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Detection of high resistive ground faults in MV mining networks basing on a phase relationship of selected current harmonics

Abstract. *In the paper a new approach to effective detection and clearing of high resistive ground faults, particularly for open-cast MV mining networks when using a phase relationship of selected current harmonics is presented and discussed. The simulations applying ATP-EMTP package have been performed for MV (6kV) mining networks operating with isolated as well as with ineffectively grounded neutral point. On the basis of the investigation results the conclusions about applicability of the new approach are formulated.*

Streszczenie. *W artykule przedstawione zostało nowe podejście do efektywnej detekcji i usuwania wysoko-rezystancyjnych zwarć doziemnych, w szczególności w sieciach SN kopalni odkrywkowych, z wykorzystaniem relacji fazowych wybranych harmonicznych prądu. Zostały przedstawione i przedyskutowane wyniki symulacji z użyciem pakietu ATP-EMTP dla sieci SN (6kV) tak z izolowanym jak i z nieskutecznie uziemionym punktem neutralnym. Na podstawie przeprowadzonych badań zostały sformułowane wnioski odnośnie do możliwości zastosowania przedstawionej metody. (**Detekcja wysoko-rezystancyjnych zwarć doziemnych w oparciu o relacje fazowe wybranych harmonicznych prądu**).*

Keywords: high resistive ground fault, current harmonics, open-cast mining network
Słowa kluczowe: zwarcia doziemne wysoko-rezystancyjne, harmoniczne prądu, sieci energetyczne górnictwa odkrywkowego.

Introduction

In spite of variety of ground fault protections offered on the market it is difficult to fulfil requirements if about effective detection, localisation [5] and clearing of high resistive ground faults, particularly in open-cast MV mining networks. It is due to conditions of operation and related changes of the network parameters. We have found that use of a phase relationship of selected current harmonics can overcame this problem. Therefore, a new detection method has been developed in which a phase correlation between basic current harmonics and injected (at selected short time intervals) even current harmonics is considered as ground fault indication factor.

Modelled network characteristic

To obtain simulation data the ATP – EMTP package was used [1]. Various possibilities of managing, testing and configurating as well as quick use of FFT (fast fourier transform) that are available, makes this software very convenient for above mentioned item.

Simulations were performed for 6 kV MV mining network (as an example) with implemented second current harmonic source. Simplified block diagram for two lines network with developed ground fault protection is shown in Fig. 1.

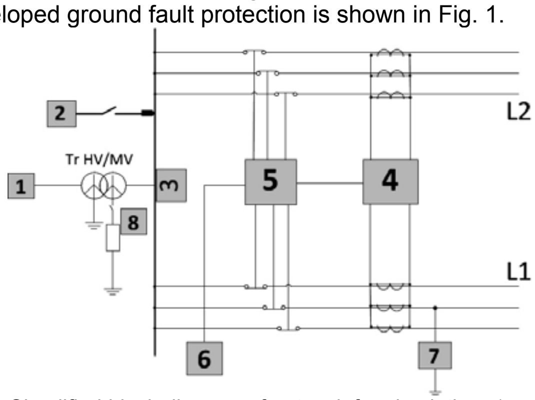

Fig.1. Simplified block diagram of network for simulation: 1 – power system, 2 – second current harmonic source, 3 – busbars, 4 – measurement and calculation unit, 5 – control and decision unit, 6 – signalization unit, 7 – resistance for simulation of short circuit to the ground

Basic data for considered model was taken as below:
- 6 kV supply voltage,
- Transformer Tr - S_n = 31.5 MVA, U_n=110/6 kV, I_n=2000/165A, I_o = 2%, e_z = 12%, ΔP_o = 15.5kW, ΔP_{Cu} = 140kW, Yy0,
- Short circuit power 110 kV – 1000 MVA
- L_1, L_2, $L_{3\text{-}n}$ – cable lines (YUHKGXSekyn 185 mm^2) with total length equal to 30 km,
- Current transformers (CT_s) for phase current measurement CT_s – 300/5 A/A, S_n = 50 VA,

Simulation model has been developed to consider ground fault phenomena in the MV network supplied via power transformer operated with neutral point either isolated or grounded by 56 Ω resistor.

The second current harmonic produced by means of a half-wave rectification [2] is injected, directly to the busbars at selected short time period Δt. (see Fig 2).

