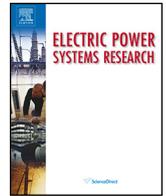




Contents lists available at [ScienceDirect](#)

## Electric Power Systems Research

journal homepage: [www.elsevier.com/locate/epsr](http://www.elsevier.com/locate/epsr)



# Comparison of different procedures to predict the volt–time curves of 15 kV insulators

M. Shigihara<sup>a,\*</sup>, A. Piantini<sup>a</sup>, M.C.E.S. Ramos<sup>a</sup>, C.P. Braz<sup>a</sup>, C. Mazzetti<sup>b</sup>, A. Ancajima<sup>c</sup>

<sup>a</sup> Institute of Energy and Environment, Lightning and High Voltage Research Center—CENDAT/USP, University of São Paulo, São Paulo, SP, Brazil

<sup>b</sup> Department of Astronautic, Electric and Energetic Engineering, La Sapienza University of Rome, Via Eudossiana 18, 00184 Roma, Italy

<sup>c</sup> Electromechanical Department, University of Piura, Piura 353, Peru

### ARTICLE INFO

#### Article history:

Received 31 May 2016

Accepted 10 October 2016

Available online xxx

#### Keywords:

Impulse testing

Insulator testing

Power distribution lines

Power system lightning effects

### ABSTRACT

This paper presents the results of the application of a novel method to estimate the parameters of the Disruptive Effect Model for the prediction of the volt–time curves of 15 kV insulators. Besides the standard lightning impulse voltage waveshape, four non-standard impulse waveshapes (namely 1.2/4  $\mu$ s, 1.2/10  $\mu$ s, 3/10  $\mu$ s, and 7.5/30  $\mu$ s), of both polarities, were adopted in the tests. The measured volt–time characteristics of a 15 kV class pin-type insulator were compared with those predicted by three different procedures related to the Disruptive Effect Model: Darveniza and Vlastos, Hileman, and the one recently proposed by the authors. The results show that for some impulse waveshapes and polarities, the methods by Darveniza and Vlastos and by Hileman do not predict insulator breakdown for the lower voltage levels. On the other hand, a relative good agreement is found between theoretical and experimental results for the calculations performed using the method proposed by the authors.

© 2016 Elsevier B.V. All rights reserved.

## 1. Introduction

The evaluation of the lightning dielectric strength of power equipment is based on laboratory tests performed using the standard lightning impulse voltage (1.2/50  $\mu$ s waveshape). However, the characteristics of the lightning overvoltages depend on many parameters of the lightning current and may vary appreciably with the line configuration and characteristics of the soil [1–9].

When an insulator is subjected to a lightning overvoltage, the occurrence of a flashover depends not only on the amplitude of the surge but also on its waveshape. Therefore, the analysis of the insulator behavior under non-standard impulses requires a model to estimate the corresponding volt–time curves. The Disruptive Effect Model (DE) [10,11] is commonly used for this purpose, but its application requires the knowledge of some parameters for whose estimation different procedures have been proposed in the literature [10–17].

A novel method for the estimation of such parameters was proposed in Ref. [16], and the procedure was applied to a 15 kV class

pin-type porcelain insulator. Impulse voltage tests of five waveshapes, including the standard lightning impulse (1.2/50  $\mu$ s), of both polarities, were performed and in this paper the corresponding volt–time curves are compared to those calculated according to the proposed method. The results are compared also with the predictions by the procedures of Darveniza and Vlastos [13] and Hileman [15].

Information about the test set-up is given in Section 2, while the Disruptive Effect Model is described in Section 3. The proposed method for estimating the parameters for application of the DE model is briefly presented in Section 4. The results and analysis are reported in Section 5 and the main conclusions are presented in Section 6.

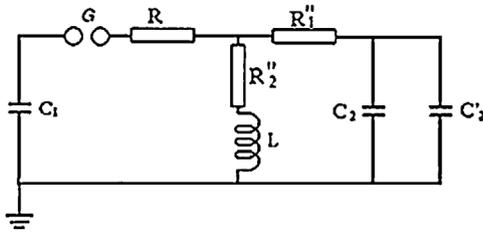
## 2. Test setup

A Marx impulse generator from the High Voltage Laboratory of the Institute of Energy and Environment of University of São Paulo was used to perform the tests. The maximum voltage is 3 MV, the total energy is 225 kJ, and total capacitance is 50 nF. The capacitance, energy, and voltage corresponding to each of the fifteen stages are 750 nF, 15 kJ, and 200 kV, respectively [18]. The test assembly and the determination of the correction factors for the ambient conditions were performed according to IEC 60060-1 [19].

The efficiency of the impulse generator for waveshapes with short-tails decreases due to the use of front resistors with val-

\* Corresponding author.

E-mail addresses: [mshigihara@usp.br](mailto:mshigihara@usp.br) (M. Shigihara), [piantini@iee.usp.br](mailto:piantini@iee.usp.br) (A. Piantini), [mcesr@usp.br](mailto:mcesr@usp.br) (M.C.E.S. Ramos), [cpbraz@iee.usp.br](mailto:cpbraz@iee.usp.br) (C.P. Braz), [carlo.mazzetti@uniroma1.it](mailto:carlo.mazzetti@uniroma1.it) (C. Mazzetti), [alejandro.ancajima@udep.pe](mailto:alejandro.ancajima@udep.pe) (A. Ancajima).



