DYNAMIC APPROACH WITH A MULTI-BRANCHES MODEL OF THE FLASHOVER ON INSULATING POLLUTED SURFACES SUPPLIED UNDER DIRECT CURRENT

F. Benazzouz [2] A. Choucha [1] D. Mahi [1]

[1]*Laboratoire d'étude et développement des matériaux semi conducteurs et diélectriques, Université Amar Telidji de Laghouat* [2] *Département de Génie électrique, Centre universitaire de Djelfa.*

Dmahi_99@yahoo.fr aganichoucha@yahoo.fr fatiha_benazouz@yahoo.fr

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Abstract- In order to determine the flashover behaviour of polluted high voltage insulators and to identify the physical mechanisms that govern this phenomenon, the researchers have been brought to establish a modelling. The observation of the discharge, during its elongation, on an electrolyte filled channel modelling a polluted HV line insulators shows that the latter emite, from its tip, some branches, which have a weaker luminous intensity. Departing from the modelling of Cheng and Nour, we have developed a survey that permit to determine a critical length of the discharge from which the system elongates using a model derived from Obenaus'electric circuit This new approach gives better account of the physical phenomena that governs the extension of the body of the discharge.

I. Introduction

Several models and several theoretical methods have been used in order to treat the flashover. Most previous models gave some results based on the simple model of Obenaus [1]. This model is a good approach of the problem. The experimental results wihch were obtainet in the laboratories gave the critical value of tension that is twice or three times superior than the predicted one by the calculations.

However , a certain number of modellings were proposed in order to correct this difference

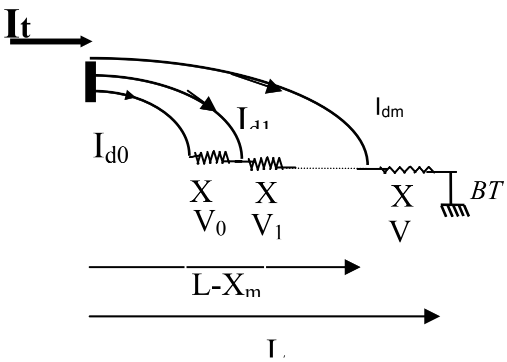
Being inspired by the works of Cheng and Nour[2] and for then sale of landing on the constraint of the total current that decreases when the length of the last branch increases, we tried to propose an approach of the problem that it is possible to represent in equivalent electric diagram. It is unidimensionnel geometry model. The latter allows us that to suppose the transverse measurements before the length of the model as being negligible

II.Theoretical survey

During its elongation, the discharge gives out some weaker subsidiary branches of luminous intensity, which are developed its tip. These observations, made by M. Ishi and Kawamura [3] match those made by Boylett - Maclean [4],[2] . In their mathematical modelling, they introduce in their several discharges of different lengths are running above the electrolyte.

The supplementary bow addition supposes supplementary contribution of energy of the source. In order to maintain them and to nourish them, it drives at the potential superior than those calculated for the mono arc model.The comparison of the theorical results obtained with the applied measurement of flashover critical voltage are satisfactory [5]. However, this procedure does not allow us totestefy the evolution of all electric parameters and esprcially the total current. While being inspired by the works of Cheng and Nours and for landing à the constraint of the total current that decreases when the last branch increases, we proposed a modelling [6] that we will represent (figure 1) by its equivalent diagram.

We suppose that the discharge is divided into m branches, while using the rule of the current divider, we can have a relation between the different branch currents



x0 is the length of the first branch
xm is the length of the last branch
Id0 is the current in the first branch
Idm is the current in the last branch
(L - xm) is the length of flight

Figure1: Electric diagram models multi - branches

The voltage drops V_0 and V_1 in the first two branches are given by the following relation :

j=0 $$V_0 = A.x_0.I_0^{-n}$$

j=1 $$V_1 = V_0 + r.\Delta x I_0$$

where V1 is the voltage drop in the branch 1

On the other hand

$$V_1 = \left(x_0 + \Delta x \right) \cdot A I_1^{-n}$$

for the branch 2, the voltage drop is:

j=2 $$V_2 = V_1 + r\Delta x \left(I_0 + I_1 \right)$$

where $$V_2 = \left(x_0 + 2.\Delta x \right) A I_2^{-n}$$

We obtain the expression of the current in various branches as well as the values of the different resistances:

$$R_d = A x_d I_d^{-n-1}$$

Using the rule of the current divider, the calculation of the j branch resistance Rdj, enables us to find the current of a branch in relation to the one that is immediately parallel to it.
(figure2)
:

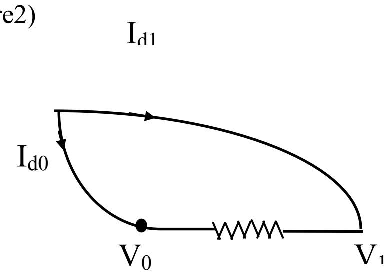


Figure2: Representation of a stitch of the proposed model

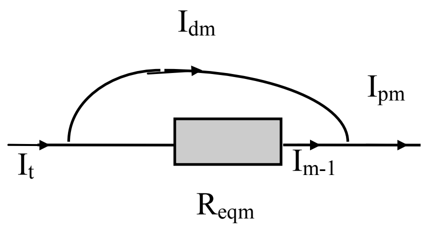
either :

$$I_1 = I_{d1} = \left(\frac{R_{d0} + r\Delta x}{R_{d1}} \right) I_0$$

$$I_0 = I_{d0}$$

One puts: $$R_{d0} + r.\Delta x = R_{eq0}$$

and this of near in near until the last branch (figure3)



$$R_{eqm} = R_{eqm-1} + r.\Delta x$$

Figure 3: Electric diagram of a stitch

where the current Im is determined in relation to the equivalent resistance of the whole circuit that it is downstream to it so that:

$$I_m = \frac{R_{eqm}}{R_{dm}} I_{m-1}$$

$$I_{dm} = \frac{R_{eqm}}{R_{dm}} . I_{pm-1}$$

or

$$I_{pm-1} = \sum_{k=1}^{m-1} I_k$$

The equation of the model is:

$$V = A x_m I_m^{-n} + r \left(L - x_m \right) I_t$$

where I_t is given by:

$$I_t = I_{dm} + \sum_{k=1}^{m-1} i_k$$

i_k: current in the branch k

the current in the pollution will be:

$$I_{pm} = I_{dm} \left(1 + \frac{R_{dm}}{R_{eqm}} \right)$$

The equation of the model will become:

$$V = A x_m I_m^{-n} + r \left(L - x_m \right) I_m \left[1 + \frac{R_{dm}}{R_{eq}} \right]$$

with $I_{dm} = I_m$

we have

$$R_{dm} = A x_m I_m^{-n-1}$$

Therefore

$$V = A x_m I_m^{-n} \left(1 + \frac{r \left(L - x_m \right)}{R_{eqm}} \right) + r \left(L - x_m \right) I_m$$

The calculation of the expression of the equivalent resistance is deducted from the diagram of the figure 1 where the branch crossed by the current presents a resistance of discharge:

$$R_{d0} = A x_0 I_0^{-n-1}$$

$$R_{eq0} = R_{d0} + \Delta x.r$$

$$R_{d1} = A.(x_0 + \Delta x).I_{d1}^{-n-1}$$

$$R_{eq1} = (R_{eq0} // R_{d1}) + r.\Delta x$$

The equivalent resistance will become : R_{eqm}

$$R_{eqm} = R_{eqm-1} + r.\Delta x$$

The graphic analysis of the new equation of the model leads up to the following critical sizes:

$$I_{m\,min} = \left[\frac{nAx_m}{r\left(L\text{-}x_m\right)} \left(1 + \frac{r\left(L\text{-}x_m\right)}{R_{eq}} \right) \right]^{\frac{1}{n+1}} \qquad (1)$$

$$I_{m\,max} = \left[\frac{A}{r} \left(1 + \frac{r\left(L\text{-}x_m\right)}{R_{eq}} \right) - \frac{x_m A}{R_{eq}} \right]^{\frac{1}{n+1}} \qquad (2)$$

The evolution of the current in the branches Id(xm) is represented in figure 4 for different lengths x0 of the first branch, which permits to notice that while this length increases , the currents in the branches decrease and become equal.

The exam of the figure4 shows that it exists a beginning length marked x0c from which the currents of the branches

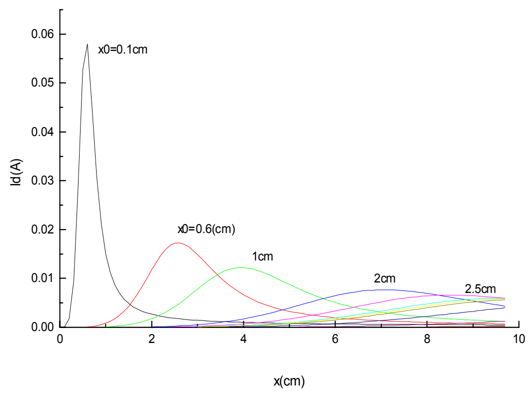


Figure 4:Current of the branches as function of the discharge length for several values of x_0

become equal with a weak density of the current while for beginning values lower than x_{0c}, the density of the current increases reaching its maximum.
These results are in agreement with those found by Flazi [7] where the electric current in the discharge penetrates the electrolyte through a small surface near the high voltage electrode, the lines of currents diverge progressively and become uniform from a certain distance.

