DETECTOR OF COVERED CONDUCTOR FAULTS

Stefan HAMACEK[1], *Stanislav MISAK*[1]

[1]Department of Electrical Power Engineering, Faculty of Electrical Engineering and Computer Science, VSB–Technical University of Ostrava, 17. listopadu 15, 708 33, Ostrava Poruba, Czech Republic

stefan.hamacek@seznam.cz, stanislav.misak@vsb.cz

Abstract. *In the Czech Republic are distribution lines with bare conductors replaced by distribution lines with covered conductor. The PAS system with covered conductors has many advantages and disadvantages that are described below. This article describes issue of fault detection for distribution lines with covered conductors, dependence of partial discharges on fault and finally the design plus realization fault detection of covered conductors. This is a prototype which will be tested and then optimized. The system will be used for different voltage levels and different types of outdoor distribution lines.*

Keywords

Covered conductor, fault detection, partial discharge, PAS system.

1. Introduction

The PAS system of covered conductors began to build in Finland. It was used in Europe and the Czech Republic later.

This system has many advantages compared to the distribution with conductors without insulation:

- it reduces the failure rate caused by falling trees or touch of wet branches,
- fallen trees on the distribution lines can be removed later under favorable conditions,
- no short circuit occurs when conductors touch each other,
- conductor insulation reduces the corrosion in extreme outdoor conditions,
- the distance between the phases is reduced by 1/3 length versus bare conductors.

Today, the biggest problem is the inability to detect the fault. Types of fault are as follows: a fallen branch on the covered conductor or wire torn off and its subsequent fall to the ground. Standard digital protection is unable to detect these types of faults. To see a standard ground fault see Fig. 1.

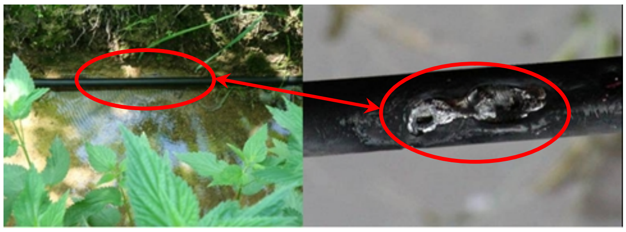


Fig. 1: The consequence of failure - Conductor fallen on the ground.

2. Analysis of Operating and Fault Conditions of CC System

All known types of CC system faults were simulated using the sample of covered conductor and discharge activity for various temperatures, relative humidity and pressure of CC system environment was analyzed within the long-term testing.

The probability of the occurrence of partial discharges in operating condition is at minimum level compared to fault conditions. Although no fault occurred on the line, the occurrence of partial discharges, however, cannot be fully eliminated. All three types of partial discharges are expected to occur during the measurement carried out under laboratory conditions, namely:

- internal discharges – generated mainly at the point of inhomogeneity inside the insulation (in our case, XLPE insulation),
- surface discharges – occur on the surface of insulation,
- corona discharges – occur at the points of increased inhomogeneity of electric field (especially sharp edges in HV part of measuring system).

A low-level signal produced by partial discharges from the background of interfering signals had to be obtained for the analysis purposes by means of a suitable measuring technique. To this purpose, a digital filter IIR –

Butterworth, [1] was used.

Record parameters: the measured signal was stored with resolution of 20 MS·s^{-1} and time 0,1 s.

Fig. 2 and Fig. 3 show the difference in the occurrence of partial discharges for the case of operating condition of the CC system and for the case of selected fault condition. The two figures show the difference in discharge activity for the case of fault and fault-free condition. The case of CC dropping onto HV pole console connected to earth was selected as fault condition from the measurement database.

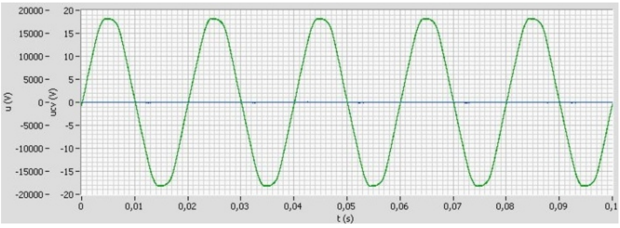


Fig. 2: Free of fault (supply voltage waveform, waveform with partial discharge).

