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Comparison of two methods for detection of UV signals emitted by PD on HV insulators made of porcelain

Abstract. *The paper presents measurements results of optical signals emitted by partial discharges (PD) occurring on various high voltage (HV) insulators made of porcelain. The following devices were considered during the research works: an insulating cylinder, a long rod insulator and a cap insulator. The optical signals were recorded with two different devices: 1) an ultraviolet (UV) camera and 2) a spectrophotometer. The measurements of optical signals were performed under laboratory conditions by changing the supply voltage and the distance between the HV and the ground electrodes.*

Based on the gathered results it was stated that the maximal number of optical emission counts, which was measured within the UV camera, was different for each of the considered device types. it was also stated that the optical signals registered with the UV camera (250-280 nm) are not the most intense signals contained in the radiation. Application of the spectrophotometer has enabled to show that there are more intense wavelength components which are in the range from 320-380 nm.

Streszczenie. *Praca przedstawia wyniki pomiarów optycznych sygnałów emitowanych przez wyładowania niezupełne (PD) występujące na różnych porcelanowych izolatorach wysokich napięciach (HV). W trakcie prac badawczych zostały rozpatrzone następujące urządzenia: kamera ultrafioletowa (UV) oraz 2) spektrometr. Pomiary optycznych sygnałów przeprowadzono w warunkach laboratoryjnych, przez zmianę napięcia zasilania i odległości między HV i uziemioną elektrodą.*

Na podstawie otrzymanych wyników stwierdzono, że maksymalna ilość optycznych emisji które były mierzone za pomocą UV kamery była różna dla każdego z rozpatrywanych typów urządzeń. Stwierdzono również, że sygnały optyczne zarejestrowane przez aparat UV (250-280 nm), nie są najbardziej intensywnymi sygnałami zawartymi w promieniowaniu. Stosowanie spektrofotometru pozwoliło wykazać, że są bardziej intensywne komponentydługości fali, które są w zakresie od 320-380 nm. ***(Porównanie dwóch metod wykrywania sygnałów UV emitowanych PD na porcelanowych izolatorach HV)****.*

Keywords: proszę podać słowa kluczowe angielskie.
Słowa kluczowe: proszę podać cztery terminy opisujące treść artykułu.

Introduction

The main aim of the research works, results of which are presented in this paper, was to determine the feasibility and to indicate the application scope of optical method in the diagnosis of high-voltage (HV) insulators made of porcelain. Technical condition estimation and diagnosis of insulation elements, which are important parts of every HV equipment are crucial, since their improper operation may lead to breakdown in the power supply. Especially outdoor insulators are exposed to faster worsening of the insulating properties due to e.g. pollution and atmospheric conditions. A high level of humidity by simultaneous occurrences of contaminants causes formation of conductive paths, which are the source of surface partial discharges (SPD) and corona discharges. The most important factors causing deterioration of the insulating properties of an insulation system is the natural aging process and occurrence of SPD. Therefore, a rapid development of various techniques for monitoring of PD is observed in recent years [1-21].

Improvement of nondestructive testing methods is the task on which authors concentrate their effort in their research works. In particular, it is to determine the feasibility and indicate the application scope of the optical method in the diagnosis of non-organic HV insulators.

This paper considers studies related to determination of the differences in the results achieved with two different measuring devices on three types of insulators made of porcelain.

Measurements methodology

In this study three HV insulators made of porcelain were investigated: a cap insulator, a long rod insulator and an insulating cylinder. In Fig.1 the considered objects are depicted.

Optical emission signals were measured under laboratory conditions using a spectrophotometer of type HR4000, from Ocean Optics and an UV camera of type DayCor Superb. The UV camera enabled for detection of light in the range from 250 nm to 280 nm. The spectrophotometer registered optical signals in the range from 200 nm to 1100 nm. During all measurement trails the same conditions were maintained. A single measurement trail was performed by the same distance between the HV and ground electrodes. The optical radiation was registered by changing the supply voltage value in the range from 0 to 100 kV. Each trail lasted for three minutes and several count number values were registered with the UV camera and five measurements with the spectrophotometer were made by each of the trails. The power supply system consisted of a testing transformer and control panel, which included an autotransformer, an over-current protection system and a voltmeter for measurement of the momentary voltage value. The voltage values were controlled by the autotransformer and forwarded to the primary winding of the single phase testing transformer. The output of the secondary winding was connected to a water resistor, which aim was to limit the short-circuit current with which the tested cap insulator was powered.

