A Mobile System for Measurements of Partial Discharges Controlled by Electroencephalographic Waves

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Abstract:

The article presents the concepts of a mobile system for measurements of partial discharges controlled by brain waves. In order to describe that, a robot, which takes measurements of partial discharges, has been worked out. The discharges may occur in an isolator of electrical devices such as capacitors and transformers. What is more, a concept of a link between the robot and a human brain is described, in order to ensure a direct communication on the level of the human brain and the robot.

***Keywords:** EEG, a mobile robot, partial discharges.*

1. Introduction

Present technological solutions enable us to work out more and more new concepts for completions of those problems, which used to be difficult to solve before. The development of bio cybernetics as well as computer science has created favourable conditions for supporting automation and robotics by means of computer mechanisms [1]. Even few years ago a direct control of a human brain by such devices as robots was difficult to complete in terms of technical requirements [2]. Nowadays it is possible to analyse brain waves emitted by neurons by means of electroencephalography. Then, after an appropriate classification, they may be used in the process of controlling [3]. The present article describes the concepts of the use of brain waves collected by an electroencephalograph in order to control a mobile robot, which would help an automatization of the process of a measurement of partial discharges.

2. Partial discharges

Partial discharges (PD) are those phenomena, which occur in isolators of such electrical devices as transformers, energetic capacitors, electric motors, etc. This phenomenon is unfavourable in terms of the description of an insulator, and an increasing frequency of the occurrence of partial discharges means its considerable degradation. The occurrence of different physical mechanisms, which accompany both complete and partial electric discharges, shows a complexity of this issue. Signs of damages of insulating materials are accompanied with physiochemical factors. The most important of these factors are [4], [5], [6]:

- the emission of an electromagnetic wave, from the place where a discharge appears, which is a result of a power-driven impulse,
- chemical conversions within the structure of insulation,
- elastic strains on the molecular level which lead to the emission of a sound wave,
- light flashes, which emit radiation on the level of a visible, an infrared and an ultraviolet spectrum,
- local implosions, which cause a rise in temperature and changes in a pressure of gas.

The occurrence of specific factors is directly connected with the complexity of energetic devices, which contain insulators. For that reason, methods of detection of partial discharges are suggested that are based on the detection about the level of the occurrence of a particular physiochemical phenomenon [7]. Nowadays the first place in diagnostics occupies non-invasive methods. In terms of partial discharges, the most important are methods for the measurement of an Acoustic Emission (AE) [8, 9, 10] and an Optic Spectrum Diagnostics (OPD) [11, 12]. Figure 1 presents a modular diagram of the system for the measurement of partial discharges by means of the acoustic emission's method.

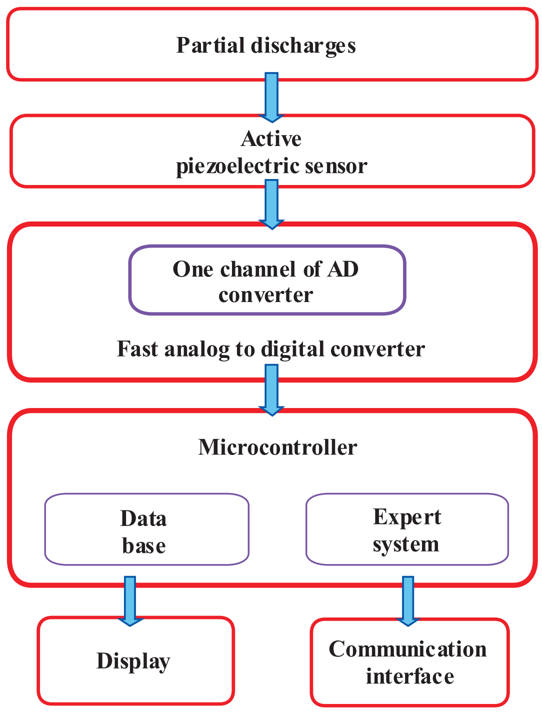

Fig. 1. A modular diagram of the detection of the partial discharges by means of the acoustic emission's method.

The main elements of the structure are a piezoelectric detector, input measuring amplifiers, a digital to analogue rapid converter and a system of data collection. The piezoelectric detector is situated close to the place where a partial discharge appears. In terms of measurements on a real object, it is necessary to 'sound' as big as possible surface in order to determine areas with a high probability of the occurrence of partial discharges. The place of the contact between the detector and the surface of the object should be fitted, as much as it is possible, in order to eliminate auditions from the surrounding. It is significant to have the opportunity to transfer the detectors what makes it easier to conduct the diagnosis. Figure 2 presents a configuration of the system in terms of the measurements of partial discharges by means of the method of detection of the optical spectrum. Three optical detectors are situated close to the place where the phenomenon of partial discharges appears. Every detector is adapted to a different optical band. The bands of a visible, an ultraviolet and an infrared light are enumerated.

