Lighting Impulse Testing and Insulation Coordination.

IEEE PES Meeting
St Pete's Beach
May 12, 2005

PART 1 of 2

Larry Farr
USNC SC 17A

Agenda

Lighting, Transmission and Distribution Systems = Steve Lambert

BIL Testing and Methods= Larry Farr

Chopped Wave Method and Testing = Mel Smith

Impulse Testing 3X 9 Method = Bill Long

Statistical Comparison of Test Method = David Peelo by Larry Farr

Insulation Coordination and BIL = Steve Lambert

Impulse Testing and the IEC = Dennis Dufournet

Section 2: General Definitions

3 Impulses

An impulse is an intentionally applied aperiodic transient voltage or current which usually rises rapidly to a peak value and then falls more slowly to zero.

For special purposes, impulses having approximately linearly rising fronts or transients of oscillating or approximately rectangular form are used.

The term "impulse" is to be distinguished from the term "surge" which refers to transients occurring in electrical equipment or networks in service.

3.1 *Lightning and switching impulses*

A distinction is made between lightning and switching impulses on the basis of duration of the front. Impulses with front duration up to 20 μs are defined as lightning impulses and those with longer fronts are defined as switching impulses.

Generally, switching impulses are also characterized by total durations considerably longer than those of lightning impulses.

4 Characteristics related to disruptive discharge and test voltages

4.1 *Disruptive discharge*

In this standard, the term "disruptive discharge" (sometimes referred to as "electrical breakdown") relates to phenomena associated with the failure of insulation under electrical stress, in which the discharge completely bridges the insulation under test, reducing the voltage between the electrodes practically to zero. It applies to electrical breakdown in solid, liquid and gaseous dielectrics and combinations of these.

Non-sustained disruptive discharge in which the test object is momentarily bridged by a spark or arc may occur. During these events the voltage across the test object is momentarily reduced to zero or to a very small value. Depending on the characteristics of the test circuit and the test object, a recovery of dielectric strength may occur and may even permit the test voltage to reach a higher value. Such an event should be interpreted as a disruptive discharge unless otherwise specified by the relevant Technical Committee.

Non-disruptive discharges such as those between intermediate electrodes or conductors may also occur without reduction of the test voltage to zero. Such an event should not be interpreted as a disruptive discharge unless so specified by the relevant Technical Committee.

Some non-disruptive discharges are termed "partial discharges" and are dealt with in IEC Publication 270: Partial Discharge Measurements.

The term "sparkover" is used when a disruptive discharge occurs in a gaseous or liquid medium.

non-sustained disruptive discharge (NSDD)
disruptive discharge associated with current interruption, that does not result in the resumption of power frequency current or, in the case of capacitive current interruption does not result in current at the natural frequency of the circuit.

18 Definitions for lightning impulse tests

18.1 *Definitions of general applicability*

These definitions apply to impulses without oscillations or overshoot or to the mean curve drawn through the oscillations and overshoot.

18.1.1 *Full lightning impulse*

A full lightning impulse is a lightning impulse which is not interrupted by a disruptive discharge

18.1.2 *Chopped lightning impulse*

A chopped lightning impulse is a lightning impulse during which a disruptive discharge causes a rapid collapse of the voltage, practically to zero value. The collapse can occur on the front, at the peak or on the tail.

NOTE — The chopping can be accomplished by an external chopping gap or may occur due to a discharge in the internal or external insulation of a test object.