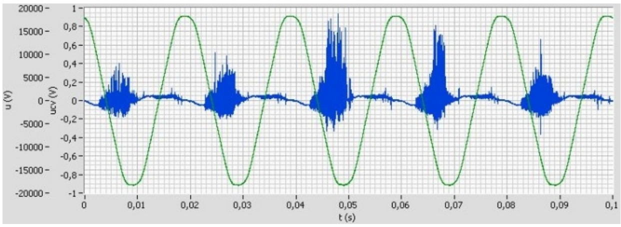


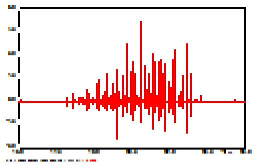
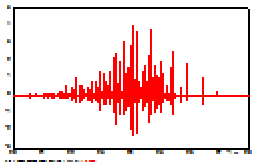
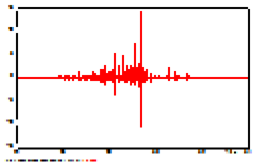
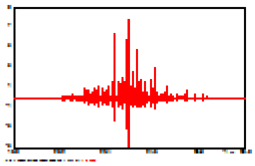
Fig. 3: With fault – conductor on the ground – sand (supply voltage waveform, waveform with partial discharge).

An example of simulated fault on PAS – 22 kV type conductor in the environment of the climatic chamber for the case of CC dropping onto the pole console is shown in Fig. 3. The measurement was carried out in enclosed climatic chamber for temperatures -20, 20 and 60 °C.

Fig. 4: Example of fault simulation in laboratory conditions: Analysis of CC discharge activity in fault condition at temperature of 20 °C. Drop of conductor onto pole console.

Temperature inside the climatic chamber was set at -20 °C. Tab. 1 indicates the selected parts of signals of partial discharges for a certain time interval.

Tab.1: Example of partial discharge signal.

Record 1	**Record 2**
	
Record 3	**Record 4**
	

The evaluation of partial discharges and the value of U_{RMS} (effective voltage signal of partial discharges) are shown in Fig. 5 and Fig. 6. In this measurement, the frequency of partial discharges and the value U_{RMS} were at maximum level. The frequency was in the range from $1{,}46\cdot10^6$ to $1{,}51\cdot10^6$ (s^{-1}), the value of U_{RMS} fluctuated around 40 mV at the beginning of the measurement and then, after approximately 32 hours, increased to 50 mV.

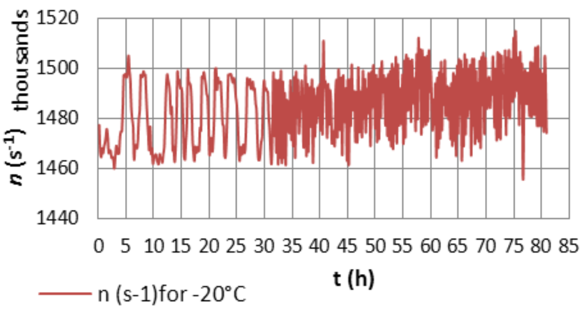


Fig. 5: Partial discharge frequency graph.

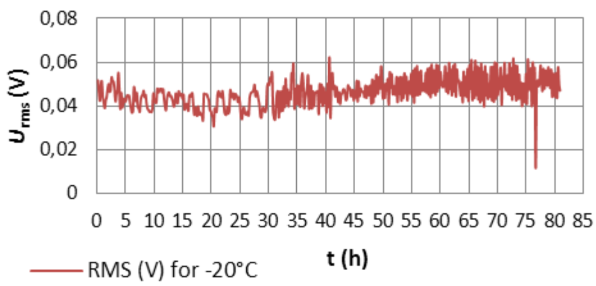


Fig. 6: Waveform of U_{RMS} for partial discharge.

The results of temperature, dew point and humidity development for a certain period of time are shown in Fig. 7. It is apparent that the change of humidity during the measurement was minimal and did not exceed 63 %.

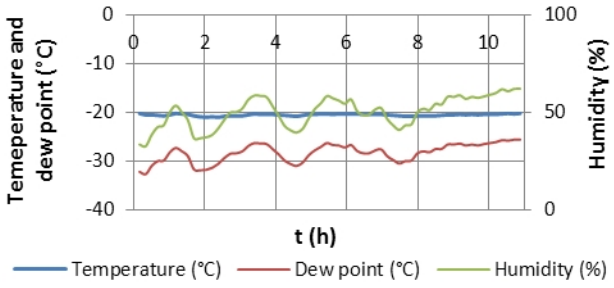


Fig. 7: Change of humidity, temperature and dew point.

