EVOLUTION OF THE POTENTIAL TAKEN FROM A CHANNEL FILLED WITH AN ELECTROLYTE SUBMITTED TO AN ELECTRICAL DISCHARGE ENERGIZED BY AN ALTERNATIVE CURRENT AND CORRELATION WITH THE EMITTED LIGHT

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ABSTRACT

The models used to describe polluted insulators in order to characterize their behaviour to the flashover are very discussed and their application is delicate.

To complete the survey and to describe better the evolution of the flashover phenomenon, we present in this paper an optical survey of the propagation of the discharge on a channel filled with an electrolyte modelling a polluted insulator, as well as, the correlation with the electric parameters taken from an experimental device, finalized in the Electrical Engineering Laboratory of Toulouse.

Two zones of different lighting have been highlighted. In relation with the evolutions of the electric parameters, the extension of the foot of the discharge is bringing to the fore.

I. INTRODUCTION

Because the importance of electrical distribution system perturbations suffered due to flashover, numerous studies have been devoted to this phenomenon. Many models of partial discharge affected polluted insulators were used to predict the flashover utilizing a channel filled with an electrolyte. The objective of these studies was to understand why and how a discharge, ignited over a low conduction surface could spread until grounding a live conductor by an arc. The procedure followed was that of modeling the surface by an equivalent electrical circuit.

The models constitute the first indispensable step for the study, but their complexity increases as and when one approaches a real insulator. Moreover, the models described are static. In order to apply them, it is necessary to admit that the system passes through a series of stationary states of identical nature and [1]<< that at every point of the trajectory, the flashover criterion is fulfilled >>. Wilkins and Al-Baghdadi [2] have signaled the existence of a current parallel to the arc column in the electrolyte on an Obenaus type of model. Mercure and Drouet [3] have measured that current intensity directly and shown that during the flashover of a channel of electrolyte, the zone where the discharge current transfer towards the liquid takes place can spread over several centimeters. Cheng and Nour [4] have proposed a model comprising of several discharges in parallel compatible with this observation. Nevertheless, none of these models describes without additional hypothesis the physical phenomena which are responsible for the extension of the discharge and thus can not give an account of the dynamics of the flashover. Therefore, comes the idea of observing the discharge propagation while measuring the variation of electrical quantities which accompany it.

The present article will be oriented towards the study of 50 Hz sinusoidal voltage flashover because of its widespread use in the electrical energy distribution network in Europe.

II. EXPERIMENTAL DEVICES

Considering the measurements to be done at a very low voltage level in an environment very much polluted by the numerous disturbances caused by the presence of the discharge under high voltage, the problems of electromagnetic compatibility to be solved have been numerous and the apparatus set-up delicate. Its different parts are described in other references [5], [6], [7] and [8]. We recall here only their most important features.

In a Plexiglas mount, a 4 cm wide by 20 cm long channel has been cut; it is crossed lengthwise at regular intervals along its median by voltage tapping pins. It can be filled by an electrolyte and one can adjust its resistance per unit length either acting on the liquid level or on its resistivity by altering the concentration of the solute (ClNa) in the solvent (water). With this flashover observation cell, the H.V. supply to the discharge, and the sensors for electrical quantities are, with some modifications, common for the two types of optical measurements carried out.

The electronic camera THOMSON CSF - TSN 503 permits the visualization of fast and luminous phenomena. There are two advantages associated with it:

- A shutter grid placed near the photocathode at a lower potential prohibits the electron passage towards the back of the tube when the camera does not sweep; this eliminates all the background noise.

- The coupling between the output screen and the photographic films is realized by means of optical fibers avoiding thereby the utilization of a repeat objective: the luminous gain is thus 20 times more important than that of a standard camera. An auxiliary photomultiplier targets the space situated under the high voltage electrode and at the appearance of the discharge, delivers a pulse which is released with a camera adjustable delay. This one in return sends a synchronizing signal to the oscilloscope, which records the current in the discharge. In order to follow the evolution from one period to the other, the ignition was spontaneous and the recordings were guided by the signals emitted by the photomultiplier.

