Effect of Profiles on AC Contamination Flashover Performance of Large-tonnage Suspension Disc Insulators

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ABSTRACT

From field experience and laboratory experiments, it was indicated that the flashover performance of contaminated insulators was significantly influenced by the insulator geometry. In the paper, insulators with three different profiles including seven types of deep under-ribs disc insulator, three types of two-shed disc insulator and three types of three-shed disc insulator were tested in an artificial climate chamber to investigate the influences of insulator profile parameters on the flashover performance of large tonnage disc insulators. The artificial contamination test results indicated that 50% flashover voltage stress ($E_{50\%}$) decreased with the increasing insulator diameter and creepage distance. The influence of salt deposit density (*SDD*) was also investigated, and it was found that $E_{50\%}$ of alternating-shed insulator decreased more rapidly than that of deep under-ribs insulator with the increase of *SDD*. An empirical expression was proposed, by employing the least-square method, to describe the relationships between $E_{50\%}$ and insulator configuration parameters as well as *SDD*. Through analyzing the generalized fitting coefficients (r) of the equation and the standard error of estimate (s), it can be concluded that the calculated results are in good agreement with the experimental data. Moreover, special attentions were also paid to the influence of the under-ribs and the ratio of shed overhang distance to the shed spacing on flashover performance respectively. This work can enrich the investigation of insulators parameters and may provide useful reference for performance evaluation and selection of insulators in EHV and UHV transmission lines.

Index Terms - **EHV and UHV, insulator profiles, pollution flashover performance, large-tonnage disc insulator, fitting equation.**

1 INTRODUCTION

WITH the increase of voltage level of power system in recent decades, large-tonnage disc suspension insulators are employed to bear the weight of transmission lines and the long insulator strings, especially in EHV and UHV transmission lines [1-3]. For instance, suspension insulators with the specified mechanical load of 300 kN, 400 kN, even 800 kN have been made to meet the increase of power voltage level [2, 4]. In addition, various profiles of insulators have been designed to adapt to the various environments, such as the three outer-ribs were introduced recently [4].

Contamination flashover of outdoor insulators still remains one of the major problems for the transmission lines, even though many works have been done to study the mechanism of arc propagation and predict the flashover voltage [5-8]. For instance, in the early 2004, power outage due to contamination flashover along 500 kV Lines caused great damages in East Grid of China [6].

Service experience and laboratory experiments have shown that the insulator shape has a great influence on the flashover performance of contaminated insulators [1-2, 10-23]. Matsuoka studied the influence of the diameter on ac contamination flashover voltages of station post insulators, and it was proposed that required creepage distance per unit increased with the average diameter [15]. However, the suspension disc insulator string is different from the post station due to the fact that the air gap distance of the former is usually much larger than that of the latter, and the effect of other insulator parameters on the flashover voltage was not involved in literature [15]. Sundarajan demonstrated that the diameter of the insulators had strong influence on the flashover voltage, irrespective of the profile [16]. Whereas, Wang proposed that the disc insulator with alternate long and short under-ribs and a wider gap between the rib tips had a higher flashover voltage and the configurations of the under-ribs had a significant influence on the flashover performance [4]. Farzaneh and Chisholm illustrated a comprehensive check on the influence of insulator parameters on the contaminated flashover performance and gave an empirical equation as follows [1]:

$$E_{50\%} = 52H^{0.2}D^{-0.4}F^{-0.1}(SDD)^{-0.24} \tag{1}$$

Manuscript received on 31 December 2013, in final form 15 April 2014, accepted 16 April 2014.

DOI 10.1109/TDEI.2014.004530

Where, $E_{50\%}$ is 50% flashover voltage, kV/m; H is insulator structure height, mm; D is insulator diameter, mm; F is insulator form factor [27]; SDD is the salt deposit densities, mg/cm^2. Hence, researchers have not come to an agreement on the influence on the insulator flashover performance.

