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Fuses in distribution systems: new applications in DC circuits

J. C. Gómez, D. Tourn, C. Reineri, and F. Romero

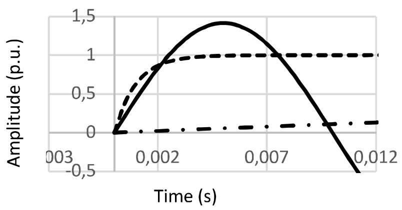
Department of Electrical and Electronic Engineering, IPSEP, Rio Cuarto National University
Ruta 36, Km. 603, 5800, Río Cuarto, Córdoba (Argentine)
Phone/Fax number: +0054 358 4676171, e-mail: jcgomez@ing.unrc.edu.ar

Introduction

The vast majority of distribution systems currently in use operate in electrical distribution with alternating current in 50 Hz or 60 Hz. Today, technological advances are reviving research on D.C. type of fuses, mainly due to the trend towards the use of distributed renewable energies which handle electrical energy in the form of direct current. Also, there are continuous end-use applications such as centralized variable speed drives, and the rapidly growing application in electric cars which has recently started. The main field of application of the direct current fuse arises from the massive application of three types of equipment: photovoltaic generators (among other generator types), the electric car and large storage batteries.

Characteristics of Direct Current Circuits

In direct current circuits, once the circuit is closed, the current grows to its final value determined only by the resistance of the circuit, based on an exponential curve whose growth rate is fixed by the time constant of the circuit ($\tau = L / R$), which is usually measured in ms.
The magnitudes of the fault currents in relation to the load current have very different values, with extremes of 20 times in the case of circuits powered by batteries to 1.15 times when the source is a photovoltaic cell, passing for 12 times if powered by a rotary generator.



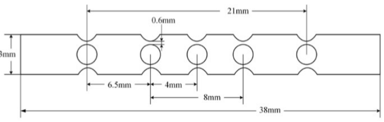
Effect of the time constant on the growth of direct current, compared to alternating current (alternating solid line, continuous dashed 1 ms and dot-trace 85 ms).

Operation of the Fuse in Direct Current Circuits

The operation of a fuse in a DC system has three fundamental parts: pre-arc, arc and post-arc processes.

A. Pre-arc process

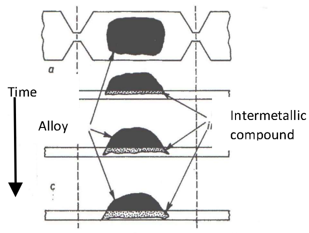
The heating and melting processes (if the current is sufficient to reach the melting temperature of the fuse element) are analogous in alternating current and in direct current.



Typical fuse element for direct current and low voltage.

B. Arc process

The operation of the fuse (pre-arc and arc) is simpler and safer when the current values are high and grow rapidly, that is, short circuits, which in the case of direct current must also have a low time constant.



Operation against dissolution overload with M-effect.

Modern Direct Current Applications

The protection of general equipment with fuses is achieved through the concept of providing through the protective device a barrier that interrupts the current before it can damage the protected equipment or shorten its useful life too much.

A. Battery circuits
B. Electric vehicle circuits
C. Power electronics
D. Solar panel circuits
E. Mass public transport
F. Mining

Conclusion

It is concluded in the need to deepen the study of these applications in order to achieve specific fuses designs for direct current. It is necessary to extend the knowledge of the behavior of the fuse against variable and repetitive loads. The DC arcing process must be improved through the development of more accurate models and the performance of extensive experimental validations, aimed at ensuring the extinction of low fault currents. It is necessary to understand the effect of the presence of transients that were not normal in alternating current uses.