However, this point of abscissa x_{0c} delimits the domain of applicability of the model mono discharge for which the current in the branches elongates to become equal.

Since the currents of the branches are nearly equal, we can, make the fellows theoretical approximation :

$$I_t = NI_m$$

N being the number of branches.
The equation of the model will become:

$$V = x_m A I_m^{-n} + r\left(L - x_m\right) \mathrm{NI_m}$$

and

$$I_{m\,min} = \left[\left[\frac{nAx_m}{r\left(L\text{-}x_m\right)} \right] \cdot \frac{1}{N} \right]^{\frac{1}{n+1}} \quad \Rightarrow \quad I_{m\,max} \rightarrow N = 1$$

$$I_{cm} = \left[\left(\frac{A}{r} \right) \cdot \frac{1}{N} \right]^{\frac{1}{n+1}} \quad \Rightarrow \quad I_{cm\,max} \rightarrow N = 1$$

These are the limits of the values of tension and current necessary to the existence of the discharge. These sizes are in agreement with those found by Alston and al [8] in the case of a discharge with only one branch.
$I_t = NI_m$ is the current in the case of the monodischarge model for a length of x_c.

Indeed when the currents of two successive branches become equal the voltage drop between these two branches elongates toward zero,
Up to the end, these two branches will merge (unite) making only one branch. It tolerate a good understanding of the passage to the model monodischarge.

The passage from the multidischarge model to the monodischarge model will postulate that N=1 and I_t = N.Im from the point x_{0c}. This point would be the initial criticizes length of the main discharge.

We can notice, In figure 5, that for the length x0c the last branch reaches the grounded electrode so x_m=L. This point x_{0c} is the most difficult point of access defined by Flazi [7] as being the starting point to leave of which it is possible to the discharge to elongate.

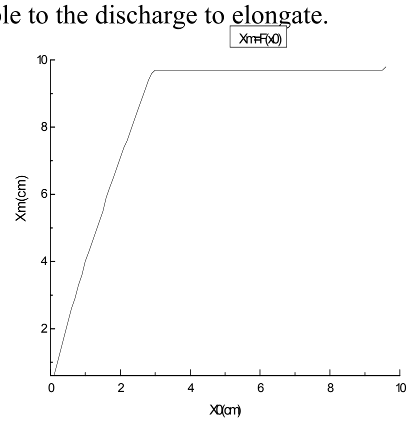


Figure 5: Length of the last branch as function of x

The critical values for the main discharge will be obtained when I_{cm} = cste because Hampton [9] and Flazi has experimentally determined that the critical current I was constant whatever parameters of the circuit may come. we notices that this current is constant from x_0 = 8cm.
The survey of the multi discharges model permits a good theoretical agreement on the critical conditions of the flashover.

$$I_d = \frac{R_{eq}}{R_d} I_{dn-1} \quad \Rightarrow \quad R_d \approx R_{eq}$$

In the expression (1)

Icm <Ic1 and Imin >Imin1

I_{cm} elongates toward I_c when x_0 to elongates toward x_c and therefore V_{cm}, the flashover voltage of the last branch elongates toward the calculated flashover voltage V_C for the mono discharge model , deducted from the expression of the V_{cm}, that depends on $r/R\acute{e}q$, the variation of which

depends on r and is represented in figure 6

In the multi branches model, the currents are distinguish s by :I_{pm}> I_m while in the mono branche model, the current of the branch is equal to the current in the pollution before the critical conditions

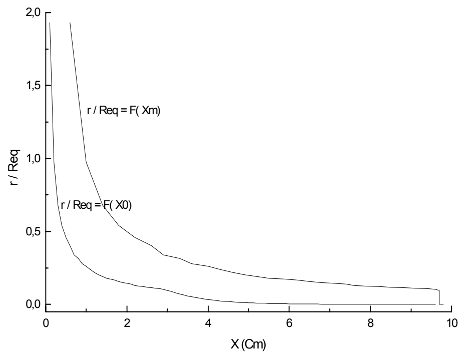


Figure 6: Variation of the factor r/Req as function of x_0

We can remark in our survey that Ip begins to decrease from a value Xoc.The variation of Ip for every length x0 of the main discharge presents one maximum Ipmax and one minimum Ipmin (figure 7).When these two extremums of currents are equal, the current in the pollution is constant, noted length xc. we notice that this point is the critical point for the main discharge (figures.8 ,9,10).