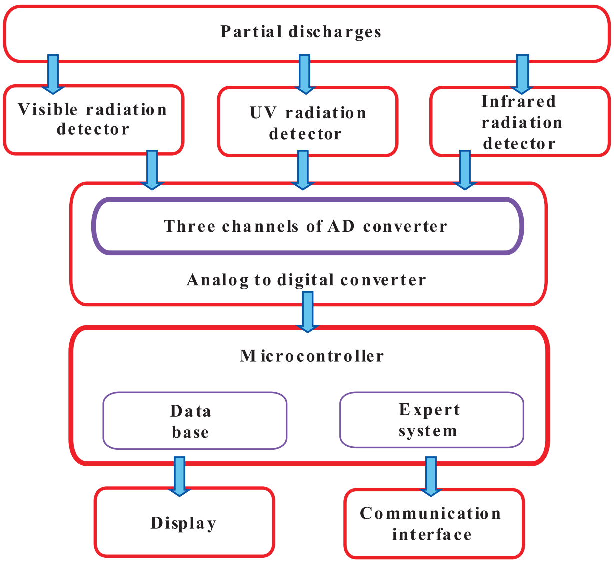

Fig. 2. A modular diagram of the detection of partial discharges by means of the method of the optical spectrum's measurement.

The detectors are built from semiconductor, photosensitive elements which purpose is directed to specific lengths of a light wave. During the measurements, a considerable activity in terms of the ultraviolet waves is observed, what directs research in this field. Because of a very low energy level of partial discharges, which mean a degradation of the insulator, very sensitive measuring tracks should be used. According to this fact, the detectors should be equipped with a high selectivity of the band, a high level of the reinforcement and a very good coefficient of a condition between the interference and the useful signal. Because of that, highly selected measuring detectors should be used for work with photosensitive semiconductor elements. It is not necessary to use rapid measuring systems because of a low dynamics of the signal. The digital to analogue processing in terms of the method of detection of partial discharges, under present consideration, does not have to exceed 100 kS/s. Then, there is a real opportunity to use a converter with an effective resolution above 16 bits.

3. The mobile robot

The possible measurements constitute a real technical challenge within areas where there are big difficulties for analysts with the access to the subject under research. A significant advantage of the mobile research unit is the opportunity to deliver the equipment to those places where the staff, which operates the robot, may suffer from health damages. The SQ1 robot is presented in the Figures 3 and 5. It is designed and equipped with an apparatus that enables to move it within the area of its potential use. The robot is fitted with such technologies as ultrasound detectors of distance, accelerometrical detectors located on the robot's legs and on the central part of its main body, digital cameras and laser scanner. The communication between an operator and the robot takes place cordlessly. The operator is able to guide the robot in the architectural space of a distribution board of average voltage by making use of an original application. Measuring samples are taken through the detectors that are placed on the research object. Information from the detectors is also transferred by means of radio waves.

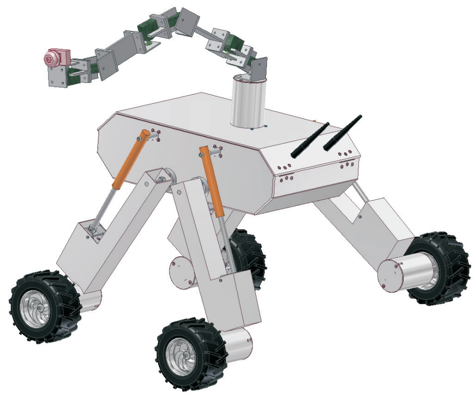

Fig. 3. The mobile robot simulated in AutoDesk Inventor 2009.

The mobile measuring system consists of few modules, which enable the operator to work remotely. The main elements of the mobile robot are a cordless module defined by the IEEE 802.11 standard (*Wireless Fidelity – WiFi*) [13], which enables a direct communication with the PDDetect2 controlling application; the main module which consists of the measuring part; a cordless transmission channel (*Bluetooth*) which enables the communication with the measuring detectors; an active underbody and a monitoring module of work parameters of the SQ1 robot. The module structure of the mobile measuring system is presented in the Figure 4.

The robot is equipped with an arm that enables the operator to install elements of the measuring systems on the surface of the research object. During a diagnosis, there is an analysis of the partial discharges that are emitted, together with a simultaneous consolidation of the knowledge of the spatial position of the detector's installation in a base. In the future it will enable to do comparative research and to determine degradation's trends, which appear in an insulating system under research. The system of magnetic clutches, which are placed on the arm, enables to operate small modules of detectors more easily and to attach them to the surface of the object.

