Analysis and Detection of Faults at Insulated Conductors of Overhead Medium Voltage Lines

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Abstract — **The paper dealt with the issue of breakdowns detection of isolated hanging wires on the medium-voltage transmission. The main aim of article is to describe the function of created breakdowns detector and evaluation its. The breakdowns detector is created based in indicators of faults such as touch between tree limbs and insulated wire, touch tree limbs with several phases or fall insulated wire on the ground. Breakdowns detector has been created because today digital protection was not able to detect the aforementioned faults (e.g. a fault between ground and insulated wire is not a complete ground fault).Therefore, the measured data in the fault-free situation will be compared with the simulated measured faults data in the 22 kV insulated wire type of SAX-W.**

Keywords: fault detector; partial discharge; insulated conductor; medium voltage

I. INTRODUCTION

More and more stress is being laid upon increasing the efficiency of electrical machines and whole systems, as well as upon increasing the reliability of electricity supply. One of the ways to increase reliability and hence, reduce the frequency of faults on the distribution lines consists in the use of PAS type lines. PAS is a system with coated conductors, which started to be used in Finland and eventually in other European countries including the Czech Republic. [1, 2]

This system with coated conductors (CCs) has many assets: for instance, a contact of phase conductors does not result in line-to-line short circuit; fault arising if a tree branch touches the line need not be eliminated promptly; and a conductor falling to the ground does not bring about lined-to-earth short circuit.

Although the above events do not bring about a short-circuit situation and their elimination may be delayed, today's numerical protection systems are unable to detect faults such as conductor fall to the ground.

This issue was addressed based on the proprietary method P2008-647. As a result, a fault detector which is able to detect faults as such those described above was created. The present contribution evaluates data obtained from experimental measurements aimed at testing the performance and selectivity of the fault detector on a 22 kV medium voltage line. [3,4]

II. EXPERIMENTAL MEASUREMENTS

The measurements were performed on an actual 22 kV line with CCs. The measurements were performed with a view to obtaining new data and verifying results of measurements performed previously. The simulations included various types of fault that the numerical protection system is currently unable to detect. They were faults such as tree branch contact with a phase conductor, conductor fall to the ground and contact of two phase conductors. Thanks to the conductor coating, faults of this type need not be remedied immediately. The fault detector tested, however, is able to detect such faults before the degradation factors at the fault site damage the coating integrity to the extent that a full conductor-ground contact is established or a line-to-line short circuit occurs.

The following fault types were simulated on a 22 kV distribution line with coated conductors:

Fault No.1: A tree branch falls over 3 phases

Fault No. 2: A CC tears off and falls to the ground

The signal in the fault-free condition was first measured (Figure 2.) as a reference. As Figure 2. demonstrates, an interfering signal, which is very difficult to filter off, is modulated on the voltage signal. The software, however, is able to recognize that this is not a discharge phenomenon, and evaluates the signal as fault-free condition. The difference between the signals in a fault condition and in a fault-free condition can be well seen by comparing the signals in Figure 2. . and Figure 4.

Figure 1. shows the site where the experimental measurement was performed.

Figure 1. The fault-free CC line

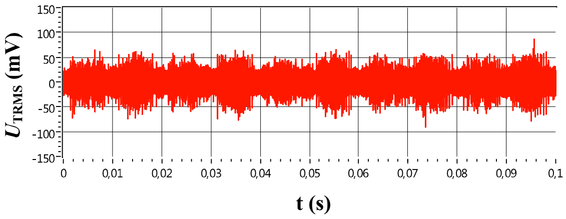

Figure 2. Development of the U_{TRMS} signal when using an IIR filter with Butterworth topology for the fault-free condition

A. *Fault No.1: A tree branch lying over 3 phases*

A tree branch was laid on the line so that it touched the first and second phases (Figure 3.). Electricity supply was then renewed and the signal in this fault condition was measured with the fault detector.