After a certain period of time, the occurrence of partial discharges on the console itself was also observable in the visible radiation spectrum. As apparent on Fig. 8, in its left section, the effect of partial discharges caused degradation of the conductor insulation. Material permittivity as well as field homogeneity changed due to gradual effect of partial discharges on conductor insulation. Particles near the place of occurrence of partial discharges started to charge, thus contributing to their visual identification. Further stress applied on the conductor and the corresponding degradation activity would most probably lead to the transition from partial discharge to full-arc discharge, with all side and destruction effects.

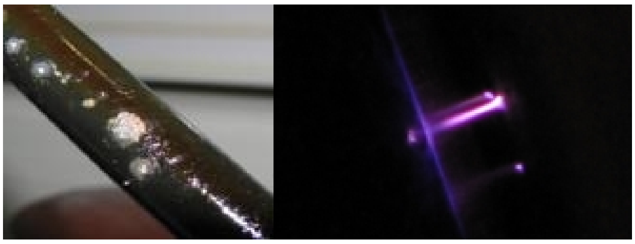


Fig. 8: Example of degradation effects of partial discharges.

3. Development of Detector Failures

Partial discharge has effect of degradation on the covered conductor. Climatic conditions may amplify these degrading conditions. The emergence of fault has resulted in increasing voltage U_{RMS} and frequency of partial discharges. These values are measured by suitable measuring system. The voltages of partial discharge are from μV to mV even so can degrade the covered conductors. Everything is dependent on the intensity of the electric field. Electrons and ions can bombing of wall cavities. Ozone is created in the cavities at the presence of oxygen. Ozone has erosive effects on covered conductors. Cavity is gradually increased and continued erosion. This can cause of electrical breakdown of the dielectric. Conductors are exposed to the partial discharges which dried covered conductors and then surface cracks occur. Effect of partial discharges can lead to such a short circuit between phases or ground fault can occur. It will be able to measure the parameters of partial discharges and evaluate the emergence of fault of the measured parameters on the overhead lines. Parameters of partial discharges will be used for the evaluation different faults on the overhead lines.

The emergence of fault "branches fall on the phase" is possible to see on Fig. 9. Faults will result in the occurrence of partial discharges as can be seen from the voltage signal. The voltage signal No. 1 is fault-free state and the signal No. 2 is a state of failure. At the No. 2 shows a partial discharge which are modulated on the voltage signal. So dependency was found between the occurrence of partial discharges and failure. This methodology is currently protected by patent P 2008-647.

Partial discharges have their measurable parameters – U_{RMS} (V, effective voltage partial discharge) and n (s^{-1}, frequency).

Fault indicators were selected:

- U_{RMS} value of the partial discharge,
- the frequency of partial discharges,
- FFT analysis in the frequency domain,

the median value of partial discharge.

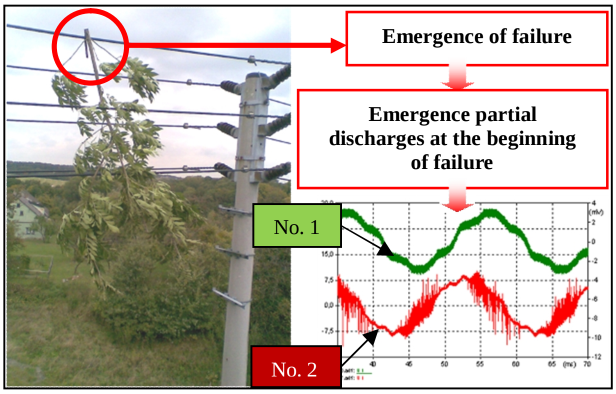


Fig. 9: The dependence of partial discharges on fault.

Detector can monitor the discharge activity of partial discharges and monitors weather conditions in the long term period of time.

Climatic variables are involved in the degradation of covered conductor. Measured parameters are therefore – pressure, temperature, dew point, humidity and global radiation.

The detector of failure of the covered conductors is placed on the mast medium voltage. Parts of the detector failures are shown on Fig. 10.

Primary requirement for the measuring system is oscilloscope's measurement of the timing voltage signal. This signal is scanned around the covered conductor hanging on the medium voltage lines. Measurement card connected via PCI interface is used for this purpose. Other measured parameters are temperature, pressure, humidity and light radiation in the vicinity. Two sensors are therefore used. The first sensor measures temperature, pressure and humidity. The sensor has an interface RS485. The second sensor is pyranometer.

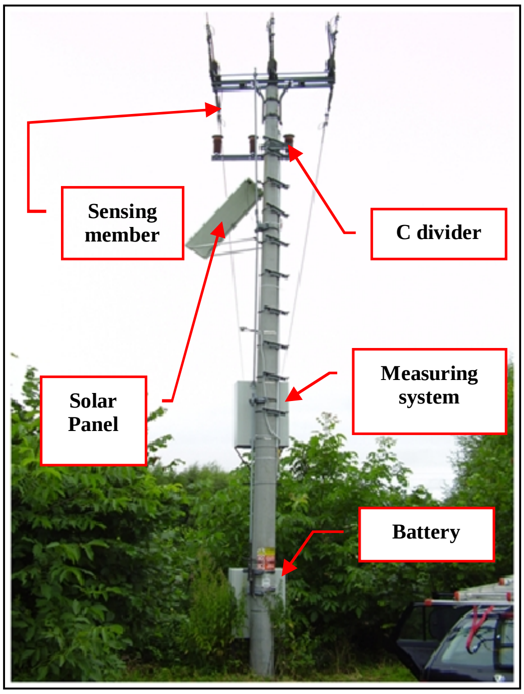


Fig. 10: The prototype detector failures of covered conductors.

Measured data will be sent to an external computer via GSM network, where will be processed. Modem for data transmission in the GSM network will be connected directly to the PC via Ethernet. We proposed a control electronic circuits for automatic control of computer. Entire supply measurement system will be charged from batteries and photovoltaic panels

3.1. Description of Hardware Part

An industrial computer ENA440 forms a basic element of the measuring system. ENA 440 contains an oscilloscopic measuring card NI PCI5102. This measuring card is provided with two analog inputs enabling to sample the measured signal at sampling frequency of up to 20 millions of samples$\cdot s^{-1}$. Since it is necessary to measure 3 phases + accumulator voltage, the signals at measuring card inputs should be switched over. A special module with relay was produced to multiplex the channels of the measuring card; output links (TxD, RTS, DTR) of the RS232 communication interface are used to control the relay.

Other measured parameters include temperature, pressure, humidity and global radiation (exposure) in the environment. Two sensors are used. A sensor for temperature, pressure and humidity measurement with direct output to RS485 interface and a pyranometer sensor, which has a voltage output, and therefore, it is provided with a converter to RS485 interface. The two sensors are then connected to the ENA440 computer, where the measured data is further processed.

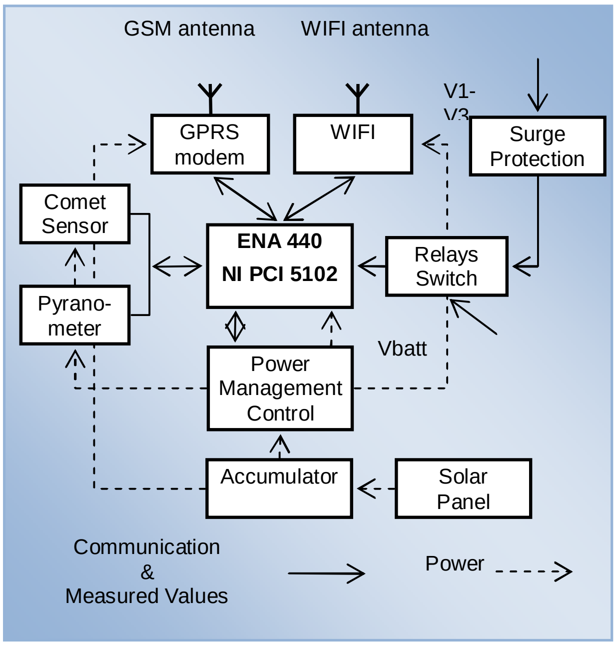


Fig. 11: Block diagram of the measuring system.

In addition, a control module with an ATmega8 microprocessor was developed, which is used to control automatically PC activation, temperature measurement inside the distribution board and if necessary, heating system activation inside the distribution board. All devices are fed from an accumulator charged by means of photovoltaic panels.