A new data acquisition device, described in references [9] and [10], permits more sensitive measurements than the camera of the emitted light intensity all along the channel and helps link them, in a reliable manner by making cyclic measurements at voltage tapping pins associated with light observation points. The tapping pins, under the channel can serve to measure the potential evolution all along its course. At a right angle to the channel, in the position of each of these tapping pins is placed an optical fiber, which targets the electrolyte-surface tangentially and permits to follow the variation of the emitted light. The different optical fibers are connected to a 64-channel photomultiplier tube, Philips X81722A. Its optical fiber entry window, in addition to its compatibility with those of the assembly, ensures a better protection against optical interference. This set is enclosed in a black-painted enclosure in order to limit the stray light. It is fed by a H.V. source, Brandebourg 2479 N and protected from the intense post-flashover light by a controllable inhibition module EA Protect.

The source current intensity is measured across the terminals of a resistance while the applied voltage drop and the potential evolution along the channel bottom are measured with the help of compensated voltage dividers.

The signals representing the electrical parameters as well as those issued from different channels of the photomultiplier tube are stocked in a data acquisition system, Keithley DAS-40. This one offers 16 analog channels admitting voltages of 10 V that an analog/digital converter stocks in a 12-bit format. The maximum acquisition speed is 250000 samples per second. A specific integrated software EASYEST LX permits the data treatment.

The great advantage of this device is that it permits the recording of quantities of different nature on the same event. This is the great contribution of the system because it is known that the dielectric breakdown is a random phenomenon and that, even by taking the greater precautions at the level of reproducibility of experimental conditions, there is always a certain statistical dispersion and that there are no two rigorously identical flashovers.

III. EXPERIMENTAL RESULTS

3.1 ELCTRICAL SIGNALS

On the figures 1 and 2 we have represented the applied voltage, the total current and the potentials in the electrolyte. We noticed that the potential progressively increase during the extension of the discharge till reaching a maximal value beyond which they begin to decrease. The total current constantly increases then during the flashover increases, then suddenly heightens during the arc crossing.

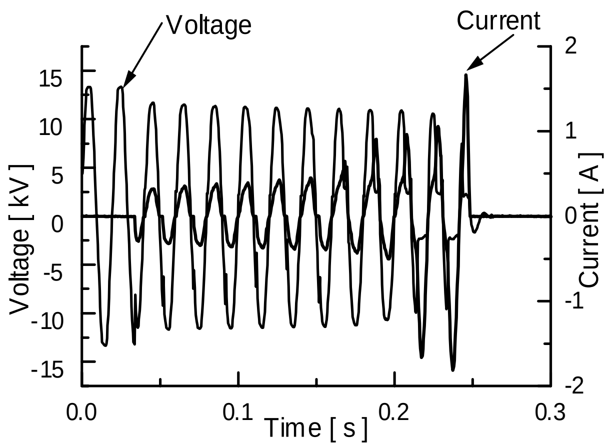
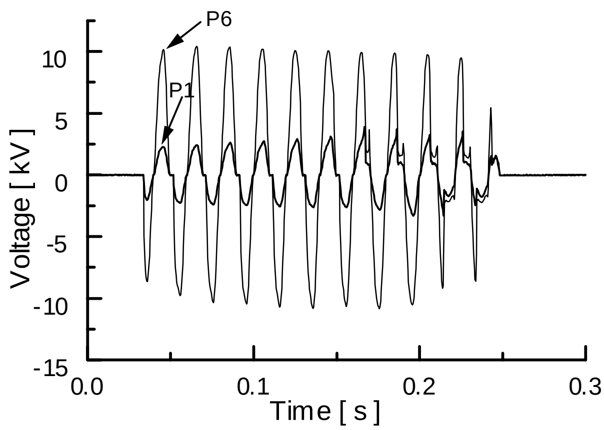


Figure 1. The applied voltage and the total current (V_{HV} = 13.2kV and r_p =5 $k\Omega$ /cm)



The potential plugs P6 placed at 2cm from HV electrode
The potential plugs P1 placed at 8cm from HV electrode

Figure 2. The potentials in electrolyte (V_{HV} = 13.2kV and r_p =5 $k\Omega$ /cm)

From the potentials taken in the electrolyte, we may estimate the current circulating in the canal. We will note I_i the current circulating between the abscissa points x_i and $\boldsymbol{x_{i+1}}$ correspondent respectively to the potential plugs P_i and P_{i+1} expressed then by the following relation:

$$I_i = \frac{V_{P_{I+1}} - V_{P_i}}{r_p\left(x_{i+1} - x_i\right)} \qquad (1)$$

We have noticed that the circulating current between two potential plugs at different points of the electrolyte canal is inferior to the measured total current. The maximal values of the current moving in the electrolyte are almost quickly reached as we go closer to the high-tension electrode (figure3 and 4). The moments where the current is at its maximal at a point of the canal could correspond to the crossing of the foot of the discharge at a certain point, we notice a rapid enough decreasing of the current in the electrolyte.

