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Plateau variation of arc current near the interruption limit in a gas circuit breaker

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The electric arc is one of the basic switching elements in power engineering and the study of its behavior will help to a better understanding of related phenomena. In this paper we discuss one of this special behavior, its reason and necessary models to describe this variation that have been observed occasionally in our measurements.

1. Introduction

Current interruption requires that the interelectrode gap of a breaker changes from a conductive plasma into an insulating gas. This transition, which occurs around current zero, is governed by the dynamic behavior of the electric arc interacting with the network and the quenching gas (mixture of sulfurhexafluoride and nitrogen 75%/25%).
If we limit ourselves to thermal processes, the dynamic behavior of the plasma column can be taken into account by writing an energy balance equation such as below [1]:

$$dQ/dt = P_{in} - P_{out}$$

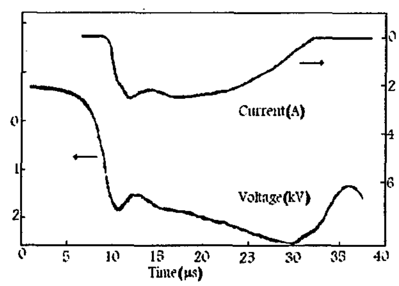
Where Q is the accumulated energy, P_{in} is the electrical input power (joule losses), and P_{out} is the removed power (by conduction, convection, radiation,...).

2.Test conditions:

The post arc current is recorded in our experiment with a particular device, the principle of which has been reported before [2], in a circuit of 4kV/11kA and a gas mixture of sulfurhexafluoride and nitrogen (75%/25%) as interrupting gas with p=2 bar N_2 and p=1 bar SF_6.

3. Recorded results:

Measurements of arc current and voltage are shown in (Fig.1). As we mentioned above the arc behavior is the result of the balance between cooling and heating effects and the study of the arc plasma will helps us in understanding the main parameters which successful breaking depends on. In the case of sufficient cooling, the electrical conductivity in the interelectrode gap will tend towards reduction and the arc current will have a tendency towards zero. However, after the current becomes zero, the transient recovery voltage drives a post arc current through the quenching arc plasma resulting in a heating effect. The balance between these effects may cause a decay of the plasma and current interruption such as shown in Fig.1.a or reheating of the gas to a well-conductive arc column which is termed "thermal re-ignition" as in Fig.2.b [3].



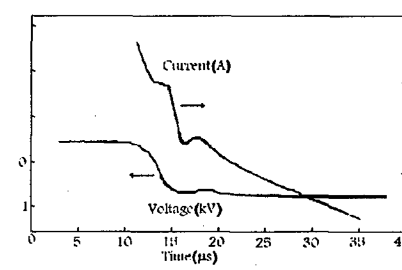


Figure 1: Interruption in the gas mixture [4].
a-With post arc current and plateau variation.
b-Re-ignition.

Thermal re-ignition occurs when there is an energetic surplus, that is when the power brought to the arc is greater than that removed. This idea, suggested by A.M. Cassie, shows that the interruption phenomenon is not an instantaneous process and that interaction with the network significantly influences the switching process. This paper concentrates on an arc interruption process that deals with thermal arc-circuit interaction as found in other gas puffer circuit-breakers and a brief discussion on a necessary model to recognize such a variation of the plasma arc current.

4.Electrical arc modelling:

There are two most commonly used types of models from simple to very complicated: black box and physical models. The first ones describe the interaction of a switching arc and the related electrical circuit during an interrupting process via a mathematical form (differential equation), and the electrical behavior is more important rather than the internal physical processes. However, the second ones include the physical processes in detail. It has to be noted that each of these models must be used in its correct range, and outside this range unacceptable errors will appear. Also it should be noted that in order to predict the plateau variation in the post-arc current we must use physical models taking into account physical processes such as conduction, convection, radiation, and so on [5]. Black box models can be applied only in cases where the switching process is governed by the arc conductance and can not be used in other cases such as for the dielectric region of the interruption process [6].

5.Conclusion:

In this paper our first aim was to recall phenomena on which successful breaking depends, and second to study the interruption in a typical gas puffer circuit-breaker. In our measurements plateau variation of post arc current was observed: this behavior is not predicted by black box models and we had to use physical models instead. Less plateau duration is equal to less probability of re-ignition and more probability of successful interruption.

6.References:

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