Compared with normal tonnage insulator, the configuration of large-tonnage insulator is larger. The relationship of flashover voltage versus insulator parameters usually acts in a complicated manner (what is called nonlinear) [1-2]. So, it is difficult to predict the flashover performance of large tonnage insulator based on the existing data of the normal tonnage insulator. Moreover, the arc propagation along the insulator surface may be different when the parameters are enlarged, such as the possibility of the spacing bridged by arc may be varied. So far, the investigation of large-tonnage disc insulator with different profiles and configurations has not been reported. Therefore, it is important to research into the influence of profiles on the flashover voltage of the contaminated disc insulator to provide useful reference for performance evaluation and selection of insulators in EHV and UHV transmission lines.

In order to make clear the relationships between flashover performance of contaminated insulators and D, H and creepage distance (L), insulator profiles as well as SDD, several kinds of large-tonnage insulators with various profiles were tested in the climate chamber and the influences of the above factors on flashover performance are analyzed in this paper.

2 EXPERIMENTAL ARRANGEMENTS AND METHODS

2.1 TEST FACILITES

The tests were carried out in the climate chamber in Pollution and Environment Laboratory of China Electric Power Research Institute (CEPRI), and the schematic circuitof the chamber is shown in Figure 1. The climate chamber, with a size of 12m×12m×12m, could meet the requirements for contamination flashover tests. The power was generated by a 200 kV/5 A, 1000 kVA transformer with a short circuit impedance less than 5% (B in Figure 1). The applied voltage was measured by a capacitive voltage divider, Y, with a voltage ratio of 1000:1. And the leakage current was obtained by measuring the voltage of the sampling resistance, R_S, in series with the specimens, S.

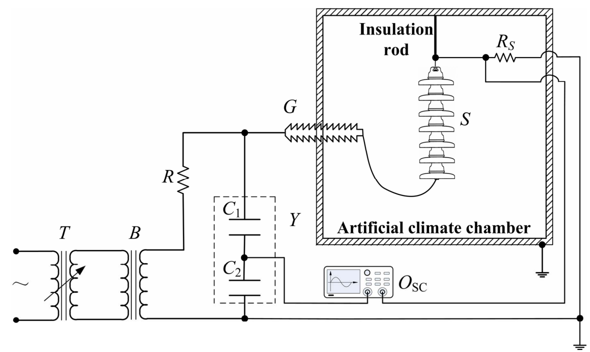
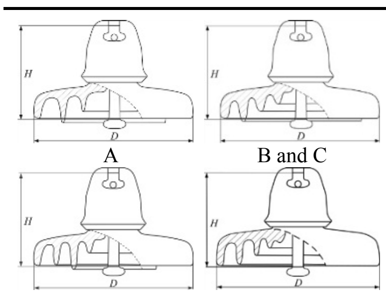
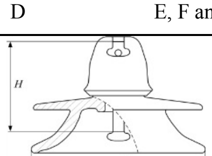
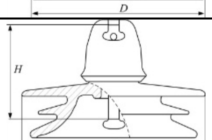


Figure 1. Schematic circuit of CEPRI chamber.

2.2 SPECIMENS

Three profiles of disc insulators as specimens were tested in this paper. Large tonnage insulators of type 1B, 1C, 1D, 1E, 1F, 1G, 2I, 2J, 3K, 3L and 3M, whose configurations and parameters are shown in Table 1, are applied in EHV and UHV transmission lines of China. Type 1A and 2H with a normal specified mechanical load were also tested as a reference to the testing results of large tonnage insulators. Two-shed insulator and three-shed insulator are collectively known as alternating-shed insulator [27].

Table 1. Configurations and parameters of tested insulators

Configurations	Profiles	Type	Shed diameter D/mm	Structure height H/mm	Creepage distance L/mm	Specified mechanical load SML/kN	Form Factor F
 A; B and C; D; E, F and G	Deep under-ribs insulator	1A	288	170	463	210	/
		1B	330	195	490	300	0.900
		1C	386	245	720	530	1.11
		1D	387	235	650	550	0.967
		1E	320	195	505	300	0.850
		1F	340	205	550	420	1.39
		1G	380	240	695	530	1.01
	Two-shed Insulator	2H	255	146	400	70	/
		2I	330	195	495	300	0.889
		2J	390	205	560	420	0.816
	Three-shed Insulator	3K	400	195	635	300	/
		3L	400	205	635	420	0.846
		3M	400	240	650	550	0.901