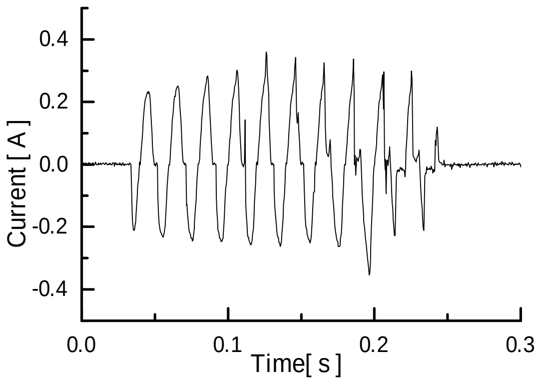


Figure 3. Current I2 circulating in the electrolyte between two successive potentials plugs at 6 and 5 cm from HV electrode.

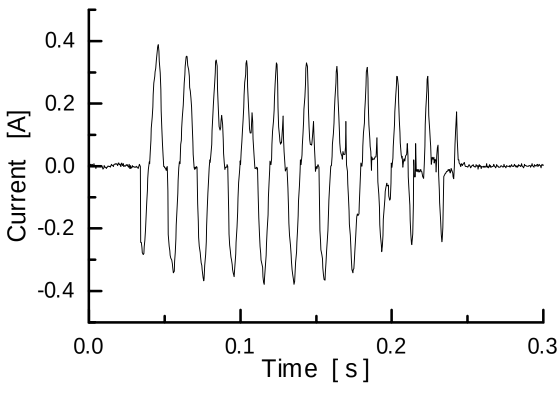


Figure 4. Current I5 circulating in the electrolyte between two successive potentials plugs at 3 and 2 cm from HV electrode.

3.2 OPTICAL SIGNALS

The figure 5 represents the evolution of the luminous intensity of the discharge during the flashover. We represented the temporal optic signal variation appropriated simultaneously in several places along the course of the discharge. One notes that the signals coming from the optic fibers provoke the saturation of the exit amplifiers progressively. This effect occurs on the exit of the signal situated the more meadows of the high voltage electrode and end on the exit of the signal situated the more meadows of the mass electrode. We note the saturation of the signal to the transition of the weak brightness zone toward the zone of strong brightness of the discharge. We notice from these signals, that, of an alternation to the other, the discharge sees its length increasing after its re-ignition. We see several picks on the shape of the luminous signals given out by the zone of weak brightness; the first shortly after the re-ignition of the discharge and the second when the current reaches its maximal value. We also notice that the luminous intensity is stronger at 6 cm than the one measured at 4 cm from the high-tension electrode.

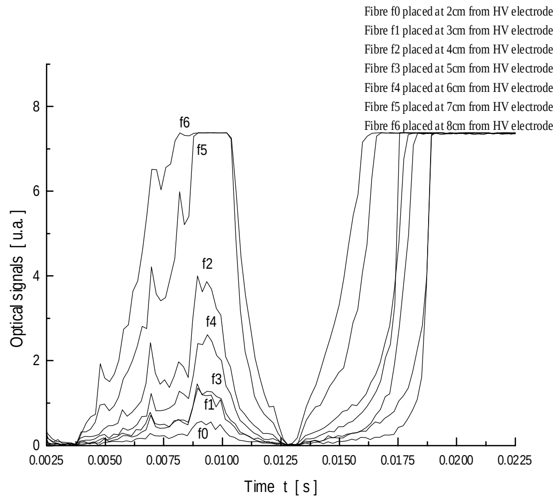


Figure 5. Evolution of light intensity of the discharge during a flashover.

The pace of these signals lets us suppose that the zone of strong brightness in the negative alternation (12.5 - 22.5 ms) is propagated by jumps between the fibers f2 and f4 situated at 6 and 4 cm from the high voltage electrode.

