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CHAPTER I

GENERAL THEORIES

Introduction

A large percentage of electrical disturbance in electrical power system is caused by voltage surges of short duration on electrical installations and on their individual parts. Sometimes, expensive equipment is exposed to these voltage surges.

The surge being such as are caused especially by lightning discharges of atmospheric origin, which are brought about by static charges and lightning (direct or indirect) strokes to the conductors of a high voltage transmission line.

The direct stroke actually contacts some parts of the power system, and the indirect stroke only effects the system by inducing a voltage in it. These two types of strokes give rise, on the conductor of the system, to direct and indirect lightning surges.[2]

This lightning stroke, which, is a component discharge of a complete lightning flash, represents the discharge of one of the charge centres of a thunder cloud.[3]

Purpose

Since the lightning surge is the most usual cause of outage and damage on the electrical installations. The insulation of the various component parts of the system is advisedly co-ordinated in such a way that

1. a limit is set by co-ordinated protective devices to a maximum amplitude of overvoltage that may be left on the system.

2. the insulation of connected apparatus is graded electrically in order to safeguard important units and localize the possible points of failure to places

which are accessible and where repairs and replacements are readily effected.

The impulse voltage tests are then recommended with the object of determining the effect of voltage surges of short duration on insulations by means of an impulse generator. And the experimented data, such as, wave shapes, magnitudes, rates of change of impulse voltages are important results.

It is the purpose of this thesis to deal the art and technique of design and construction of the small 32 KV. impulse generator, and to obtain its results, in an effort to fill a need which is left to be overdue.

Theories relating to lightning surges

Elster and Geitel's Influence Theory[4]

They consider a large water drop falling toward the earth in the earth's electric field. Because of this field the drop will be polarized, with its top negative and bottom positive. In its fall through the air, the large drop catches up with a smaller one which, because of its size, is decending at a slower rate. The smaller drop is also polarized, with its top negative and bottom positive. When the smaller drop makes electrical contact with the lower surface of the large drop, it will gain a positive charge. The large drop will gain a corresponding negative charge. The small drop will then be carried upward in the rising air current, taking along its positive charge. These meetings of large and small drops, the exchange of charge between them, and their separation by the action of gravity and air currents will occur again and again. Thus a separation of electricity occurs which continually increase the field until lightning discharges occur.

Simpson's Breaking Drop Theory[4,5]

The upward air currents, which exist in active thunderstorms carry condensing water drops. Until they join with other drops and grow larger and move against the rising air currents due to the force of gravity. They soon break up into many small droplets which lie the electrification process of thunderstorms. When the drops break, negative ions are released into the air, while the water drops become positive charged. The negative ions joining with minute cloud particles are carried upward by the rising air currents. to the upper regions of the thunderstorm. The rain drops acquire a higher positive charge and accumulate in the lower part.

In figure 1-1, the lower region of positive charge is located at the head of the strong upward current, to the rear of this region the vertical current is weaken and the heavy rain which falls out is positive charged. Apart from the local region of positive charge and the lower half of the cloud is negatively charged.

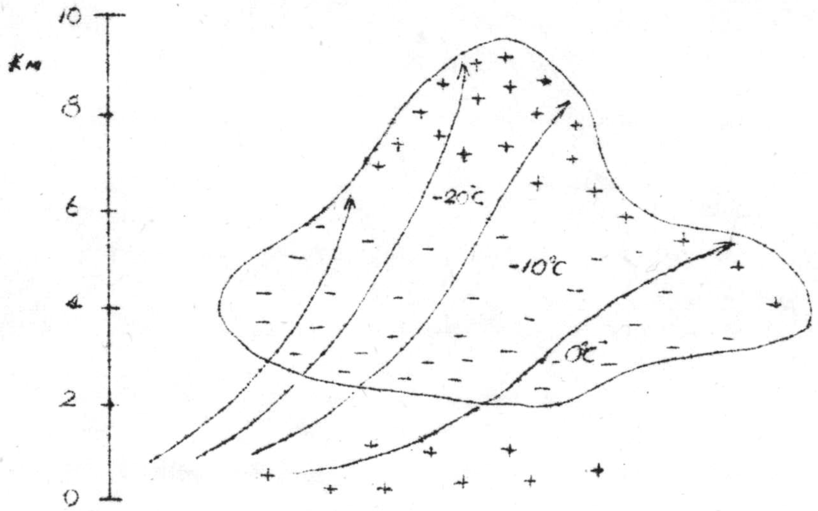


Fig. 1-1 Generalized diagram showing air current and distributed of electricity in a typical thunderstorm

The region of separation between the negative charge and the upper positive charge occurs at a level where the temperature is between 0°C and -20°C. For this reason, it is considered that the generation of the upper charge depends upon the presence of ice crystals and not on the water drops. The position of the lower positive charge supports the idea that it is generated by the breaking-drop process.

