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Automatic disconnector: Influence on the performance of medium voltage arresters and a new design proposal

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ABSTRACT

This paper discusses the modes of actuation and misoperation of the automatic disconnector of distribution surge arresters. Taking into account the laboratory test results and field data search campaigns, the main problems concerning the operation of these devices and how it affects the reliability of the surge protection of transformers are discussed. In general, the misoperation of the disconnector is a design problem, concerning materials and production quality control. Considering this, a new design is also proposed, trying to avoid the main operation problems, resulting in a more simple and reliable device.

1. Introduction

Surge arresters are widely applied on distribution networks to protect switches and transformers against lightning surges. When well dimensioned and in good operational conditions, they control the increase of overvoltages beyond the basic insulation levels of the equipments they protect. When not sound, they are not able to manage severe transient overvoltages and, more than this, they can cause the line to switch off due to excessive currents to ground.

Modern surge arresters are simple devices, composed by a stack of metal oxide varistors in a polymeric housing. The varistors are the main components of the surge arresters, as they are responsible for the protective characteristics, as though as, in general, the main source of degradation.

There are basically two ways of failure for a surge arrester. The first one, due to continuous degradation [1,2]. The second one, related to the discharge of currents above the withstanding limits of the surge arrester [3,4]. For both cases, the maintenance of the surge arrester in operation can affect the reliability of the line or the integrity of the protected equipment, as it will not be able to avoid lighting overvoltages or it will become a source of phase-to-ground fault.

2. The automatic disconnector

Medium voltage surge arresters are associated with automatic disconnectors: external devices that have the objective of disconnecting a failing surge arrester from line, taking it out of operation and visually indicating the necessity of its replacement.

The conventional automatic disconnector is a device composed of a gunpowder cartridge that is supposed to be triggered by a spark. Generally, the spark is produced in a gap in parallel with an equalization, shunting, resistor or capacitor. These two elements are responsible for the conduction of the surge arrester continuous operation leakage current, as though as for developing a triggering overvoltage on the gap, in case of discharges or increasing leakage currents [5,6]. A simplified diagram of a disconnector is shown in Fig. 1.

The cartridge triggering is achieved by an overvoltage high enough to cause the spark of the parallel gap or by the increase of the leakage current, producing heat. Considering this, the disconnector should operate only for two conditions: a transient surge, high enough to cause a discharge current above the withstanding current of the surge arrester, or an increase on the continuous

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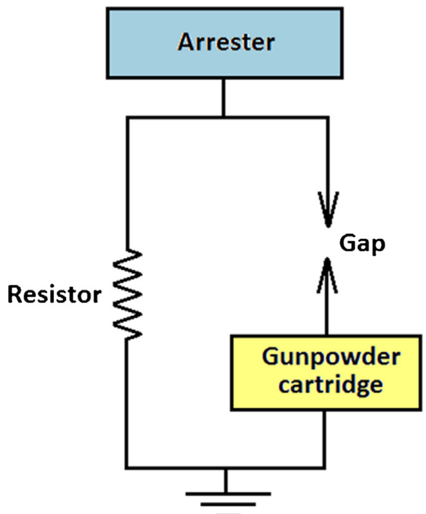

Fig. 1. Schematics of a conventional automatic disconnector.

Table 1
Classification of medium voltage arresters.

Group	Nominal discharge current (kA)	Maximum discharge current (kA)
Light duty	5	40
Normal duty	5	65
Heavy duty	10	100

leakage current, caused by degradation or thermal runway of the surge arrester. For lightning withstanding capacity, the limits are usually determined by standards [7,8], as shown in Table 1, which specifies minimum limits.

In the case of actuation due to continuous power frequency current, there is no statement on the standards about the limits of current or operation time. The only implicit requirement is that the surge arrester disconnector must bear, at least, the current stresses related to temporary overvoltages (TOV) according to the voltage versus time characteristics of the surge arresters. Therefore, a correlation between the current associated to the overvoltage and the actuation time of the disconnector must be analyzed to evaluate if the disconnector is really adequate.

Any actuation of the disconnector diverting from the situations stated above can be considered a failure or misoperation. As a general rule, the complete surge arrester is replaced. Therefore, the main component (surge arrester), still in good operational condition, is substituted due to a failing actuation of its accessory (disconnector). It is an economic issue, as the failing component costs less the 10% of the main component and the replacement may cost higher than the cost of the full surge arrester set. It is also a reliability problem, as the network components are unprotected while the surge arrester is not replaced.

3. Misoperation of conventional automatic disconnector

3.1. Random actuations

The misoperation of the disconnector is related both to improper actuations and to non-actuations when necessary. In this last case, a failing surge arrester is kept on the line, leading to a ground fault or explosion of the surge arrester housing.

The improper actuation is usually related to unpredictable ignition of gunpowder, as it is susceptible to factors as humidity and temperature. It can also be a dimensioning problem. As a matter of fact, measurements in arresters removed from field due to actuation of disconnectors reveals that more than 50% of them are still fully operational [9]. This corroborates researches as old as thirty years [10], indicating the early improper actuation of disconnectors.

For the non-actuation, considering the structure of the conventional disconnector, there are three main possible causes. The first one is the existence of defective impedances – resistor or capacitor, avoiding the passage of the leakage current and, consequently, the creation of an overvoltage to promote the necessary spark. Problems with the impedance can be result of a careless assembly or even the utilization of bad quality material. In this case the impedance can become an open circuit or a short-circuit. In both situations, there will be no proper overvoltage on the spark gap. Open impedances also introduces unnecessary radio interference noises on the surge arrester set.

Measurements on a set of disconnectors, shown in Table 2 for five unities, indicate how random the value of their internal impedances can be. The values are for samples as received and after a set of impulse tests representing a simplified operational live span. Most samples present values in the order of some kilohms, some present only few ohms (short-circuit) and others, on the order of megohms (open circuit). A similar behavior is achieved comparing measurements before and after aging tests, as exemplified in Table 3 for other six samples submitted to thermal cycle aging procedure.

Table 2
Internal impedances of conventional disconnectors.

Sample	Resistance values					
	New	After 3 kA	After 10 kA	After 40 kA	After 150 A	After 250 A
1	3.62 kΩ	3.60	3.58 kΩ	1.37 kΩ	1.82 kΩ	2.04 kΩ
2	4.30 kΩ	4.26	4.22 kΩ	1.78 kΩ	2.39 kΩ	2.28 kΩ
3	1.08 MΩ	N/P[a]	N/P[a]	0.83 kΩ	1.26 kΩ	1.17 kΩ
4	4.64 kΩ	3.59	3.57 kΩ	0.2 Ω	0.8 Ω	3.28 kΩ
5	3.62 kΩ	3.60	3.58 kΩ	1.37 kΩ	1.81 kΩ	2.04 kΩ

[a] Measurement not possible – value above the measurement instrument capability.

Table 3
Internal impedances before and after thermal cycling.

Resistance	Sample					
	1	2	3	4	5	6
Before test	10.4 MΩ	3.70 kΩ	4.20 kΩ	4.30 kΩ	N/P[a]	3 MΩ
After test	N/P[*]	3.74 kΩ	N/P[a]	N/P[a]	5.2 kΩ	4.30 kΩ

[a] Measurement not possible – value above the measurement instrument capability.