Software of the measuring mobile system was completed with support of Real Time Operation System (RTOS).

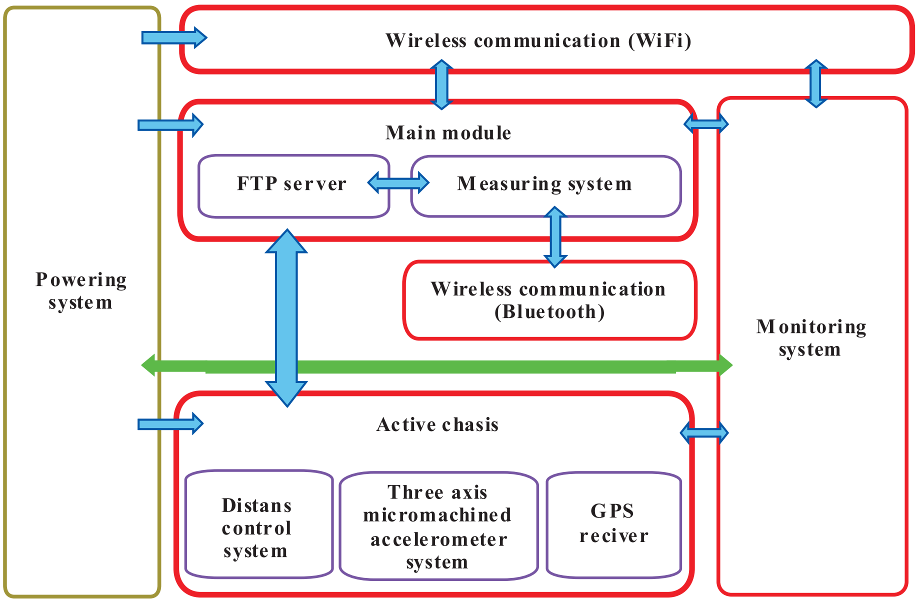

Fig. 4. The module structure of the mobile measuring system.

Particular modules, which constitute the robot, were designed according to the architecture suggested by the producer of RTOS. The use of resources accessible in the library of the operation system gives a chance for a fast implementation of new functions, which lead to the development of the measuring mobile system.

A module of a cordless detector was implemented by the use of a fast microcontroller with an ARM root. It allows a registration of the signal of acoustic emission generated from partial discharges with a speed to 8 MS/s. Samples registered by the detector (Figure 6) are sent to the mobile robot. In sequence, data are gathered as a file in the fixed memory. An access to information happens with the use of a FTP server (by means of the FTP client) or with a PDDetect2 application, which simultaneously implements the process of visualization and an analysis.

Fig. 5. The mobile robot – a laboratory photograph.

The automation of the process, which eliminates the necessity of disconnecting a live element of the electro energy system, remarkably shortens the time of the analysis and at the same time it does not cause interferences in the work of the energy system. Regular diagnosis of the elements of the energy system and a consolidation of their parameters enable to gather information, which are useful within the process of planning the service. In addition, the measuring mobile system memorises the track and the topology of the area of the electro energetic station and the place of the installation of objects, which are diagnosed.

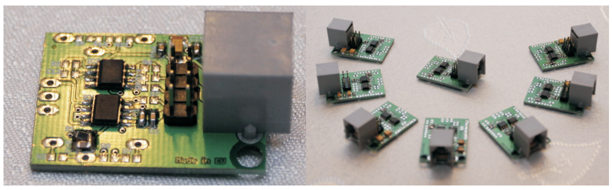

Fig. 6. The module of the detector: active piezoelectric probes.

4. The control of the robot by means of the brain

The PDDetect2 application, installed in the working station from which the process of control of the robot takes place, enables the implementation of this process by an analysis of the electroencephalographic signal. The EEG signal is collected with a non-invasive method by means of active electrodes that are placed on the skin of a person's head under research [14]. The arrangement of the electrodes is specified by the 10-20 IFCN international specifications. Then, the signal is transported to an electroencephalograph, which is connected by means of a USB 2.0 port to a working station with the PDDetect2 application. Software accomplishes an appropriate classification of the EEG signal in order to specify conclusions about the robot's reactions on brain stimuli in a particular moment of time. Figure 7 illustrates ideas about implementations of the communication with the use of the EEG signal.