Formation[6] of Lightning Surges

In the thundercloud, the strong rising air current and the freezing water droplets cause the separation of the accumulated charges. As these charges are separated, they proceed the potential between the cloud base and the earth below.

The potential gradient in the vicinity of the earth surface seldom exceeds 100 V/cm, while the potential gradient in the clouds is some hundred times greater than this, With the result that, as the critical break down strength of the air is exceeded, a discharge process is precipitated downwards, resulting eventually in the familiar lightning stroke, which, more oftenly, lowers negative charge from the cloud base to ground.

Thus the majority of the lightning surges on transmission lines are of negative polarity. There are only a few lightning surges of positive polarity. The ratio of negative to positive strokes is about 3 : 1. If there is a selective effect, as for strokes to transmission lines, this ratio rises to 8 : 1.

The field strength needed for a stroke is of the order of 100 KV/m with a peak current of partial discharge up to 200 KA. The average stroke has a charge of about 30 conlombs.

Definition[1] of Impulse Voltage

Impulse Voltage

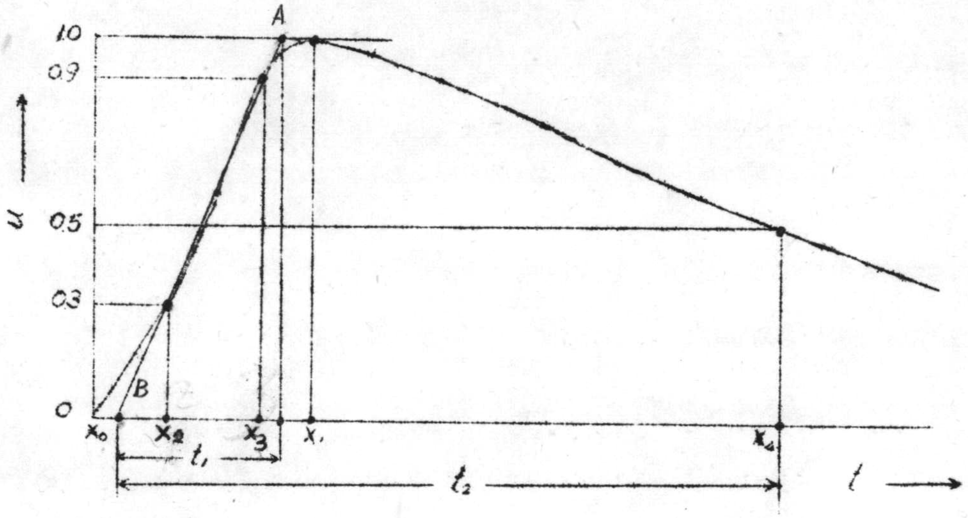
An impulse voltage is a unidirectional voltage which, without appreciable oscillations, rises rapidly to a maximum value and falls less rapidly to zero.

Peak Voltage

The peak voltage is the maximum value of the impulse, and the impulse voltage is specified by this value.

Amplitude Oscillation

Small oscillations are tolerated, provided that their amplitude is less than 5 per cent of the peak value of the impulse voltage. In such case, for the purpose of measurement, a mean curve for the voltage time characteristic of the impulse voltage shall be accepted. A full impulse voltage wave shape is given in figure 1-2.



7

Fig. 1-2 Analysis of impulse voltage wave shape.

Chopped Impulse Voltage

If an impulse voltage develops with causing flashover or puncture; that is, causing a sudden collapse of the impulse voltage. It is then called a chopped impulse voltage, figure 1-3.

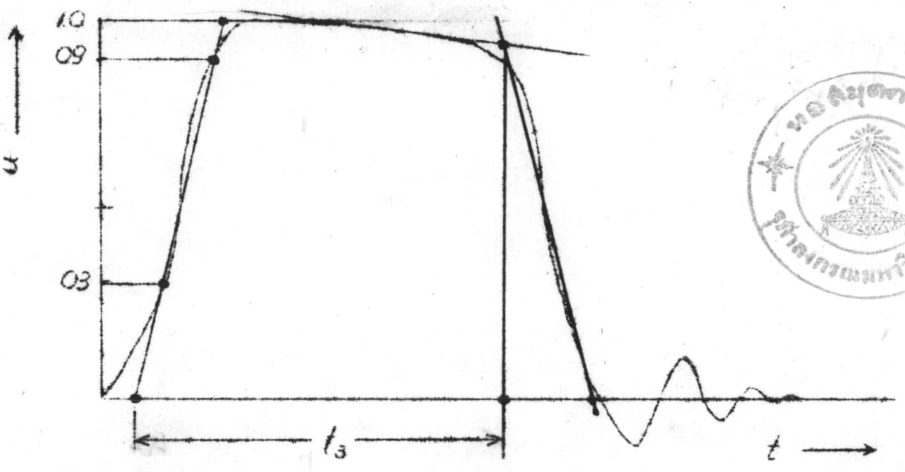


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Fig. 1-3[8] Chopped Impulse Voltage

Both full impulse voltage and chopped impulse voltage are characterized by two time intervals t_1 and t_2 defined Below, and is conveniently reffered to as a t_1/t_2 wave.