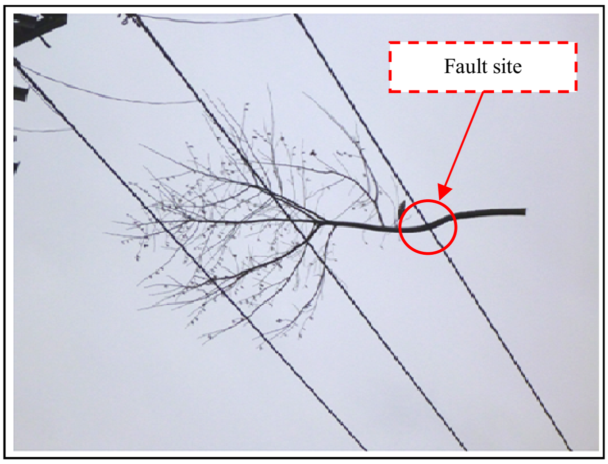

Figure 3. Fault No. 1: A tree branch lying on the transmission line

Figure 4. shows pulses that were modulated upon the voltage signals (an IIR filter with Butterworth topology was employed). This was due to the partial discharge arising as a consequence of the branch fall. The fault indicators selected, i.e. n and U_{TRMS} of the partial discharges, were compared in all measurements.

The following values were obtained:

$$n = 178\ s^{-1}$$

$$U_{TRMS} = 7\ mV$$

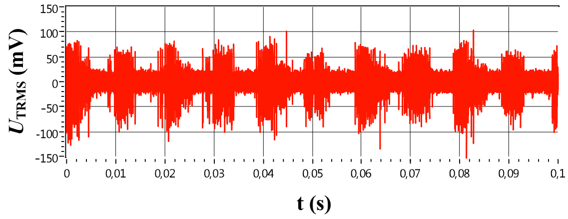

Figure 4. Development of the U_{TRMS} signal when using an IIR filter with Butterworth topology for fault No . 1

B. *Fault No. 2: A CC tearing off and falling to the ground*

The next fault simulated comprised a CC which, after tearing off, has fallen to the ground. This fault was simulated by connecting a SAX-W 22 kV type conductor and laying it onto the ground (Figure 5.). The end of the conductor was separated with a ceramic insulator so that no ground connection took place. Partial discharges of capacitance nature are formed in the point of conductor contact with the ground, and the voltage signal which propagates along the conductor insulation is recorded by the fault detector. This fault type is very easy to detect, and therefore a variant with the conductor lying on grass was chosen, whereby contact with the ground was limited. Figure 6. shows the voltage signal after using an IIR filter.

The following values were obtained:

$$n = 174\ s^{-1}$$

$$U_{TRMS} = 10{,}7\ mV$$

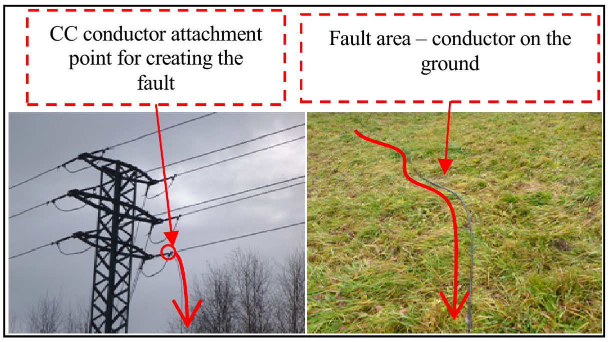

Figure 5. Fault No. 2: A branch falling on the CC line

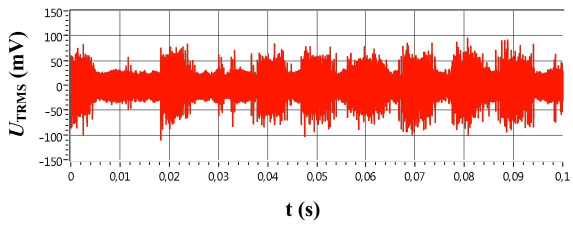

Figure 6. Development of the U_{TRMS} signal when using an IIR filter with Butterworth topology for fault No . 2

A climatic data table (Table 1) and a table of the fault indicators selected (Table 2) were set up to obtain a comprehensive overview of the observed values. Table 1 demonstrates that the measurements were performed in inclement weather. Partial discharges having the shape of a corona are expected to form on the line at temperatures near zero Centigrade and at high humidity levels. Corona is most frequent at sites with higher local values, i.e. with non-homogeneous electric fields, i.e. at sharp edges, bushings, connectors and other structural elements on the line. The highest values. In Table 2 are found for the fault consisting in tree branch falls over 3 phases (Fault No. 1). This was mainly due to the fact that the tree bark was soaked with water, which increased conductivity and in turn, the occurrence and intensity of the partial discharges. And since the fault consisting in CC tears off and falls to the ground was associated with the highest energy of the current pulses of the partial discharge, the U_{TRMS} level is the highest among the measurements as well.

