The influence of environment on condition of location damage in screen of the coaxial cable

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This paper presents the results of laboratory tests of influence of the environment on pulses propagation conditions in the screen of coaxial cable. The reference level for the screen is the environment, which in real maintenance conditions, is the soil or it could be the inner work conductor. The objective of this work is to determine the possibility of using the pulse method for fault location of screen isolation of electric power cable line or telecommunication line. The special measurement system is described, which allows taking measurements of the influence of different substances types, which surround the location of damage, on the propagation of testing pulses. The results of measurements are shown in oscillograms obtained for typical substances which surround the cable in real exploitation conditions.

KEYWORDS: damage of cable shield, surround of cable, fault localization, pulse methods

1. Introduction

In some constructions of electrical and telecommunication cables the conductive screens which surround the cable are used. In electrical lines the screen is usually made in form of braid of copper wires, aluminum, a copper and aluminum foil can be also alternatively used. Then, the screen is covered by isolation (coating), which separates it (isolates) it from the environment [1, 3, 4].

In power cables the screen is mostly used as a return wire for short-circuits current in case of damage of isolation between work conductor and the screen. Short-circuit current flows then through the screen to the ground point, which is mostly supply point that is substation. The flow of short-circuit current through the screen and work conductor is used to detect the fault in the power system and to the fault localization of the line. Whereas, the screen in telecommunication cables is mainly used as the protection system of work conductors against the negative influence of the environment on the condition of pulses propagation and plays the protection role against the penetration of disturbance. It is made as a braid of copper wires, aluminum and copper firm or from braid and firm together. The screen from the outside is covered also by isolation, which as in case of electrical cables, protects it from the influence of external factors, mainly from humidity [1, 3, 7, 8].

In fact, the damages of the outer isolation of the cable line doe not happen often. If present, they mostly occur as mechanical damages and stems from improper of line exploitation (for example frequent bending), the movement of soil as a result of carrying the earthwork, intentional damages. The damage of shield isolation can also occur as a result of arcing inside the cable. High temperature at arcing may cause softening of isolation, which can lead to its damage.

Different and also quite unusual causes of damage of isolation shield are animals, mainly rodents. They cause damage of cables of small diameter (for single centimeters) on small surface, however such damages can be found in many places, mostly in the cables which are arranged in cable channel, where rodents can move [2].

The damage of the cable isolation shield especially the power cable is important in the line operation and shall be treated almost equally with fault localization of isolation between work conductor and the screen. In the literature different ways of fault localization of a shield are preferred, like for example methods: acoustic, current propagation, point method [5].

In many publications there can be found a remark, that application of pulse methods, which are commonly used to pre-locate work conductors faults, in such damages is not possible, because the return way for the pulse send to the screen cannot be provided. In most cases the soil is the surrounding for the cables, and in case of cables arranged in cable channel systems, it is free space or small surface of contact with adjacent cables. The soil is the material of poor electrical properties and therefore it is not possible to use it as a reference level for the screen of the cable. In case of cables arranged in cable channel systems the environment for the screen is mostly air, which means that in such case, it is no possible to take the outer environment relative the screen as a reference level [6].

Great influence on the result in localization process of damage of cable shield in the ground have physical and chemical properties of the nearest surrounding of the damage place. Most significant is the resistance between screen cable and the surrounding. Many factors have influence on the value of this resistance, among them, the surface of the damage, the character of the damage (isolation losses, insulation cracking), kind of the surround substances (water, loose materials, close- or coarse-grained, etc.), chemical composition. The resistance in the fault location will be also determined by the value of the voltage, at which the measurement is performed.

During the high voltage measurement, when the short circuit is as electrical arc, the resistance in the place of the damage is the lowest. It is obvious that localization of the damages of small resistance transition with the usage of pulse methods and by measurement of the flow of the current surface is the best.

2. Construction of the measurement system

Measurement system was constructed in order to test the usefulness of pulse method for fault localization of coaxial cable shield for different surrounding conditions. As it is known, the basic for calculations of distance to the location of damage in pulse method is the measurement of the time needed for propagation of testing pulse from the beginning of the line to the fault place and back.

It should be remarked that the effectiveness of that method mainly depends on the quality (readability) of oscillograms obtained as a result of sending testing pulse to the line, more precisely it depends on the influence of the damage on the shape and on the amplitude of reflected pulses [5, 6]. Therefore, the research was limited to the recording of the influence of the surrounding of the place of the shield damage on the shape of oscillograms measured at the beginning of the cable line.

In order to test the influence of different types of shield damage and the substances which surround the damage place on the shape of oscillograms the measurement system was constructed as shown on the Fig. 1.

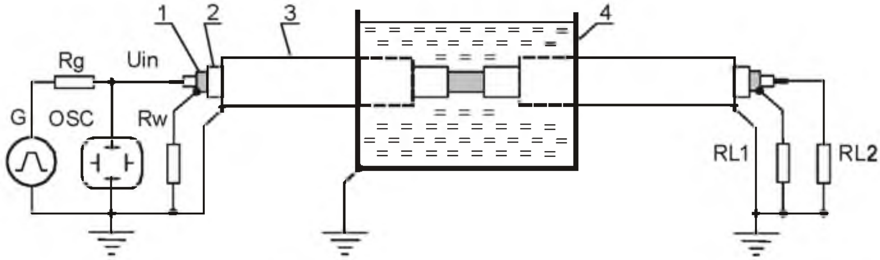

Fig. 1. Schema of the measurement system for the case when the test signal is sent into the working conductor, G - voltage pulse generator, Rg - internal resistance of the generator, OSC - oscilloscope, Rw, RL1, RL2 - load resistors of the cable conductors, Uin - the voltage measured at the beginning of line 1 - the cable shield, 2 - layer of insulation, 3 - copper pipe, 4 - metal container

Place damage encased in a metal container with dimensions 40x40x40 cm and filled by the material, which can surround the cable in its real operating conditions. The measurement were done for the case where the container was filled by strongly compacted soil (indeterminate class type), wet sand, dry sand, clear water, salty water (about 100 g of salt per 1 dcm^3). Cable shield damage was simulated by removal of isolation on the whole perimeter and the length of about 2 cm. The dimension of the container in relation to the dimension of the damage place were assumed in such a way so as the space which surrounded this location was large and at the same time did not have an influence on the current flow for measurement signals. The cable segment prepared in such way was placed in a container and inserted in the middle of the length of the cable line with an overall length about 32 m.

In order to receive good reference level for the screen cable, it was put into thick-walled cooper pipe. Then, the pipe together with the cable was rolled into circle of the 1 m diameter, and the scroll was arranged in such a way so as the outer walls of the pipes were touching each other over the entire diameter. Thus, the reference system for the screen of compact construction was arranged, which caused the significant reduction of long line phenomenon for propagation pulses. Cooper pipes were connected with metal container. The measurements for pulses propagation in the line were arranged separately for each of the mentioned substances and for the case, when the testing signal is sent to the working conductor or to the screen.

Single testing pulses of duration time about 60 ns and amplitude 11 V were send directly from the generator G with internal resistance Rg equal 50 Ω. Non connected wires was loaded by resistors Rw, RL1 and RL2 with the value similar to the characteristic impedance of the cable, this is about 50 Ω. For the measurement and the oscillograms recording digital oscilloscope OSC was used, which works on the timeline with the resolution 80 ns/cm, and on the voltage axis with the resolution 600 mV/cm. The voltage Uin was recording at the beginning of the line in the conductor to which the pulse signal was send from the generator.

3. Measurements results

The results of the measurements are oscillograms of voltages obtained in the conductor, to which the testing pulses were sent. Fig. 2 shows the voltage waveform measured in the screen regarding the reference level and by the working conductor loaded by the resistor Rw and for the different substances which surround the damage place.

The occurrence of the clear pulse reflected from the damage place in the case, when the air is the surrounding (free space) results from the change of the characteristic impedance in the connection place of the segment with damaged line shield. Thus the influence of the kind of the substance on the shape of the reflected pulse was considered as a change in regard to the pulses obtained for the case, in which the surrounding is the free space.

The oscillograms in the Fig. 2 shows, that the greatest changes in the oscillograms are caused by the salt water, which is the case, for which the conductance of the surrounding has the greatest value. This is the case, which may take place only for the marine cable. Whereas, the influence of the surrounding from the ground and the wet sand, in which mainly the cable can be found, is relatively hardly noticeable, because it causes small changes in the shape of the reflected pulse.

Fig. 3 represents the results of the recording of the voltage, obtained in the system, in which the testing pulses are sent to the middle conductor or the line. The objective of the measurement done in this system was to verify, whether the damage in the isolation shield can be detected with the help of the pulse send to the middle (working) conductor.

The reason why the measurements are performed in such system is practical, because in many cases of cable line construction, disconnection of conductor screen from the earth installation of the substation for the time of measurement performance–may be difficult to make, in some cases, with a view to ensuring adequate shock protection against, even allowed.

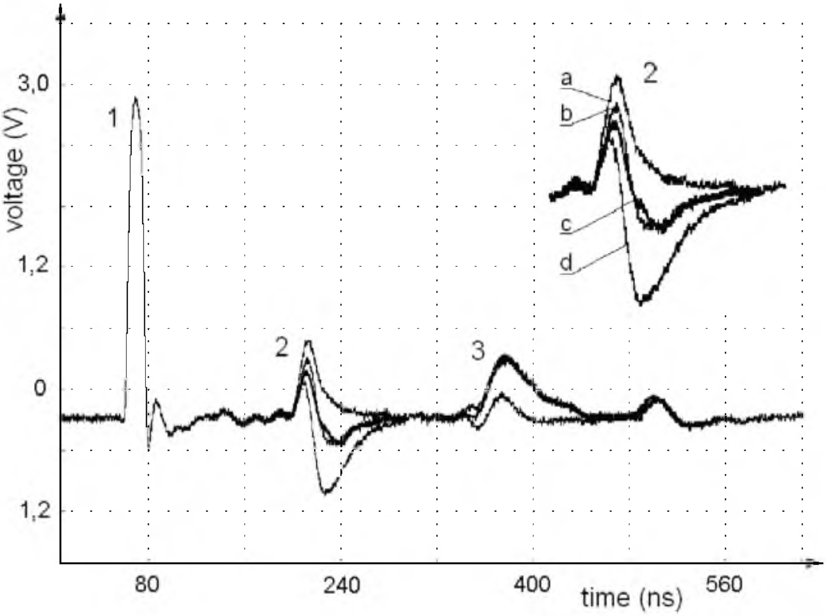

Fig. 2. The measurement result of pulses propagation in the cable line shield regard the reference level, made in corresponding system as in Fig. 1 and for different substances surrounding the fault place of the screen; 1 - pulse sent, 2 - pulses reflected from the damage for the environment: a - the air, b - water, c - wet sand, soil moist, d - salt water, 3 - pulses reflected from the end of the line

In the place of shield damage the characteristic impedance value is different with respect to the rest of the line segment, which contributes to the pulse reflection which moves in the middle conduction. When considering the oscillograms shown in the Fig. 3, it present that the influence is minor, though. Furthermore, the amplitude of the returning pulse after the reflection from the damage place is much smaller than the sending pulse. This is very unprofitable for the localization process and moreover it shall be taken into account that in the real lines, which are much longer, the pulse reflected from such place will be even more muted than it is in the made measuring system.

Another kind of screen cable damage is galvanic separation (discontinuity). This kind of fault occurs as a result of influence of external mechanical factors, however they can be also caused be invalid repair of the damage location (for ex. missing screen connection within the joint, the replacement of the damaged section). For such type of damages the measurement in laboratory conditions were carried out in analogous system as shown in the Fig. 1.

The break in the screen was made by removing the external cable shield on the periphery length 2 cm, and the break in the screen was made also by its removing on the periphery length about 0.5 cm. The same substances as in the previous measurements were used as the environment of the damage place. The measurement results are shown in Fig. 4.

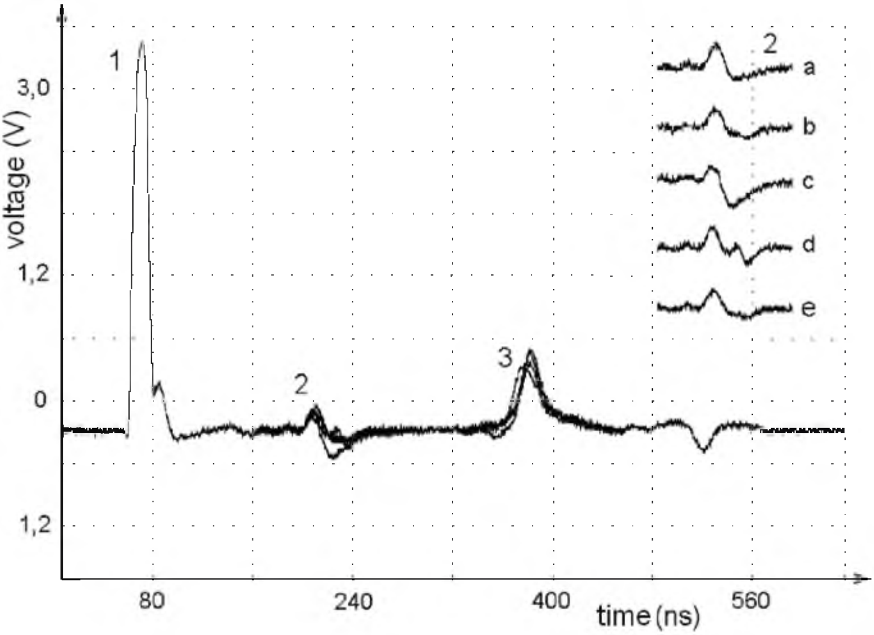

Fig. 3. The measurement result of pulse propagation in the working conductor carried out in the system as shown in Fig. 1 and for different substances surrounding the fault place of the screen; 1 - pulse sent, 2 - pulses reflected from the damage place for the environment: a - the air, b - water c - salt water, d - wet sand, e- soil moist, 3 - pulses reflected from the end of the line

Another measurement was to examine how the damage surface for particular type of surround substances influence on the shape of oscillograms. The measurement was carried out in the system as shown in the Fig. 1. The pulse signal was sent to the cable screen and the reference level was the copper pipe. The surrounding for the damage place was dry sand, wet sand and sweet water.

For the case, when the surrounding was sand measurements were carried out for the damage surface respectively about 30 and 80 cm^2, and for the case when the surrounding was water, additionally for the damage surface approximately equal to 4 cm^2. The measurements results are shown respectively in Fig. 5 and 6.

Analyzing the oscillograms of Fig. 5 and 6, it is shown that the pulse reflected from the place of isolation damage of the screen sees this place like opening, because polarization of the reflected pulse in relation to the sent pulse is the same. This results from the construction of the measuring system. Which causes that in the simulation place of the damage is also the change of the environment dimensions. It follows from this that influence of the damaged surface and the surrounding material type on the pulses shape can be considered as changes in relation to the pulse, when the environment is the free space.

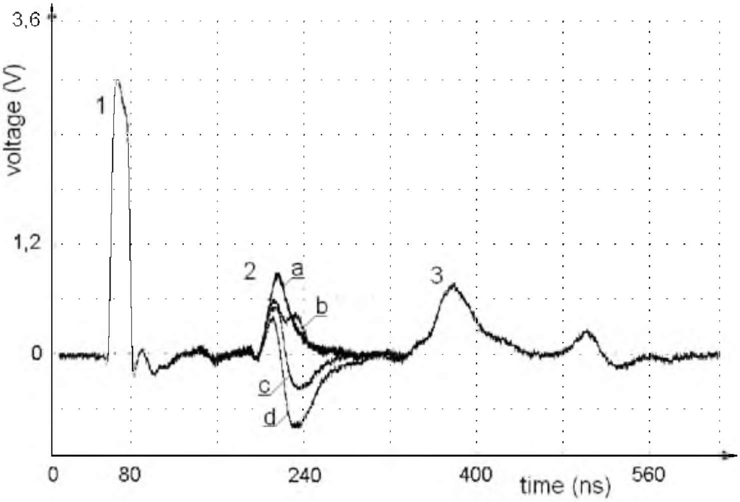

Fig. 4. The measurement result of pulse propagation in the screen of the cable line with a break in the screen obtained in the same system as in Fig. 1 and for the different substances surrounding the damaged place, 1 - pulse sent, 2 - pulses reflected from the fault for the environment: a - the air, b - water, c - wet sand, soil moist, d - salt water, 3 - pulses reflected from the end of the line

