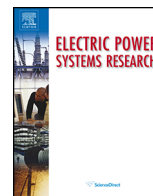




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Hydrophobicity characteristics of algae-fouled HVDC insulators in subtropical climates

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ABSTRACT

Algae contamination was observed on the surface of composite insulators in a subtropical environment especially China; this contamination affects the external insulation performance of high voltage direct current transmission and distribution equipment. This paper explores the effects of algae on the hydrophobicity of silicone rubber under various circumstances and its mechanism, through hydrophobicity experiments and the measurements of surface conductivity and flashover voltage. Particularly, as a biological contaminate, algae population was changing during the test period, so the results were corrected to illuminate the effect of algae growth. Among the climate parameters, humidity was noted as the major environmental factor affecting the extent of the decrease of hydrophobicity rather than temperature and illumination. Other factors, such as algae density and surface roughness, played a minor role in the influence of hydrophobicity of algae-fouled insulators. The surface conductivity increased with algae cells density in different humidity exponentially. The algae contamination decreased the flashover voltage significantly with the change of algae density. Besides, extracellular polymeric substances, including polysaccharides and proteins, were deduced to be primarily responsible for the change of hydrophobicity because of their strong viscosity and water adhesion effect. The results about hydrophobicity of algae-fouled silicone rubber could provide useful information for the maintenance of algae-fouled insulators.

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1. Introduction

Composite insulators provided several advantages over original ceramic insulators with respect to hydrophobicity and antipollution flashover. However, a primary disadvantage of composite insulator is its poor biological corrosion resistance, which is the consequence of being an organic polymer [1–3]. Biological contamination phenomena on outdoor insulators have been observed in miscellaneous environments around the world, including tropical climates around coastal areas such as Sri Lanka and Tanzania [4], a subtropical monsoon climate such as northeastern Japan [5], the unique tropical rainforest climate of Papua New Guinea [6], and the highly humid climate of the New Orleans area, USA [7]. Considerable bio-contaminants were also observed to make incursions

into insulators in subtropical areas of China, especially in Sichuan, Yunnan and Guangdong provinces, and the main component of biological contamination is algae [8].


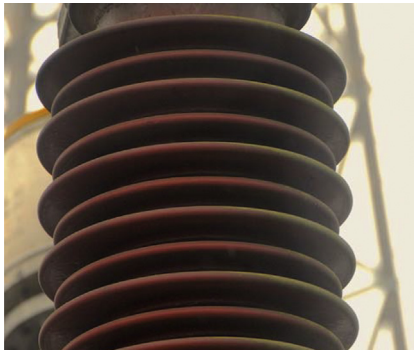


We had investigated biological contaminated insulators all over China. Generally, the visible algae contamination has a cell density of greater than $1,000,000 \text{ cm}^{-2}$, and the severity of algae growth was divided into 4 grades judging by the cell density and the contaminated area (Table 1). According to this classification method, the biological contaminated condition of insulators in China was elaborated as Fig. 1. Biological contaminates covered the power device around nearly half China, ranging from the central area to the southern coastline.

Insulator strings on transmission lines are susceptible to the effects of algae contamination, therefore poses a serious risk to power systems [9]. In the mechanism of flashover, the wetting process of contaminates upon insulator surface was a necessary factor for the pollution flashover process [10]. Unfortunately, the surface of the shed was tendentious to form a large area of water film rather than stay hydrophobic in the algae-fouled area (Fig. 2). Seriously,

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Table 1
The contaminated severity of algae-fouled insulators.

Degree of algae contamination	Maximum cell density D_{max} (cm ⁻²)	Description of growth portion	Sample image
no algae	0	No visible algae	
blocker	$0 < D_{max} \leq 10^5$	One direction of the top shed was covered with algae, but almost in the edge	
critical	$10^5 \leq D_{max} \leq 10^7$	One direction of the shed was full of algae, including the inside of the shed	
major	$D_{max} > 10^7$	Major of the shed was thoroughly covered with algae contaminates	

algae would even cover the whole surface of the insulator and form an algae channel between its two ends as “major” condition, which may lead to a poor situation about hydrophobicity.

Hydrophobicity of algae-fouled silicone rubber has been investigated by many researchers, and algae quantity, humidity and water retention ability were some of the most prevalent risk factors for its changing. Most results demonstrated that a silicone rubber sur-

face with colonized algae exhibits a substantial loss of hydrophobic character [11–13]. Depending on algae growth concentration from visual inspection, the hydrophobicity of the algae-covered regions was HC3–7 [14,15]. The effect of humidity in the air has been confirmed, but evidence to deduce the relationship between humidity and hydrophobicity has not been established [16–18]. In terms of mechanism, Fujii et al. [19] indicated that algae, on the insulator

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