Table 1 Climate data

Ambient temperature (°C)	3.2
Humidity (%)	85.1
Dew point (°C)	1
Atmospheric pressure (hPa)	968.5
Global radiation (W.m^{-2})	0
Temperature in the distribution box (°C)	5.4

Table 2 Frequencies and U_{TRMS}

	U_{TRMS} **(mV)**	***n*** **(s^{-1})**
Faultless Condition	6	17
Fault No. 1	9	170
Fault No. 2	10.7	174

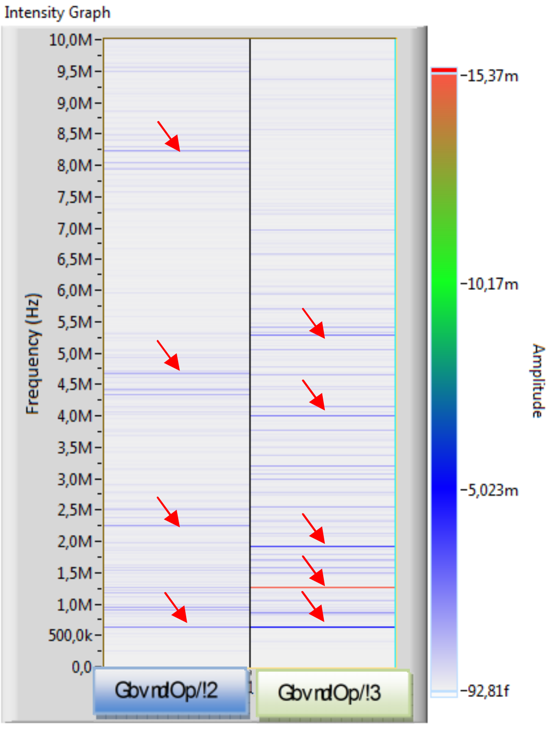

Figure 7. FFT analysis for the three faults

FFT analysis of the signals was also applied as a next method for evaluating the faults. For a graphic comparison, the calculated spectrum was inserted into an Intensity Graph type diagram (Figure 7.). It is then simple, by using this diagram to identify the frequency band with the highest fault intensity. Each fault has its column in Figure 7. ,and the red arrows indicate segments of the spectrum which are characteristic of each fault.

Fault No. 1: Intensity was increased in spectral segments about 1 MHz, 2.25 MHz, 5.5 MHz, and 8.25 MHz

Fault No. 2: Intensity was increased in spectral segments about 0.75 MHz, 1.25 MHz, 2 MHz, 4 MHz, and 5.4 MHz

In conclusion, the highest segment of the spectrum and, at the same time, the largest changes in the frequency spectrum amplitude are linked with fault No. 2 (contact between the conductor and the ground).

III. Conclusion

The goal was to demonstrate the ability of the experimental measurement device to detect a fault in the medium voltage lines with CC. This detector was based on the methodology P2008-647.

For the experimental measurements were chosen two types of faults that often occur in the MV lines with CC.

In the first case, a 3 phase fall down failure of leads. In this disorder have been reported higher values of the partial discharge U_{TRMS}= 9 mV and increased frequency n= 170 s^{-1}. Basing on the comparing of the values that were measured before the experimental measurements in faultless condition, we come to the conclusion that there was indeed an increase of the values of selected faults indicators (U_{TRMS}, n).

In the second case was simulated fault where there is a tear wires and its subsequent fall to the ground. In this case, the measured values are U_{TRMS}= 10.7 V and n= 174 s^{-1}. Comparing the values in Table 2 we can say that the failure detector can actually detects the defect of MV networks with CC. The more Detail description of the measurement results is located directly in the text of this paper.

Basing on the further analysis using FFT (Figure 7.) is also seen that each failure is characterized by the occurrence of a characteristic in the frequency domain (see Section 2.2) [5]. In order to increase the reliability of the fault detection will be continuously monitored occurrence of PD throughout the whole year. Further research will be also focus on a variety of experimental measurements and the development of evaluation software of fault detector.

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