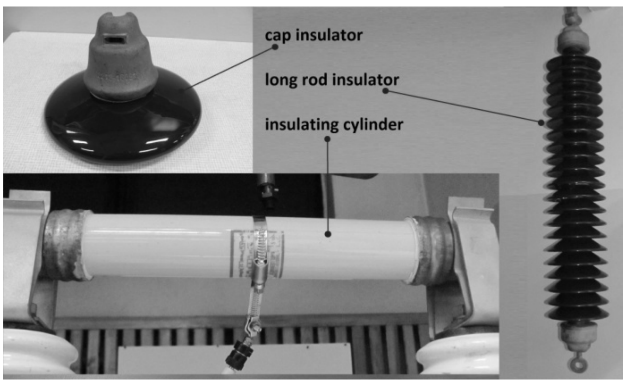

Fig.1. Pictures of the HV insulators applied in the study

Results and discussion

In Figs 2-4 the intensity of optical signals, recorded with the UV camera (to the left) and with the spectrophotometer (to the right), in dependence to the supply voltage value is depicted. The particular figures relate to results gathered by the three considered devices.

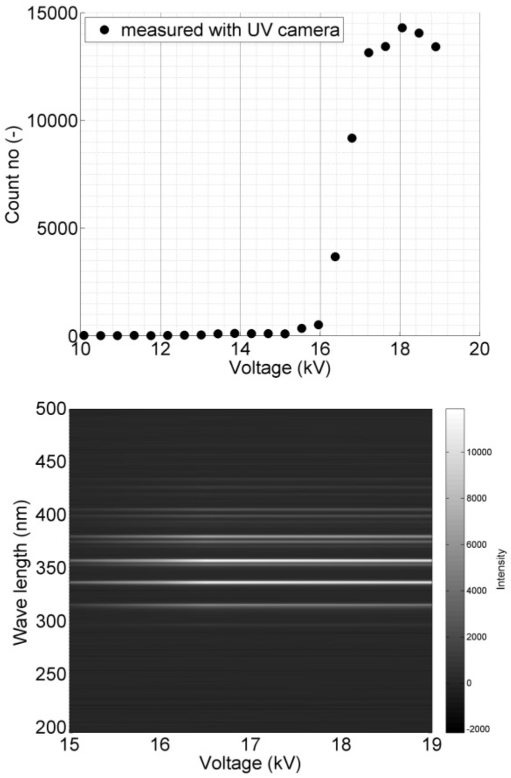

Fig. 2. Optical signals registered with the two considered methods on the cylindrical insulator

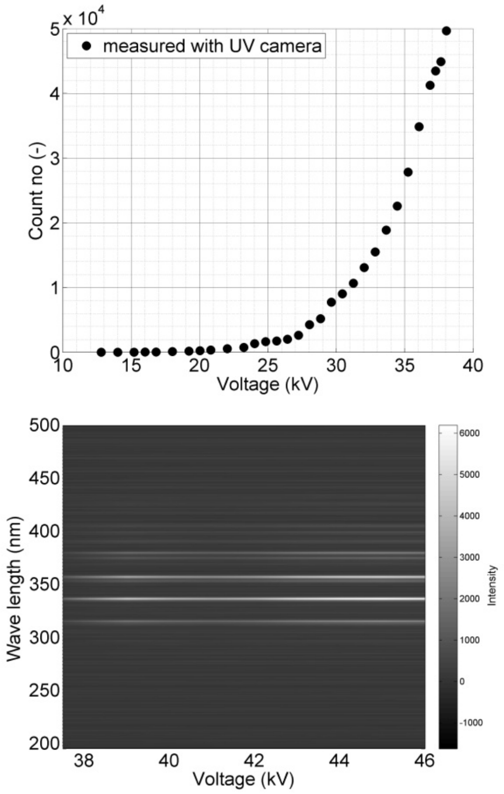

Fig.3. Optical signals registered with the two considered methods on the cap insulator