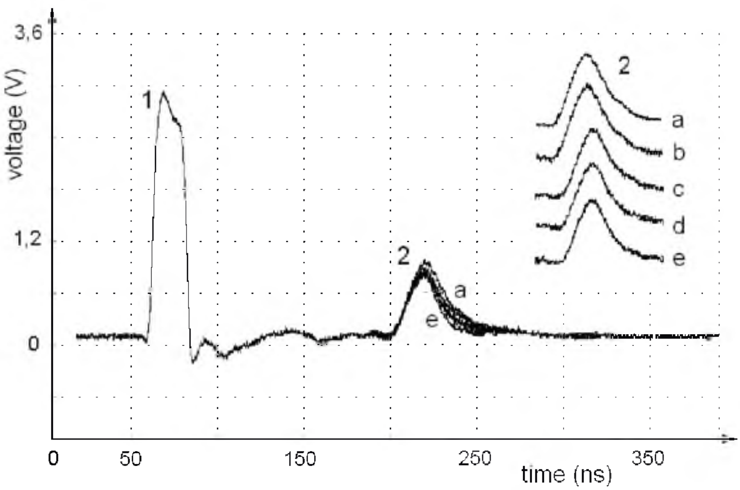

Fig. 5. The measurement result of pulse propagation in the screen of the cable line for the case when the environment is sand and for different surface of damage, 1 - sent pulse 2 - pulse reflected for a - free space, b, d - damage surface of $30cm^2$, c, e - damage surface of $80 cm^2$, b, c - dry sand, d, e - wet sand

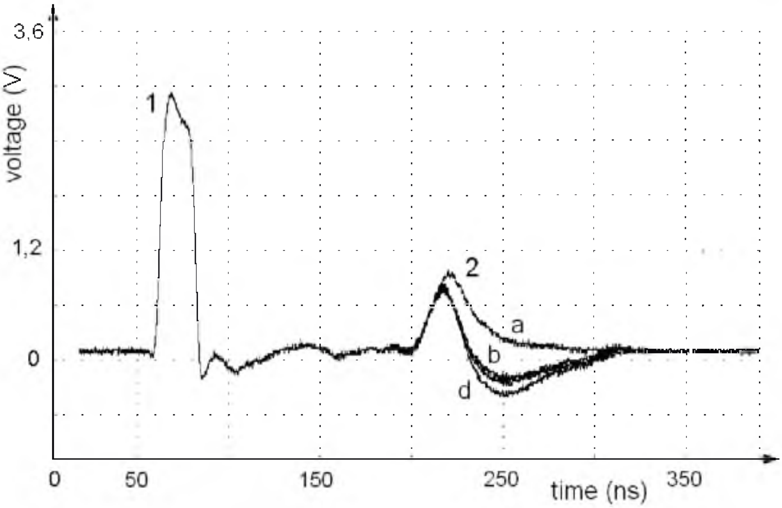

Fig. 6. The measurement result of propagation of pulses in the screen of the cable line for the case when the surrounding is sweet water and for the different surface of damage, 1 - sent pulse 2 - pulse reflected from damage for: a - free space, b, c, d - the fault surface, respectively: $4cm^2$, $30cm^2$, $80cm^2$

Increasing the surface of damage in the case when the environment is sand, both dry and wet, cause small changes to the shape of the reflected pulse, and only in scope of rear edge causing its slight shift in the direction of opposite polarization. In turn, the case, when the surrounding is water, the increase of the damaged surface causes slight shift of amplitude of negative pulse in direction of higher negative values.

Comparing the oscillograms in Fig. 5 and 6 it can be clearly noticed that the damage with the water surrounding is much more noticeable on the oscillograms than with the sand surrounding and even wet. The cause of this difference can be explained by higher conductivity of water in relation to the conductivity of sand, also wet sand. This implies further result, that the pulse methods which are used to the fault localization of shield screen are hardly useful in such cases, because the changes in the shape of reflected pulse are rather slight.