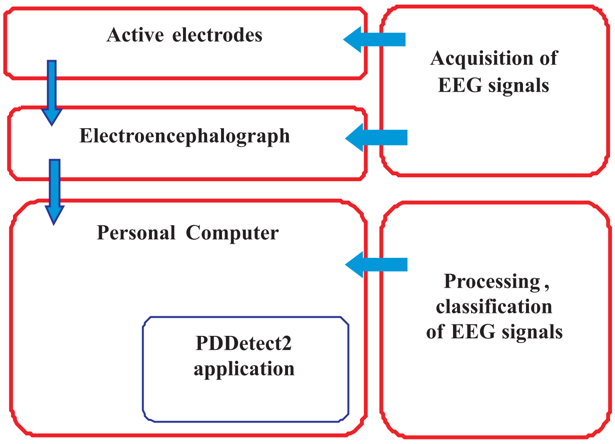

Fig. 7. The module structure of the system of the collection of brain waves.

An appropriate analysis of the oscillation of the EEG signal in terms of the ?α, β, γ rhythms has an impact on the process of a proper control of the robot [15]. During the analysis of the EEG signal a big synchronisation of the β rhythms in the attention process can be seen, what is essential from the point of view of the control of the mobile robot. In the same time, a big activeness of pyramidal cells appears and a strong synchronisation of them. The γ rhythms are seen during an intensity of the amount of the processing information by neurons in the unit of time 't'. In terms of the γ rhythms, a synchronisation of activity takes place, which is directly connected with the processing of information [16], [17]. Nonlinerality has a direct impact on the frequency of the rhythms and their shapes that is connected with specific character of stimulation, which appears then. Oscillations of the γ rhythms can be observed on many electrodes within areas of those that were placed directly above the motor cortex. During a measurement of the electroencephalographic signal, it is also possible to observe a disynchronisation of the signal, which is seen in the difference of the energy of the measuring signal. The measurement of the disynchronisation of the signal is based on the study of its power (1).

$$P_A(m) = \frac{1}{N}\sum_{n=1}^{N} A^2_{f(n,m)} \quad , \qquad (1)$$

where A is the value of an m-point of the signal in an n-repeat of the experiment and N means the number of repeats. Then, disynchronisation may be defined as it follows (2).

$$ERD = \frac{P_A(m) - Z}{Z} * 100\% \quad , \qquad (2)$$

where Z is the level of reference (3).

$$Z = \frac{1}{l}\sum_{m=i_0}^{i_0+l} P_A(m) \qquad (3)$$

l – the length of the reference area,
m – the point of the signal.

Besides the non-invasive Brain Machine Interface suggested in this article, there are also invasive methods. This type of BMI was described by scientists in the United States and Europe. They use a surgical implant, which consists of beams of electrodes. From the technical point, it is more difficult to implement and less practical in such uses as the mobile system for the measurements of partial discharges. That is why the non-invasive method was used for the system of measurement of partial discharges.

The mobile measuring system for research of partial charges, which occur in the insulating structures during the progressive process of the degradation of the dielectric material in electroenergetic capacitors with the use of the EA method, will be tested during diagnostic investigations in factory conditions. It will enable to specify the scope of practical adaptations. Experimentations during big levels of electromagnetic interferences, which accompany work of electroenergetic devices, will enable to state directions towards further transformations of the system what will result in its improvement. The use of the mobile system of recording of the EA signals generated by partial discharges in the insulation of the electroenergetic capacitors will allow among others to automatize of the measuring system which was conducted manually before, to automate the process of registration, to present the results (automatic change of places where converters are situated, the way of its connection with a particular object), to separate the technical personnel effectively from the place of measurement ensuring security; a mobility – the possibility for sending measuring data from the place of measurement to the station of the operation by means of a cordless network based on the TCP/IP protocol.

5. Problems on the stage of the completion of the connection between the brain and the mobile robot

Undoubtedly, the greatest problems, which occur on the stage of correlation between a human brain and the mobile robot, are different kinds of both biological and technical interferences [18], [19]. Technical artefacts seem to be especially significant in the system under present analysis because the system works near big concentrations of electroenergetic devices, which disrupt a proper reading of the signal [20], [21]. According to this fact, it is necessary to isolate the control station from the mobile robot's area of work. Apart from the technical problems mentioned above, a certain biological criteria are required from the person who controls the robot. A special attention should be paid to people with high blood pressure, accelerated pulsation of heart or those who possess different kind of nervous tics. Unfortunately, such people cannot control the mobile robot in an easy way.

6. Conclusion

The control of the mobile robot by means of brain waves also requires a constant improvement. It is necessary to elaborate on population models that are imagings of particular populations of neurons and their mutual correlations. By means of advanced mathematical methods, it is possible to simulate proper preservation of the EEG signal in specific mental states of a human being. It is the key to success in the case of the structure and the implementation of both Brain Computer Interface and Brain Machine Interface communication.

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