Study Committee B2

Overhead Lines

10302_2022

A Novel Method for Pollution Detection of External Insulation

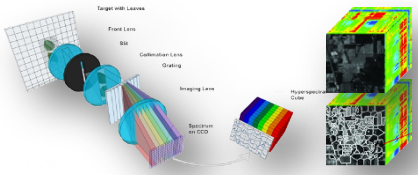
Guangning WU, Yujun GUO , Xueqin ZHANG, Guizao HUANG , Chengfeng YIN
Southwest Jiaotong University, Chengdu, China

Motivation

- At present, measurement methods commonly used in insulator pollution degree have certain limitations.
- A novel method for detecting pollution degree and pollution distribution based on hyperspectral technology is proposed in this paper.

Method/Approach

- Hyperspectral reflects the reflective properties of substances to electromagnetic waves and can be applied to insulator surface pollution detection.



hyperspectral identification process

- The hyperspectral profile of the region of interest in the labeled sample is extracted and an analytical model is built to classify the degree of contamination of the sample to be measured.

Objects of investigation

- insulator pollution

Insulator contamination can trigger contamination flashover, which can affect the safe operation of transmission lines.

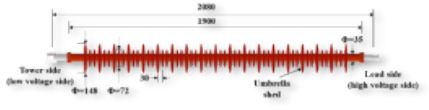


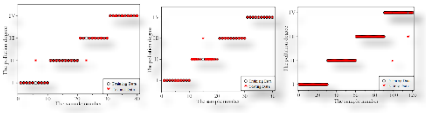
diagram of the composite insulator structure (unit: mm)

- components of pollution

Insulator pollution soluble substances are mainly Ca2+, Na+, Fe3+, SO42-, Cl-. The insoluble components of SiO2 account for about 80%.

Experimental setup & test results

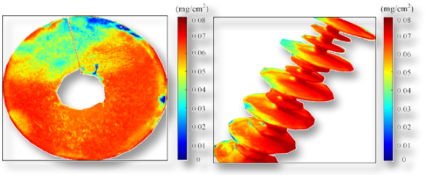
- produce samples with different pollution degrees
- establish hyperspectral imaging platform
- extract the region of interest
- spectral line pre-processing
- spectral line multiple scattering correction
- calculate spectral line characteristic band
- build multi-category recognition model
- single pollution recognition accuracy up to 97.5%
- mixed pollution recognition accuracy up to 97.5%



the degree classification results of different pollution

Discussion

- expansion of the spectral library can further improve the accuracy
- mixed pollution recognition can further improve accuracy by refining algorithm parameters



visualization of the insulator shed

- visualization image clearly shows the pollution distribution

Conclusion

- The ELM-classification model can accurately and rapidly classify the pollution degrees of a mixture of different salts and the surface of insulator umbrellas.
- The hyperspectral technique allows visual documentation of the severity and non-uniform distribution characteristics of the pollution.

Study Committee B2

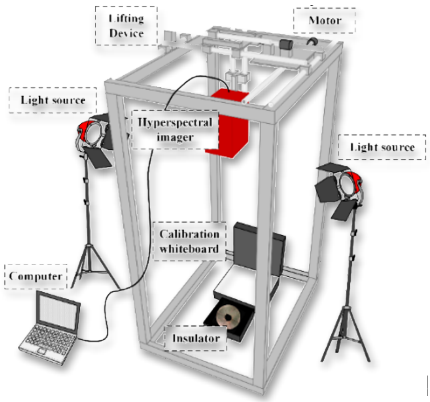
Overhead Lines

10302_2022

A Novel Method for Pollution Detection of External Insulation continued

Experiment platform

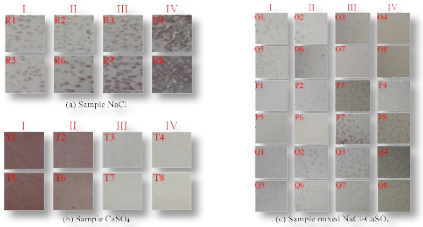
- The system consists of a hyperspectral imager, a computer, a standard calibration whiteboard with a reflectance greater than 99%, two light sources, and a hyperspectral lifting device that can move in three dimensions .
- The imaging data are transferred to the computer via the USB cable. The light source is used to simulate sunlight indoors and is placed on both sides of the sample to ensure the uniformity of the light on the sample surface.



experiment platform

Experiment platform

- The artificial samples were divided into three groups, and samples were prepared according to the IEC standard 61245 and IEC standard 60815-1 , and the silicone rubber insulation sheet was used as base material.



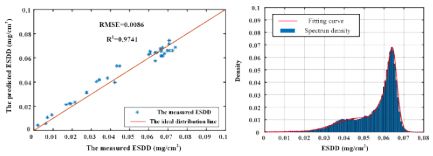
samples made by solid layer method

Classification of pollution degrees based on the ELM model

- 10 sets of data were extracted from each tag sample of three groups of samples as training data.
- the reflectance values of 256 bands were taken as the input to ELM, and the output was the classification result of test sample data.
- Results shows single pollution recognition accuracy up to 97.5% and mixed pollution recognition accuracy up to 97.5%

Methodology of determining ESDD spectral density distribution

- Partial least squares regression (PLSR), which is based on multivariate statistics and has been widely used in quantitative prediction, was chosen as the modeling method.



PLSR detection model and spectral density of the insulator shed

ESDD (mg/cm²) / Insulator sheds	0-0.03	0.03-0.06	>0.06
#A	3.17%	45.24%	51.59%
#B	1.01%	36.52%	62.47%
#C	1.52%	48.43%	50.05%
#D	1.60%	47.70%	50.70%
#E	1.38%	54.86%	43.76%

THE STATISTICAL PROPERTIES OF THE POLLUTION DEGREE

- Because the ESDD of each pixel cannot be measured, the overall ESDD of the insulator shed is calculated with the following formula:

$$Y = \frac{\sum_{i=1}^{n} X_i}{n}$$

- The characteristic wavelengths of the original hyperspectral data were selected based on the SPA algorithm.
- The PLSR model was used to transform the original data matrix into an ESDD data matrix. Finally, the new matrix was transformed into a 2-D color image, which was called the ESDD visualization image.