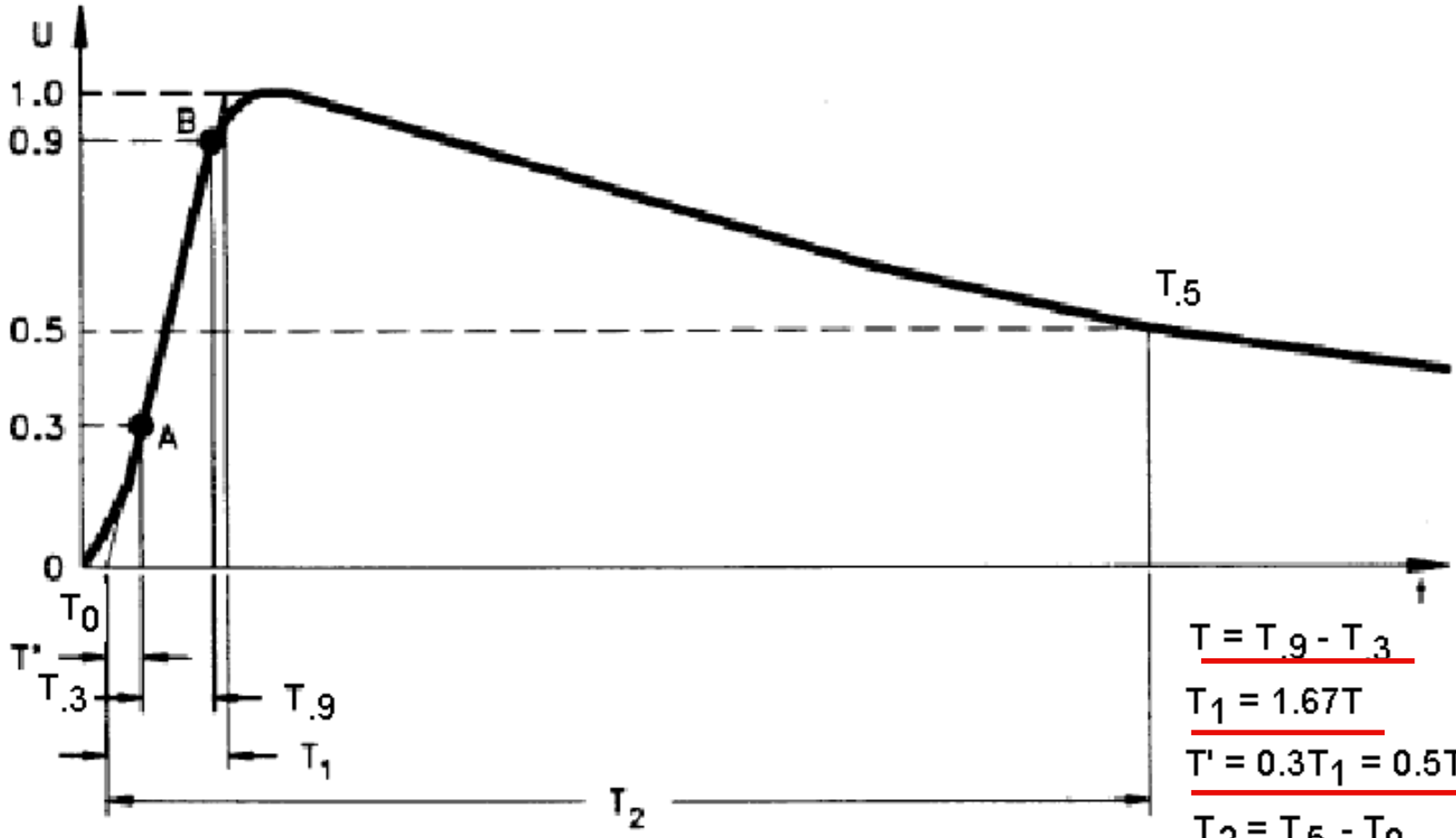
18.1.3 *Value of the test voltage*

For a lightning impulse without oscillations, the value of the test voltage is its peak value.

The determination of the peak value in the case of oscillations or overshoot on standard lightning impulses is considered in 19.2.

For other impulse shapes (see for example figures 10 e–h) the relevant Technical Committee shall define the value of the test voltage taking into account the type of test and test object.

Full lightning impulse.



$T = T_{.9} - T_{.3}$

$T_1 = 1.67T$

$T' = 0.3T_1 = 0.5T$

$T_2 = T_{.5} - T_0$

19 Test Voltage

19.1 *Standard lightning impulse*

The standard lightning impulse is a full lightning impulse having a front time of 1,2 μs and a time to half-value of 50 μs. It is described as a 1,2/50 impulse.