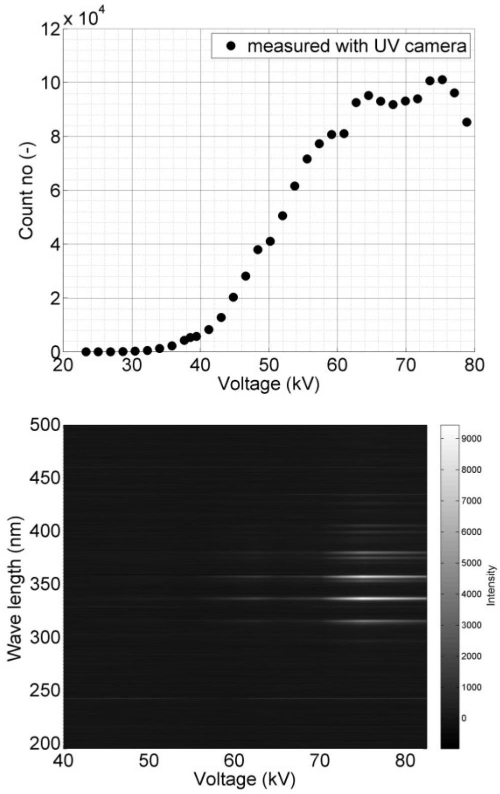

Fig.4. Optical signals registered with the two considered methods on the long rod insulator.

Considering data presented in Figs 2-4 to the left, one can recognize that the mean count number increases exponentionally after the supply voltage achieves a specific value that is different for each of the considered devices (16 kV by the cylinder, 38 kV by the cap and 25 kV by the long rod insulator). The largest increase was observed by the cylindrical insulator, where a change by only 2 kV caused a rise of PD number from 0 to the maximal registerd value. The smallest increase of PD number was observed by the cap insulator but the number of PD was the largest and achived a value equal to 100 000. By the cylindrical and cap insulators it was also observed, that the count number remains stable after the maximal PD numebr was achieved before a breakdown occures. However, the count number values which were not exceeded differ by the two devices: the maximal PD count number does not exeed 15 000 by the cylinder and reaches 100 000 by the cap.

Images presented in Figs 2-4 to the right depict the intensities of particular wavelengths in dependence of the voltage supplied to the analyzed devices. It was observed that the most intense wavelength components are in the range from 320 nm to 380 nm for all devices. One can also recognize that the wavelength spectra gathered by the cylinder and long rod insulators, apart from the supply voltage range and the intensity values are very similar in shape. Less intense but still significant wavelength components were observed beyond the main range. In contrast to this, the spectra for the cap insulator indicate lower intensities for smaller supply voltage values, less than 70 kV. The highest intensities, reaching 11 000, were observed for the cylinder insulator. The smallest intensities, exceeding 6 000, were registered on the long rod insulator.

Conclusions

In general it is to conclude that the spectrophotometry enables for to determine intensities of particular wavelength components included in the measured signal. While within the UV camera it is possible to detect visually the PD occurring in the insulator vicinity.

Based on the gathered results it was stated that the maximal number of optical emission counts, which was measured within the UV camera, was different for each of the considered device types. The lowest radiation was emitted on the cylindrical insulator and the highest on the cap insulator. It was also stated that the rising number of PD occurs after the voltage exceeds 16 kV by the cylinder, 38 kV by the cap and 25 kV by the long rod insulator. The short circuit occurred by exceeding 18 kV by the cylinder, 79 kV by the cap and 39 by the long rod insulator.

The most important conclusion considers the fact, that the optical signals registered with the UV camera (250-280 nm) are not the most intense signals contained in the radiation. Application of the spectrophotometer has enabled to show that there are more intense wavelength components which are in the range from 320-380 nm.

Comparison of the characteristics gathered from analysis of data registered within the two measuring devices resulted in statement that the intensity values do not correlate with the count number. Thus, application of only one of these methods does not present the holistic nature of optical radiation associated with generation of PD. It is recommended to apply both methods for diagnosis of HV insulators.

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REFERENCES

[1] Biswas S., Koley C., Chatterjee B., Chakravorti S., A Methodology for Identification and Localization of Partial Discharge Sources Using Optical Sensors, *IEEE Transactions on Dielectrics and Electrical Insulation*,19 (2012), 18-28

[2] Coenen S., Tenbohlen S., Location of PD sources in power transformers by UHF and acoustic measurements, *IEEE Transactions on Dielectrics and Electrical Insulation*, 19 (2012), nr.6

[3] Cleary G.P., Judd M.D., UHF and current pulse measurements of partial discharge activity in mineral oil. Science, *IEE Proceedings of Measurement and Technology*, 153 (2006), nr.2

[4] Nasrat L.S., Hamed A.F., Hamid M.A., Mansour S.H., Study the flashover voltage for outdoor polymer insulators under desert climatic conditions, *Egypt. J. of Petroleum*, 22 (2013), 1-8

[5] Abderrazzaq M.H., Abu Jalgif A.M., Characterizing of corona rings applied to composite insulators, *Elec. Pow. Sys. Resear.*, 95 (2013),121-127

[6] Giriantari I., Monitoring the insulator condition by on-line voltage distribution measurement, *IEEE Int. Conf. on Condition Monitoring and Diagnosis*, (2008), 392-394

[7] Ma B., Zhou W., Wang T., Ding Y., Study on corona discharge test under power frequency voltage of the severe non-uniform electric field based on the UV-light imaging technology, *IEEE 4th Asia-Pacific Conf. on Environmental Electromagnetics*, (2006), 253-259

[8] Stolper R., Hart J., Mahatho N., The design and evaluation of a multi-spectral imaging camera for the inspection of transmission lines and substation equipment, *World Insulator Congress and Exhibition*, (2005)

[9] C., Zhao X., He S., Lei H., Jiang Z., Ye H., Jiang Z., Research on mechanism and ultraviolet imaging of corona discharges of electric device faults, *IEEE Int. Symp. on Electrical Insulation*, (2008), 690-693,.

[10] Zang C., Lei H., Jiang Z., Ye H., He S., Zhao X., Jiang Z., Study on application of ultra-violet instrument in external insulation detection of electric device, *IEEE Int. Conf. on HV Engineering and Application*, (2008), 391-393

[11] Zhou W., Li H., Yi X., Tu J., Yu J., A criterion for UV detection of AC corona inception in rod-plane air gap, *IEEE Trans.*,18 (2011), nr.1, 232-237

[12] Zmarzly D., Nagi L., Analysis of Ionizing Radiation Generated by Partial Discharges, *Acta Phys. Pol. A*, 125 (2014), 1377-1379

[13] Borucki S., Boczar T., Cichon A., Investigation of the acoustic pressure distribution occurring around an aerial substation adjacent to apartment buildings, *Arch. of Acous.*, 32 (2007), nr.4, 291-297

[14] Wotzka D., Zmarzly D., Boczar T., Numerical Simulation of Acoustic Wave Propagating in a Spherical Object Filled with Insulating Oil, *Acta Phys. Pol. A*,118 (2010), nr.6, 1272-1275

[15] Cichoń A., Borucki S., Wotzka D., Szmajda M., Characteristic of Acoustic Emission Signals Generated by the Contacts of the Selector, *Acta Phys. Pol. A*,122 (2012), nr.5, 804-807

[16] Cichoń A., Borucki S., Wotzka D., Modeling of Acoustic Emission Signals Generated in On Load Tap Changer, *Acta Phys. Pol. A*,125 (2014), 1396-1399

[17] Wotzka D., Boczar T., Acoustic emission signals analysis in electric power transformer model, *Przegląd Elektrotechniczny*, 86 (2010), 74-77

[18] Szmechta M., Boczar T., Frącz P., Frequency and Time-Frequency Analysis of Acoustic Cavitation Noise in Insulating Oils, *Acta Phys. Pol. A*, 120 (2011), 744-747

[19] Borucki S., Cichoń A., The influence of the power transformer load on vibroacoustic signal analysis results, *Przegląd Elektrotechniczny*, 86 (2010), 45-47

[20] Yan C., Hao Z., Zhang B., Zheng T., Zhang S., Chao G., Yang X., Zhou D., Simulation and analysis of power transformer internal arcing faults overpressure characteristics, *Proc. 2014 Int. Conf. Power System Technology*, 685 - 690

[21] Boya C., Ruiz-Llata M., Posada J., Garcia-Souto J.A., Identification of multiple partial discharge sources using acoustic emission technique and blind source separation, *IEEE Tran. on Dielectrics and Electrical Insulation*, 22 (2015), nr.3