١-Lightning conductor should run by piezoelectric system or electrostatic field effect system. There is no any radioactive matter inside it.

٢-lightning conductor should have the test certificate for being in compliance with French standard NFC ١٧ ١٠٢.

٣-lightning conductor should be serviceable and be made of a kind of material that does not suffer from electrochemical corrosion so that it is not effected by rain and bad weather conditions and be covered.

٤-lightning conductor sould run by well throughout ٢٤ hours in any atmospheric conditions.

٥-it should have an operation and non corrosive guarantee for ٢٥ years . the guaranteed period must also cover the damages of lightning conductor taken during discharges.
٦-the firm witch had mounted the system and the firm manufacturing the lightning conductor should have the quality management certificate ISO ٩٠٠١:٢٠٠٠
.
٧-superiority of (t) triggering should be in compliance with NFC ١٧ ١٠٢ Standards.

٨-it should have an arrangement ensuring that the active part is effected less during lightning discharges .so , there should not extra Attachement component like cables etc.

٩-lightning conductor should be functional in cases of both positive and negative lightning.

١٠-the operational performance of lightning conductor should be tested in case of nessity.

١١-lightning conductor materials except headgear should be in compliance with TS ٥٠١٦٤-١.

١٢-The staff on duty for insulation should be insured.

١٣-the weather conditions should be taken into consideration while mounting and demounting and it should be not worked on rainy days certainly.

١٤-lightning conductor pole should be durable and sound in spite of any weather conditions and the external factors also be support the lightning conductor that has minimum ٢"diameter safely.

١٥-lightning conductor should be settled on to the highest possible point on the structure . if there are antenna pole , parapet pole etc . on the structure , unite should be higher than of these point.

١٦-if the lightning conductors pole is higher than ٧ meters , it should be fixed by stretched wires from three points at least.

١٧-the whole metal installation placed one meter near by the down conductr (antenna , parapet poles etc .) should be connected electrically to the down conductor . connection points should consist of the same materials with the down conductor .

١٨-down conductor should be ٢*٥٠ mm mono copper or ١*(٢٥*٣)mm copper strip.

١٩-the down conductor should be installed as straight as possible along the shortest path to the ground without any sharp bends.

٢٠-the conductor should be fixed by using copper conductor clips at intervals on ١٠٠ cm . for installing over the vertical or horizontal surfaces and at intervals on ٥٠ cm for installing horizontally over the vertical surfaces.

٢١-the down conductor requires being seamless. When it has to be jointed on the conductors , joints should be stretched by screws or rivets or exothermic welding and be made safe electrically or mechanically . it should not joint by soldering.

٢٢-the test clamps should be settled just over the protective pipe . clamps should be made especially for this aim by using copper or brass and be fixed by galvanized clamps strongly.

٢٣-mounting the lightning stroke counter just over the testing clamp that can be useful for controlling the lightning rod head and determination the maintenance period.

٢٤-from withen isolated galvanized protective pipe in ١/٤" diameter should be replaced ٢٠٠ cm . above the ground and ٥٠ cm. below the ground where the down conductor meets with the ground.

٢٥-Earthing should be done with conductors that have length of at least ٢٠m or ٤ unit vertical earthing rods with each length of ١.٥ m . The distance between earthing rods should be more than two times long than rod length .

٢٦-The connections below the ground should be made by exothermic welding for prevention the corrosion .

٢٧- The top ends of the earthing rods and conductors should be buried into a minimum of ٥٠cm deep below the ground In addition these electrodes should be buried deeper the edge of the starting of the freezing depth and the earth moisture in the arid regions below the ground . The earth conductivity had to increase using additive materials supported from undertaken firm .

٢٨-If earthing plates are to be used , they should be buried vertically into ground.

٢٩- It should be obtained passing resistans lower than ٥ ohm after earthing .

٣٠- If the required passing resistance value cannot be obtained by using earthing rods up to ٤ units, then the required earth resistance value will be reached by using ground enhancement chemical materials or extra electrodes .

٣١- When the installation is completed , the earth resistance be measuring by licenced personnel should be reported with the confirmation of firms authorized engineer. The engineer confirming the earth resistance , should have the expertise certificate in the subject of earthing procured by electrical engineering commission and a copy of this certificate should be delivered with the earthing test report after the work is over.