The activation of the ENA 440 industrial computer is controlled by means of a HW module equipped with an ATmega8 microprocessor provided with an application activating periodically the measuring computer at an adjustable interval of 1-128 minutes. The measuring computer is activated on a periodic basis due to saving on energy taken from the accumulator. Industrial computer activation is also dependant on ambient temperature (operating temperature of ENA 440 is 0-60 °C). As soon as the temperature inside the distribution board of the measuring system drops below 0 °C, the microprocessor activates the heating system inside the distribution board before the activation of ENA 440. As soon as the distribution board heats up to an appropriate temperature, the measuring computer is activated.

Due to minimum electricity consumption, the LM2575T switching source is used to feed the control module with the microprocessor. This is a step-down type switching source converting the supply voltage from the level of approximately 13,8 V (voltage on accumulators intended for supplying power to the measuring system) to the level of 5 V.

The internal distribution board temperature is measured by means of a DS18b20 temperature-sensitive element communicating with the ATmega8 microprocessor via a 1-Wire communication bus. The microprocessor and the measuring system communicate via the RS232 communication interface.

The measured data is stored in PC. This data can be then downloaded using the functionality of connecting to a PC remote desktop by means of GSM or Wi-Fi network. To be able to download the measured data from PC, the control unit should be put into a special mode by means of an activation SMS sent to the GSM modem.

Fig. 12: Photo of the measuring system.

3.2. Description of Software Part

The software part is composed of two applications: main (measuring) application – running on the ENA440 industrial computer and additional application running on the microprocessor within the extension electronic circuits.

The measuring application on PC is developed in the LabVIEW2009 program. The application reads out the measured values from the sensor for external temperature, pressure, humidity and pyranometer via the RS485 interface. Internal distribution board temperature is read out from the control module via the RS232 interface. The application measures oscilloscopic waveforms of voltage from two measuring channels at sampling frequency of 20 $MS \cdot s^{-1}$, then switches over the multiplexer with relay and measures waveforms on other channels. The measured data is stored on a semiconductor disk and can be sent to a remote computer via GSM modem. After error-free completion of the measuring cycle, the control module turns off automatically the computer.

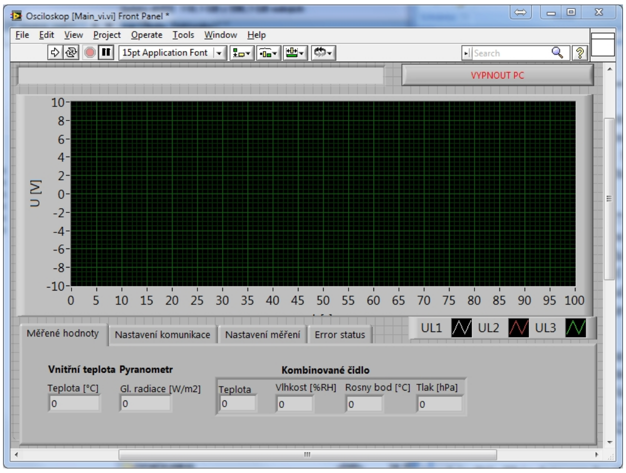


Fig. 13: Front panel of the measuring application.

4. Conclusion

The proposed system to detect failures of covered conductor will be checked on real medium voltage lines. The detector is placed in the selected area and is exposed to real climatic conditions in the long time. Sensitivity and selectivity of the prototype detector will be determined by measurement. The whole system will be optimized to the needs of fault detection on overhead distribution lines with covered conductor. This prototype is developed based on methodology of patent P 2008-647. No more information can be given for this reason.

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About Authors

Stefan HAMACEK was born in Cadca. He graduated SOUS Cadca in 2004. In 2008 he graduated VSB-Technical University of Ostrava, Faculty of Electrical Engineering and Computer Science. Today he is Ph.D. student in the Department of Electrical Power Engineering, Technical University of Ostrava and he applies himself to the issue of medium-voltage lines with covered conductors and problems associated with faults detection of covered conductors.

Stanislav MISAK was born in Slavicin. He graduated VSB-Technical University of Ostrava in 2003. In 2007 he graduated doctoral study and he habilitated in 2009 in VSB-Technical University of Ostrava, Faculty of Electrical Engineering and Computer Science. Today he is research worker in Department of Electrical Power Engineering Technical University of Ostrava.