The expression of I_{pm} become:

$$I_{pm} = I_m(1 + \frac{R_d}{R_{eq}})$$

This occurs in the only case when only one branch remains in the pollution having $I_c = I_p$ as critical current. It is one of features of the mono discharge model : at the same time the total current is equal to the current in the last branch when the discharge reaches a crirical length x_c=8.3cm

Up to this point the current in the pollution decreases rapidily to zero and the discharge moves to the final jump.

In the figures 7, 8, 9, we represente separately four different lengths of beginning x0, judged the most meaningful currents of the pollution Ip in the last branch Im according to the length of the branch x . We can see that all this curves Ip(x) cut the curve I(x) in two points :Ipmin and Ipmax (figures 7, 8).

The graphs represented on figures 10 and 11 describe the evolution of the voltage drop in the pollution

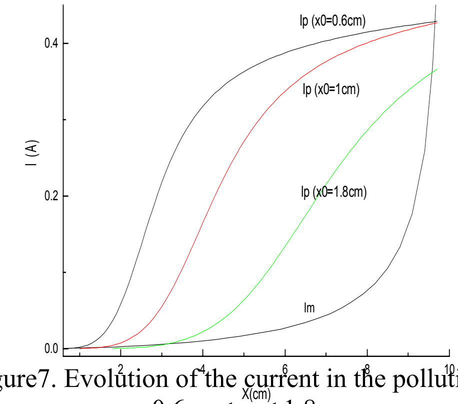


Figure7. Evolution of the current in the pollution for 0.6cm< x_0< 1.8cm

for various lengths of beginning x_0 of the main discharge

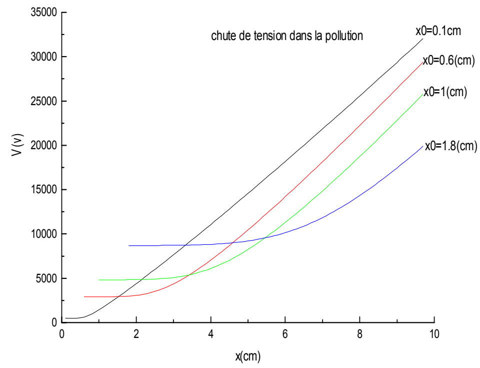


Figure8: Evolution of the current in the pollution for . 1cm <x0 <2.9cm

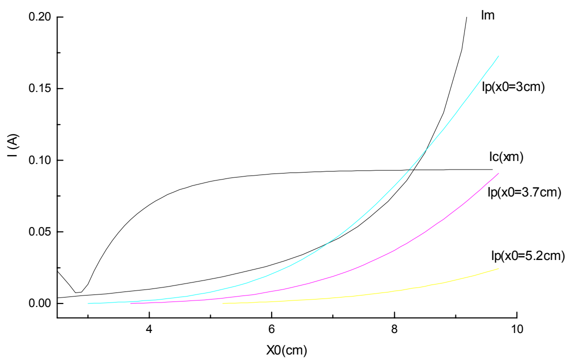


Figure10 : Voltage drop in the pollution for 0.1cm<x0<1.8cm

III. Conclusion

According to the graphic studies made on the proposed formalism, we see that the point x0 close to 3cm is a particular point. In this point we note the following facts :

- The length of the last branch xm is maximal and is equal to L the flaxhover is accomplished for this branch
- The currents of the branches become weak and uniform, what has the effect of shorting the branches of pollution between two successive branches, the voltage drop in the pollution is minimal
- The current in the pollution elongates toward Ic

$$I_{p\min} \langle I_c \langle I_{p\max}$$

- the total current extended to be equal to the current in the pollution.
- The point x0 = 3 cm is the point of the passage from the multi discharge model to the mono discharge model.

The related analysis of the mono discharge model and the survey of the multi discharge, begin at x0 = 3 cm where we notice that:

- Ic elongates toward a constant value from x0 = 3 cm
- Vc elongates toward a constant value from x0 = 3 cm

These two values are the critical parameters of the mono arc model.

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