Wave-front

The wave-front of an impulse voltage is the rising portion of the voltage-time characteristic of the impulse voltage.

Wave-tail

The wave-tail of an impulse voltage is the following portion of the voltage-time characteristic of the impulse voltage.

Duration of the Wave-front (t_1)

The duration of the wave-front of an impulse voltage is the total time occupied by the impulse voltage in rising from zero to the peak value. For measurement, the nominal value t_1 of the duration of the wave front is defined as

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$$t_1 = 167\ X_2X_3 \qquad \ldots\ 1\text{-}1$$

Where X_2 is the point on the wave front where the voltage is 30 per cent of the peak value.

X_3 is the point on the wave front where the voltage is 90 per cent of the peak value.

Time to Half-value of the Wave-tail (t_2)

The time to half-value of the wave tail of an impulse voltage is the total occupied by the impulse voltage in rising to peak value and declining there-from to half the peak value of the impulse. For measurement, the nominal value t_2 is defined as

$$t_2 = X_oX_4 \quad \mu s \qquad \ldots\ 1\text{-}2$$

Where X_o is the point where the line **AB** cuts the time axis, and is referred to as the nominal starting point of the wave.

X_4 is the point on the wave tail where the voltage is one-half of the peak value.

Nominal Steepness of the Wave-front (S)

The nominal steepness of the wave-front of an impulse voltage is the average rate-of-rise of voltage measured between the points on the wave-front where the voltage is 30 per cent and 90 per cent of the peak value respectively, given as

$$S = \frac{\hat{U}}{t_1} \qquad \ldots\ 1\text{-}3$$

The nominal steepness of the front of an impulse voltage chopped on the front is the rate of rise of voltage measured between the points where the voltage is 30 per cent and 90 per cent respectively of the voltage at the instant of the chopping

Impulse Flashover Voltage

1. The 50 per cent impulse flashover voltage is the peak value of that impulse voltage which causes flashover of the object under test for about half the number of the applied impulses.

Flashover occurs at an instant subsequent to the attainment of the peak value. The value of the impulse flashover voltage depends on the polarity, the wave front and the wave tail of the applied impulse voltage.

2. Impulse flashover voltages in excess of the 50 per cent impulse flashover voltage :

2.1 The impulse flashover voltage for flashover on the wave-tail is the peak value of the impulse voltage which causes flashover on the wave-tail.

2.2 The impulse flashover voltage for flashover on the wave-front is the value of the impulse voltage at the instant of flashover on the wave front.

Impulse Puncture Voltage

The impulse puncture voltage is the peak value of the impulse voltage which causes puncture of the object under test when puncture occurs on the wave tail, and is the value of the voltage at the instant of puncture when puncture occurs on the wave front.

Impulse Ratio for Flashover

The impulse ratio for flashover is the ratio of the impulse flashover voltage to the peak value of the power-frequency flashover voltage.

For a given wave-shape, the minimum impulse ratio is the ratio obtained from the 50 per cent impulse flashover voltage.

The impulse ratio is not constant for any particular object, but depends upon the shape and polarity of the impulse voltage, the characteristics of which should be specified when impulse ratios are quoted.

Impulse Ratio for Puncture

The impulse ratio for puncture is the ratio of the impulse puncture voltage to the peak value of the power frequency puncture voltage.

The ratio is also not constant for any particular object, but depends upon the shape, polarity and manner of application of the impulse voltage. Information on these points should be given when impulse ratios are quoted.

Time to Flashover and Time to Puncture

The time to flashover and time to puncture are the durations of the impulse voltage prior to being chopped by flashover or puncture respectively. The nominal times are measured from the nominal start of the wave to the instant when chopping occurs.

Voltage Efficiency (η)

The voltage efficiency of an impulse generator is given by the ratio of the peak value of the impulse voltage to the applied voltage or charging voltage.

$$\eta = \frac{u_{peak}}{U_o} \qquad \ldots \quad 1\text{-}4$$

The efficiency depends upon the circuit elements, and it should be as high as possible for economic reasons.

Specified Standard Wave-shapes

The standard wave shape specified in B.S 923 is a 1/50 wave, that is a wave front of 1 μS. and a wave-tail of 50 μS. If a shorter wave is required, it is recommended that a 1/5-wave be used.

A tolerance of not more than 30 per cent on the duration of the wave front and ± 20 per cent on the wave tail is allowed.

The 1/50 wave is also that specified by the International Electrotechnical Commission and the **Verband Deutsher Elektrotechniker.**

The American Standard Association recommends a 1.5/40 wave, with permissible variations of ± 0.5 μS on the wave front and ± 10 μS on the wave tail.

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