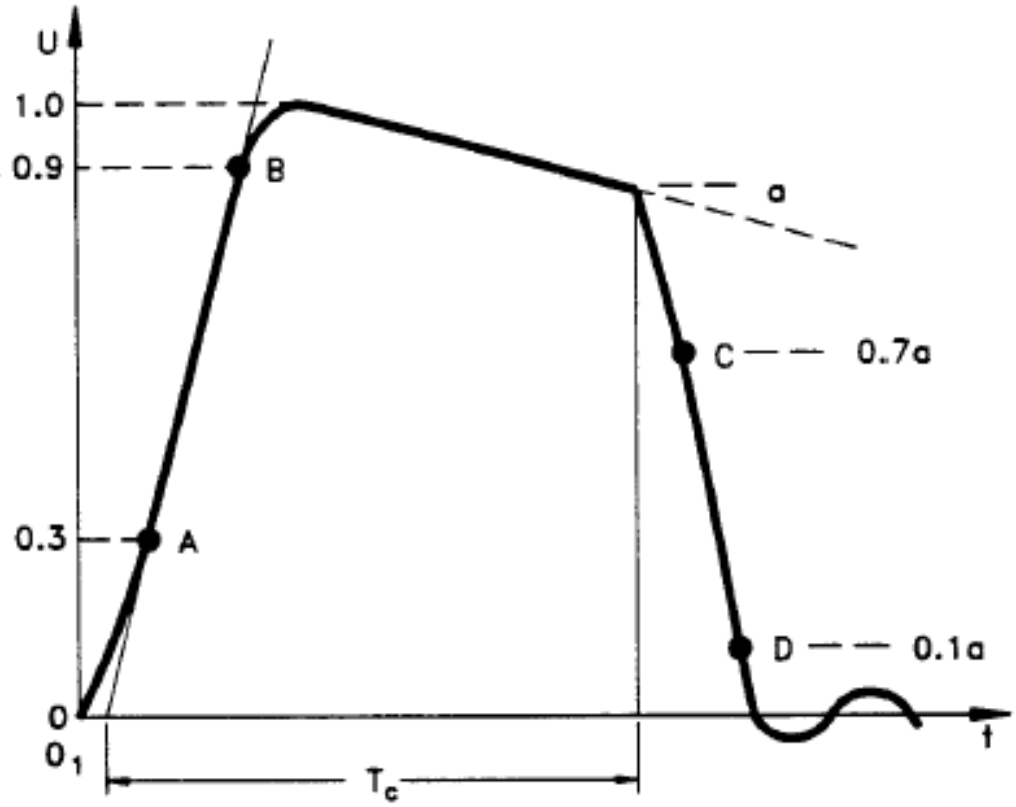
19.2 *Tolerances*

If not otherwise specified by the relevant Technical Committee, the following differences are accepted between specified values for the standard impulse and those actually recorded:

Peak value	±3%
Front time	±30%
Time to half-value	±20%

NOTE 1 — It is emphasized that the tolerances on the peak value, front time and time to half-value constitute the permitted differences between specified values and those actually recorded by measurements. These differences should be distinguished from measuring errors which are the difference between the values actually recorded and the true values. For information on measuring errors, see IEC Publication 60-3 and 60-4.

Lightning impulse chopped on the tail.



11 Atmospheric conditions

11.1 *Standard reference atmosphere*

The standard reference atmosphere is:

temperature $t_0 = 20°C$

pressure $b_0 = 101{,}3$ kPa (1013 mbar)

absolute humidity $h_0 = 11$ g/m^3

NOTE — A pressure of 101,3 kPa corresponds to the height of 760 mm in a mercury barometer at 0°C. If the barometer height is H mm of mercury, the atmospheric pressure in kilopascals is approximately:

$$b = 0{,}1333H \text{ kPa}$$

Correction for temperature with respect to the height of the mercury column is considered to be negligible.

Eaton Electrical Arden Plant

BIL Calculation Chart

5/5/2005 9:17

Phone Number 681-0131 Call AVL Airport Weather Station

Calibrated Rod Dia =	0.813	Inches	BIL Level =	60000	kVolts
Reported Pressure	30.1	In Hg	+3%	56022	
Temperature	79	Deg F	Arc Volts	54390	
Elevation of Plant Floor	2204.12	Feet	-3%	52758	

Tolerance of Arc Voltage +or - 3% ***

Pressure Adjustment for Elevation

Do not count any voltages outside these values.

H = 1,600,000((P1-P2)/(P1+P2))*(1-0.004(t1-t2) In cm

H= change in elevation in (cm)

P1 Barometric Pressure at Sea Level in Feet

P2 Barometric Pressure at Site in Feet

H1 change in elevation in Feet

Adjusted For Elevation in Feet. Temperature is assumed to be the same.

H1/52,493= ((P1-P2)/(P1+P2))

Adjustment Factor = (1-H1/52,493)/(1+H1/52,493)

Af = 0.919 Or 27.67

**Kd = (P/Po)x[(273+to)/(273+t)]

Po=	29.913	In Hg
to=	20	Deg C
t=	26.11	Deg C
P	27.68	In Hg
Kd	0.9065	

*Formula from Handbook of Chemistry and Physics 47 Edition Page F-58

**Formula from IEEE Std 4-1978 Paragraph 5.5.3.2.1

*** From IEC 60060 - 1982

Arc Voltage	BIL	Arc Voltage	BIL	Arc Voltage	BIL
45000	49641	61000	67292	77000	84942
46000	50744	62000	68395	78000	86045
47000	51848	63000	69498	79000	87148
48000	52951	64000	70601	80000	88251
49000	54054	65000	71704	81000	89354
50000	55157	66000	72807	82000	90458
51000	56260	67000	73910	83000	91561
52000	57363	68000	75014	84000	92664
53000	58466	69000	76117	85000	93767
54000	59570	70000	77220		
55000	60673	71000	78323		
56000	61776	72000	79426		
57000	62879	73000	80529		
58000	63982	74000	81632		
59000	65085	75000	82736		
60000	66188	76000	83839		

Test Procedures ; IEC 60060-1/IEEE 4

20 Test Procedures

20.1 *Withstand voltage tests*

The recommended test procedure depends on the nature of the test object, as defined in Clause 5. The relevant Technical Committee shall specify which procedure shall be applied.