**Fig. 1.** Scheme of the general lumped circuit used to generate the impulse voltage waveshapes. (Adapted from Ref. [20]).

**Table 1**  
Values of the components selected to generate the impulse voltage waveshapes adopted in the tests.

Waveshape	Number of stages	C <sub>1</sub> (nF)	R (Ω)	R <sub>1</sub> '' (Ω)	R <sub>2</sub> '' (Ω)	L (mH)	C <sub>2</sub> ' (pF)
1.2/4 μs	3	250	90	110	15	0.37	~2700
1.2/10 μs	3	250	100	200	100	0.37	~2700
1.2/50 μs	3	250	0	880	255	0	~300
3/10 μs	5	150	0	800	10	0.63	~2300
7.5/30 μs	15	50	0	180	4450	0	~1740

ues greater than those used in circuits for generating the standard waveshape. In some cases, depending on the waveshape, it was necessary to make adjustments in the generator circuit such as adding resistors, changing the capacitance load and generator capacitance by varying the number of stages, and including an air-core inductor in order to improve the generator performance [20].

For the generation of impulse voltages with short wavetails, the circuit proposed by Carrus and Funes [21] was adopted, in which a resistor R is placed before the tail resistor and an inductance L is connected in series with the external tail resistance. The circuit used to generate the five impulse waveshapes adopted in the tests (1.2/4 μs, 1.2/10 μs, 1.2/50 μs, 3/10 μs, and 7.5/30 μs) is shown in Fig. 1, where C<sub>1</sub> is the generator capacitance, R<sub>1</sub>'' is the external front resistance which controls mainly the voltage front time, R<sub>2</sub>'' is the external tail resistance, C<sub>2</sub> is the insulator capacitance, and C<sub>2</sub>' represents the capacitance of a capacitor placed in parallel with the insulator. Table 1 shows the values of the circuit components corresponding to each impulse waveshape adopted in the tests.

A general view of the test set-up is shown in Fig. 2. The 15 kV pin-type porcelain insulator, whose picture is shown in Fig. 3, was connected to a 1.05 m vertical metal rod located above a metal grounded base [22]. The characteristics of this insulator are: basic insulation level (BIL) of 95 kV, leakage distance of 230 mm, and arcing distance of 140 mm; its measured capacitance was about 20 pF.

### 3. The Disruptive Effect Model

The Disruptive Effect Model (DE) was originally proposed by Witzke and Bliss [10,11] for the assessment of the effect of surge voltages on oil-insulated transformers. Its equation can generally be expressed by:

$$DE = \int_{t_0}^{t_b} [v(t) - V_0]^K \cdot dt \quad (1)$$

where  $v(t)$  is the voltage applied to the dielectric at time  $t$ ,  $V_0$  is the minimal voltage that starts the breakdown process,  $t_0$  is the time at which  $v(t_0) = V_0$ , and  $t_b$  is the time to breakdown.

The parameters  $V_0$  and  $K$  are usually estimated using different procedures, as e.g. those proposed by Witzke and Bliss [10,11], Kind [12], Darveniza and Vlastos [13], Chowdhuri et al. [14], Hileman [15], and Ancajima et al. [17,23,24]. The method proposed by Anca-

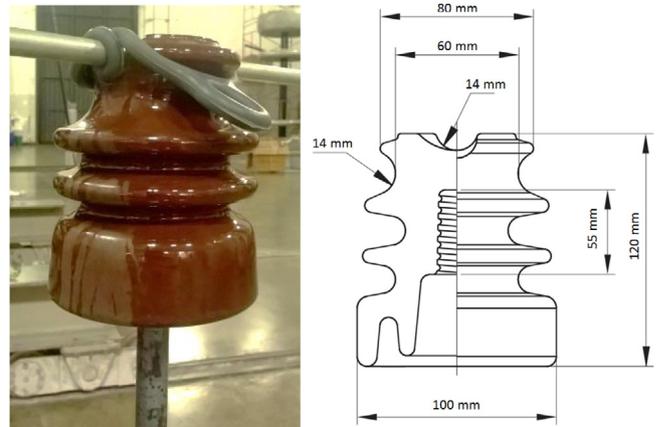


**Fig. 2.** General view of the test set-up.

jima et al. [17,23,24] represents an improvement of the Chowdhuri et al. [14] method for the calculation of  $V_0$ , as it presents an important modification that takes into account the voltage  $v(t_{bM})$ , which corresponds to the longest recorded time to breakdown ( $t_{bM}$ ) among all applications. The parameter  $K$  is computed from [17]:

$$K = \alpha \times \frac{v(t)}{V_0} \quad (2)$$

The best value of  $\alpha$  is the one which leads to the minimum mean square deviation of  $DE$  ( $\sigma_{DE\%}$ ), being each value of  $\sigma_{DE\%}$  calculated by averaging the values of  $DE$  corresponding to the voltage levels obtained from the volt–time tests. That is, for each value of  $\alpha$  there is a corresponding value of  $\sigma_{DE\%}$ . According to Ancajima et al. [17], the best value of  $\alpha$  is that which corresponds to the minimum value of  $\sigma_{DE\%}$ .



**Fig. 3.** 15 kV class pin-type porcelain insulator used in the tests.

متن کامل مقاله

دریافت فوری ←

**ISI**Articles

مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات