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Automatic detection of the flame during the determination of the comparative tracking indices

***Abstract**. The determination of the Comparative Tracking Index (CTI) according to PN-EN 60112:2003 standard is a time-consuming process, which can last for several hours. In this work, a solution based on advanced image processing, allows the detection of the flame occurrence on the sample's surface during the complex test procedure, is presented. By reducing staff involvement an automated detection of flame allows to decrease the costs of the procedure. In the paper, the principles of the algorithms development and their performance verification results are presented.*

Streszczenie.** Badania odporności materiałów dielektrycznych na działanie łuku elektrycznego (prądów pełzających) zgodnie z normą PN-EN 60112:2003 są procesem długotrwałym, mogącym trwać kilka godzin. W pracy zaprezentowano bazujące na zaawansowanej analizie obrazu rozwiązanie umożliwiające wykrycie płomienia na powierzchni materiału. Opracowany system pozwolił obniżyć koszty realizacji badań poprzez redukcję zaangażowania pracowników. W pracy zaprezentowano podstawy działania algorytmów oraz wyniki weryfikacji skuteczności ich działania.* ***(Automatyczne wykrywanie obecności płomienia w badaniach odporności dielektryków na łuk elektryczny)

Keywords: Comparative Tracking Index determination, flame detection, advanced image processing
Słowa kluczowe: badanie odporności na działanie łuku elektrycznego, detekcja płomienia, zaawansowane przetwarzanie obrazu

Introduction

The wide range of insulation materials used for electrotechnical applications imposed the need for comparing them by property values. Common method for making this comparison is the technique for determination of the proof and comparative tracking indices of solid insulating materials. The Comparative Tracking Index (CTI) test [1] is specified in PN-EN 60112:2003 [2]/ IEC 60112:2003 [3] standards. It involves the determination of voltage which causes electrical breakdown on the surface of the insulating material after 50 drops of ammonium chloride solution have fallen on the material. When the electrical breakdown of the material is detected (fig. 1), the test is complete and the properties of the material are determined.

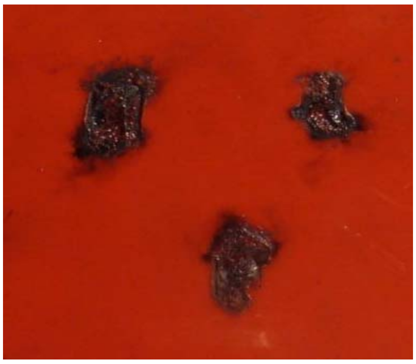

Fig.1. The examples of the surface of the insulation material after performing the Comparative Tracking Index tests

However, there is a risk of flame occurrence during the test, as the temperature of the insulation material can reach its ignition point. If such state is persistent, the procedure should be terminated, due to the standard requirements and the safety of the device and personnel. Therefore the test stand must be supervised in order to provide a reasonable response time for such event. As the standard does not define the way the flame appearance should be detected, it is mostly performed by direct visual inspection. This solution causes the cost increase, as a single test may last up to a few hours. Therefore another approach should be developed in order to provide a reliable and cheap tool for flame detection.

Such a problem can be solved with advanced image processing tools which are widely utilized for solving various technical and scientific problems [4]-[9]. As recently the medium-class personal computers with CCD cameras can effectively acquire and process visual data as a stream, we've decided to develop such a solution.

The setup and test procedure

The test stand used in this experiment was from Friborg (Tracking index Analyzer, Model 4200). This device was designed specifically to meet the PN-EN 60112:2003 standard requirements. The view of the setup is presented in figure 2.

Fig.2. The view of the Tracking index Analyzer, Model 4200

In order to perform the flame detection, a personal computer with a CCD CMOS-based camera with a resolution of 640 x 480 pixels, fixed focal lens f = 3.25 mm and aperture f/2.4 was used. Sensor has an automatic exposure control while the image sharpness is adjusted manually. By utilizing the interpolation process, the device allows to acquire the video data stream with a maximum resolution of 800 x 600 pixels with 20-60 frames per second speed. Data is transmitted to the computer via USB 2.0 interface.

The software

The software was developed using LabView 2012 environment [10]-[13], which allows to design the algorithms and the user interface using graphic programming language. Its main task is the image data stream processing and analysis in terms of quantity of three color components (green, blue, and red) within the area of interest. As the flame causes significant increase of the brightness in large fraction of the observed area, analyzed quantities can be correlated with this event. Therefore, during the first phase of the test, the software performs the calibration in order to provide the reference level, and then, searches the maximum values of high brightness counts. As observed quantities reach the threshold level, the software enables visual and sound alarm. In case of too high sensitivity, one can increase the threshold up to 150% of the highest observed value and continue the flame detection. The user interface is presented in figure 3.

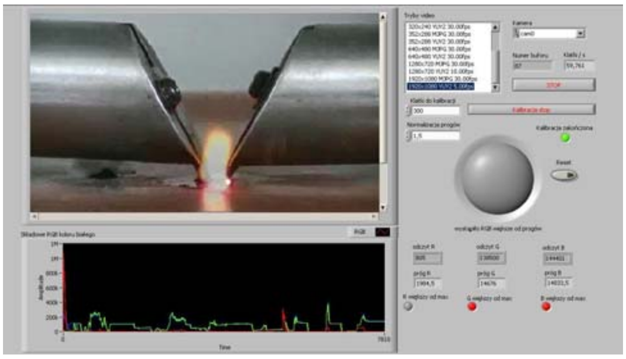

Fig.3. The user interface of developed software

The software also allows to select the USB device as well as the image resolution and imaging rate.

The test procedure

In order to verify the reliability of developed solution, the set of various materials was tested such as: polycarbonate, epoxy resin, acrylonitrile butadiene styrene (ABS) and polyamide. Each material was a subject of the tests according to PN-EN 60112:2003 standard. The tests were repeated several times until the current limit of flame appearance was noticed. When the flame appeared (fig. 4), the values of observed quantities were related to certain events.

Fig.4. The acquired image of flame during the test procedure

Additionally, the relation between three basic colors were verified in order to check whether it can be considered as a signature for certain type of material.

Results of the experiment

Obtained data allowed to identify the flame appearance with a high level of confidence. Significant increases of calculated values were easy to recognize (fig. 5 top). It should be underlined, that during the tests, some false alerts occurred, as first brighter phenomena could be observed. Therefore additional adjustment button was used to increase the threshold level (fig. 5 bottom). Additionally, one can see that the flame can appear either as persistent or a short-time event. Therefore, an event timer allows to ignore irrelevant flame ignitions.

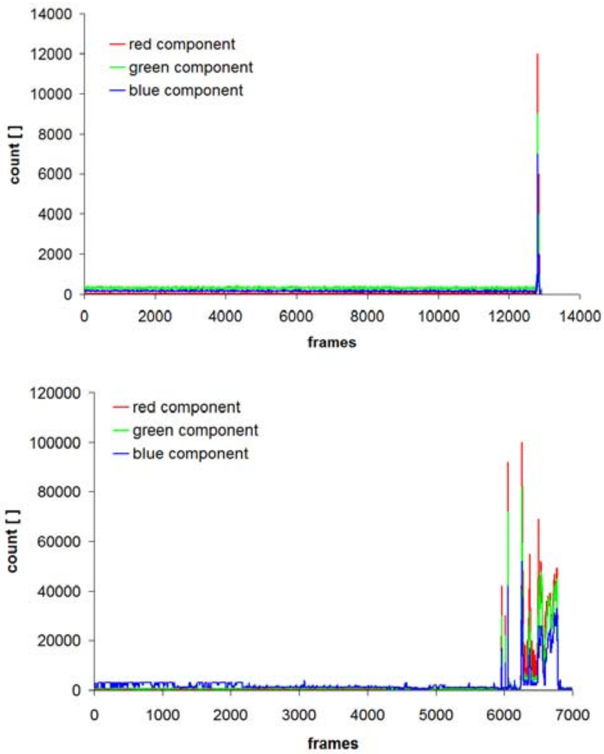

Fig.5. The charts showing the colors intensity changes during the tests, including the flame appearance

Table 1. The color values ratios for the peaks acquired during the flame presence

Peak no.	Material: ABS		
	Red [a. u.]	Green [a. u.]	Blue [a. u.]
1	1	0,71	0,40
2	1	0,78	0,46
3	1	0,82	0,52
4	1	0,58	0,31
5	1	0,65	0,38
	Material: polyamide		
	Red [a. u.]	Green [a. u.]	Blue [a. u.]
1	1	0,40	0,24
2	1	0,40	0,34
3	1	0,55	0,45
4	1	0,77	0,56
5	1	0,54	0,39
	Material: polycarbonate		
	Red [a. u.]	Green [a. u.]	Blue [a. u.]
1	1	0,70	0,60
2	1	0,68	0,58
3	1	1,02	0,84

Table 1 shows an example of data analysis in terms of the colors values ratios as the flame was present. Due to the fire temperature, the red color reached the highest values. Therefore it was used as the reference. Green and blue were significantly lower.

One can note, that for certain materials there is a specific relation of the colors, as the temperature of the flame can differ. Nevertheless, differential method which was utilized in the presented solution, basing on the observation of the relative increase of certain factors, was reliable. It should be noted however, that the analysis of red component provides the best detection sensitivity.

Discussion and outlook

The developed method for optical flame detection basing on advanced image processing was tested and provided satisfying results. As a new feature of the measurement system is enabled, the tests can be performed without continuous visual supervision of the laboratory staff. No danger of compromising the test quality as well as the safety of the personnel appeared, while the labor costs were reduced. Further tests will be performed in order to verify the reliability of the flame detection algorithm. It is also planned to implement fuzzy logic algorithms as different samples can be challenging in terms of reliable detection.

One can argue if the solution could based on a single photodiode and voltage peak detection. Such solution would however suffer from limited spatial accuracy, as image processing allows to select the area of interest. Moreover, the developed software can be supervised via LAN. Therefore a staff member can perform other tasks using another computer, and still be able to provide immediate visual inspection when the software indicates the flame appearance. It is worth of mentioning, that such functionality can be implemented in FPGA-based devices providing lower unit price and compact design.

This work was performed within frames of IEL statutory work. The authors would like to acknowledge the contribution of Bartosz Boharewicz.

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