3.3 CORRELATION BETWEEN ELECTRIC AND OPTICAL SIGNALS

On the basis of the évolutions of current circulating in the électrolyte between two successive potential plugs, and the recorded optical signals we have ploted in figures 6 and 7 for the same flashover these sizes for different positions along the route of the discharge. According to the previous analysis, the foot of the discharge could find two potentiel plugs. We can notice on thèse figures that at the moment when the current is maximum,the zone where the luminosity is detected by the optical fibres situated at a certain distance from the high voltage electrode is the biggest.

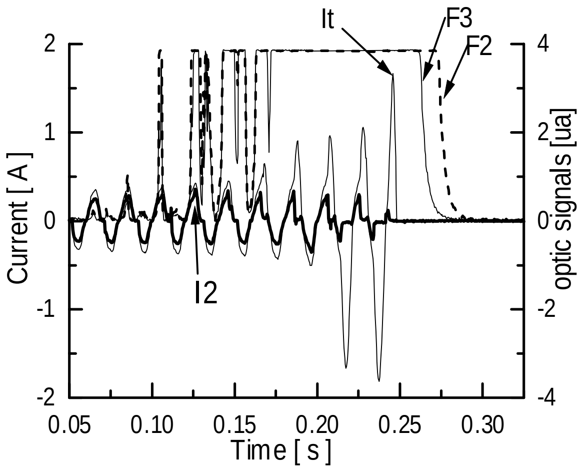


Figure 6. Evolutions of total current , current circulating in the électrolyte between two successive potential plugs at 5 and 4 cm from HV electrode and light signals broadcasted by F3 and F4 fibres.

(V_{HV} = 13.2kV and r_p =5 $k\Omega$ /cm)

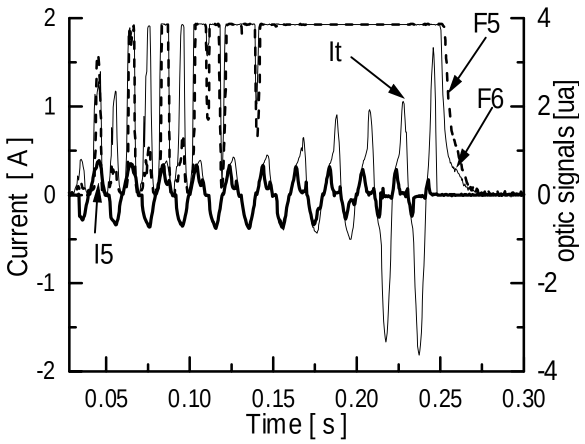


Figure 7. Evolutions of total current, current circulating in the électrolyte between two successive potential plugs at 5 and 4 cm from HV electrode and light signals broadcasted by F2 and F3 fibres.

(V_{HV} = 13.2kV and r_p =5 $k\Omega$ /cm)

IV. CONCLUSION

As a conclusion, we can say that the luminous zone corresponds to the light given out by the body of the discharge and that the zone that precedes it takes place before the crossing of the foot of the discharge before the considered fiber. This is in accordance with the observations of Pissolato [7] and Mahi [8],[12] They have studied, using ultra-rapid camera the light intensity of the discharge during its extension above a canal filled of electrolyte. The results they obtained show that the discharge is divided in two zones of different light intensity. The first zone, the brightest, is formed close to the high voltage electrode; the second one, which has by far a weaker lightening, develops below the first one.

From the maximal values of the currents circulating in the electrolyte, we can position the advancement of the foot of the discharge according to the time. Notes on the first half of the course that the discharge nearly propagates with an constant instantaneous velocity , accelerate then its progression on the second half with discontinuities capable to be assigned to progressions by jumps characterizing a change of mechanism of propagating discharge that supports the hypothesis of the discharge elongation by successive jumps suggested by Wilkins[13].

A review of the earlier models proposed shows the difficulty of taking into account correctly in a simple modeling, the right description of the flashover and to foresee from it its dynamics or even its occurrence. In particular, our observations show that it is unwise to describe the flashover under a.c. voltage by a static model associated with a simple criterion of re-ignition.

Our results bring to the fore the presence, ahead of the principal discharge, of a photoionization zone in which the development can occur of the streamers serving as precursors to its extension.

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