Measurements were also carried out in order to verify how the value of resistance between the screen and the surrounding has an influence to oscillograms of the pulse propagation in the screen and in the working conductor. Measurements were made in such system as shown in the Fig. 1 except for that the damage was simulated by the resistor which was put between screen and the reference level.

Measurements were performed for resistance equal to 10 Ω and 70 Ω and additionally for the opening and metallic short circuit. The pulse signal was send into the screen conductor and the propagation of the pulses in the same screen and working conductor were observed which in this case was treated as an adjacent wire. The measurement results are shown in Fig. 7.

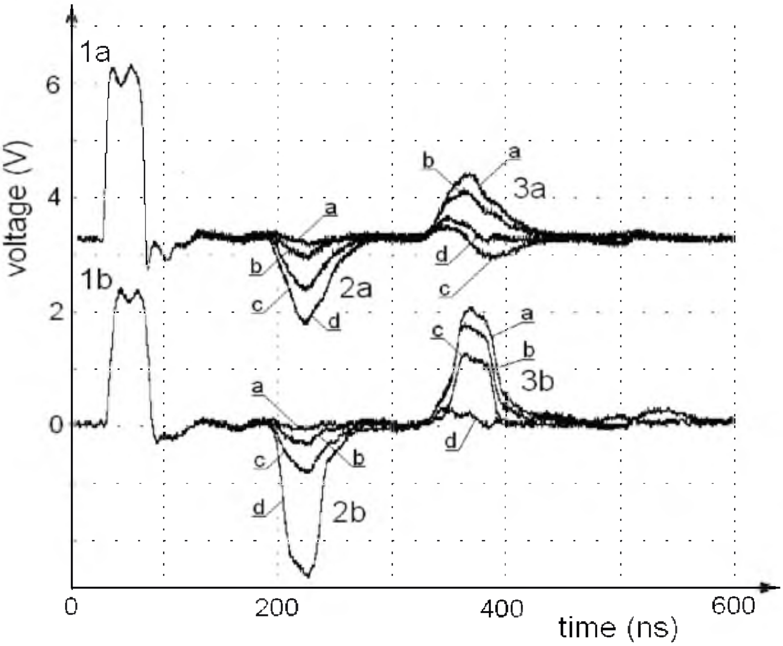

Fig. 7. The measurement result of pulse propagation in a coaxial line for the case where the signal is sent to the screen relative to the reference level and for different values of resistance damage place Ru; 1a, 2a, 3a - pulses propagation in the screen, respectively sent, reflected from the damage, reflected from end of the line, 1b, 2b, 3b - pulses propagation in the working conductor, respectively induced at the beginning of a line, reflected from the damage, reflected from the end of the line for damage resistance: a - ∞ (perfect isolation), b - = 10Ω, c - = 70Ω, d - = 0 (metallic short-circuit)

As the Figure shows, in the working conductor as a result of coupling both conductors the pulse was inducted, which was travelling from the beginning towards the end of the line.

The coupling of conductors causes, that the pulses propagation in the line are the result of wave phenomena in the same conductor, but they are also the result of the influence pulses from the second conductor, especially in the places, where there is a change of characteristic impedance of the cable [6].

Analyzing the oscillograms in the working conductor and the screen, one can observe a large influence of resistance between the screen and the reference level on the oscillograms in the working conductor as adjacent conductor.

Such interaction of the conductors implicates the conclusion, that the damage between screen and the surrounding can be located by observing the voltage signal in the working cable. From a practical point this is very important, as it does not required special technical treatment related to connection of the measurement system at the beginning of the line.

4. Conclusions

The researches of the influence of the environment on the fault localization of cable shield performed with the usage of pulse methods in the laboratory conditions, demonstrate that the effectiveness of this method depends on conductivity of the material which surrounds the damage place and is the better, when the conductivity is greater. The measurements show also that the good result can be achieved by changing the reference level from the screen into working conductor. Another step of work in this area will be performing measurements in the real conditions.

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