Classifications of insulation in Test Object

5 Classification of insulation in test objects

Insulation systems of apparatus and high voltage structures must basically be classified into self-restoring and non-self-restoring insulation and may consist of external and/or internal insulation.

5.1 *External insulation*

External insulation is the air insulation and the exposed surfaces of solid insulation of the equipment, which are subject both to dielectric stresses and to the effects of atmospheric and other external conditions such as pollution, humidity and vermin.

5.2 *Internal insulation*

Internal insulation comprises the internal solid, liquid or gaseous elements of the insulation of equipment, which are protected from the effects of atmospheric and other external conditions such as pollution, humidity and vermin.

Classifications of insulation in Test Object

5.3 *Self-restoring insulation*

Self-restoring insulation is the insulation which completely recovers its insulating properties after a disruptive discharge caused by the application of a test voltage.

5.4 *Non-self-restoring insulation*

Non-self-restoring insulation is insulation which loses its insulating properties, or does not recover them completely, after a disruptive discharge caused by the application of a test voltage.

NOTE — In high voltage apparatus, parts of both self-restoring and non-self-restoring insulation are always operating in combination and some parts may be degraded by repeated or continued voltage applications. The behaviour of the insulation in this respect shall be taken into account by the relevant Technical Committee when specifying the test procedures to be applied.

Procedure A; 3x0 IEC 60060-1/IEEE 4

20.1.1 *Withstand voltage test: Procedure A*

Three impulses of the specified shape and polarity at the rated withstand voltage level are applied to the test object. The requirements of the test are satisfied if no indication of failure is obtained, using methods of detection specified by the relevant Technical Committee.

NOTE — This procedure is recommended for tests on degradable or non-self-restoring insulation.

Procedure B; IEC 60060-1/IEEE 4

20.1.2 *Withstand voltage test: Procedure B*

Fifteen impulses of the specified shape and polarity at the withstand voltage level are applied to the test object. The requirements of the test are satisfied if not more than two disruptive discharges occur in the self-restoring part of the insulation and if no indication of failure in the non-self-restoring insulation is obtained by the detection methods specified by the relevant Technical Committee.

Procedure C; IEC 60060-1/IEEE 4

20.1.3 *Withstand voltage test: Procedure C*

Three impulses of the specified shape and polarity at the withstand voltage level are applied to the test object. If no disruptive discharge occurs the test object has passed the test. If more than one disruptive discharge occurs the test object has failed to pass the test. If one disruptive discharge occurs in the self-restoring part of the insulation, then nine additional impulses are applied and if no disruptive discharge occurs the test object has passed the test.

If any detection of failure in a non-self-restoring part of insulation is observed with the detection methods specified by the relevant Technical Committee during any part of the test, the test object has failed to pass the test.

NOTE — This procedure corresponds to an American practice modified so as to be statistically equivalent to Procedure B.

Procedure D; IEC 60060-1/IEEE 4 Waybill Method

20.1.4 *Withstand voltage test: Procedure D*

For self-restoring insulation the 10% impulse disruptive discharge voltage U_{10} may be evaluated by using statistical test procedures described in Appendix A.

These test methods permit either direct evaluation of U_{10} and U_{50} or indirect evaluation of U_{10}.

In the latter case U_{10} is derived from the U_{50} value using the relationship:

$$U_{10} = U_{50}(1 - 1,3z)$$

The relevant Technical Committee shall specify the value to be assumed for the conventional deviation z of the disruptive discharge voltage. For dry tests on air insulation, without any other insulation involved, the per-unit value $z = 0,03$ can be used.

Procedure D; IEC 60060-1/IEEE 4 Waybill

The test object is deemed to be satisfactory if U_{10} is not less than the specified impulse withstand voltage.

The following test methods can be used to evaluate U_{50}:

a) the multiple-level method (see Clause A.1.1) with $n \geq 4$ voltage levels, and $m \geq 10$ impulses per level;

b) the up-and-down method (Clause A.1.2) with $m = 1$ impulse per group and $n \geq 20$ useful applications.

To evaluate U_{10}, the up-and-down withstand method, with $m = 7$ impulses per group and at least eight useful groups, can be used.