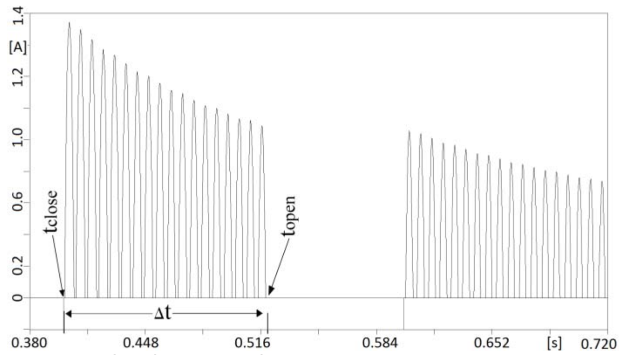

Fig.2. Part of half cycle rectified signal injected to all three phases

Injection time intervals were controlled by time controlled switch with implemented switching characteristic, which open/close values are shown in table 1.

Table 1. Values of switching characteristic for controlling of injection intervals

t_{close} [s]	t_{open} [s]
0.20	0.30
0.40	0.50
0.60	0.70
0.80	0.90

Detection method description

The developed detection method is based on comparison of phase relationships of zero sequence currents (Figs 3, 4, 5) for first and second harmonic measured in protected lines. Such the relationship appears due to change of current circuit parameters for faulty line.

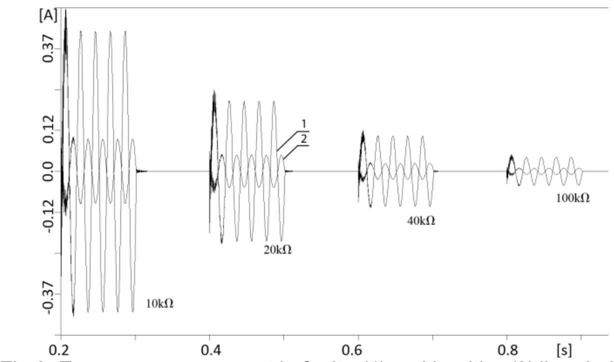

Fig.3. Zero sequence current in faulty *(1)* and healthy *(2)* line during ground fault without second harmonic injected

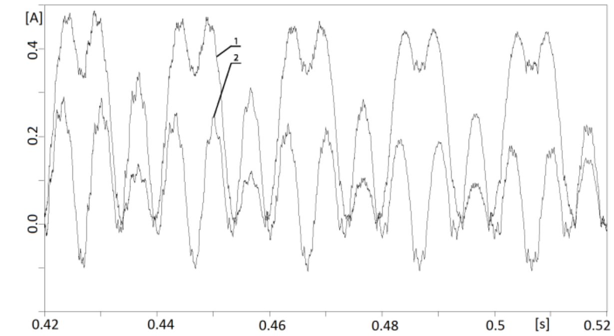

Fig.4. Zero sequence current in faulty *(1)* and healthy *(2)* line during ground fault with injected second harmonic in isolated 6 kV MV network

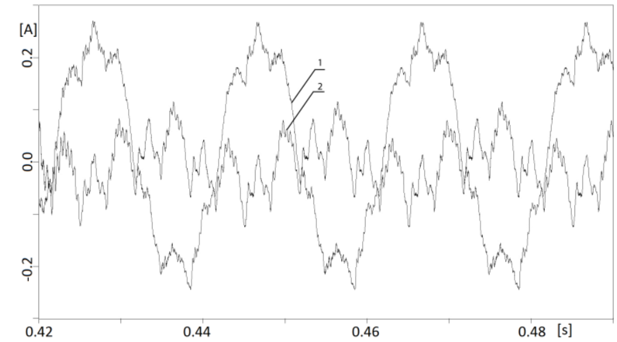

Fig.5. Zero sequence current in faulty *(1)* and healthy *(2)* line during ground fault with injected second harmonic in earthed via resistance (56 Ω) MV 6 kV network

Because usually in the network the second harmonic practically doesn't exist therefore we force it by injection half wave rectified 50Hz current signal. Such injection combined with external source of the signal described above appear to be more effective solution than this described in [1, 4].

For simulated network as in fig.1 and with consideration of ground fault theory in general [3] the influence of ground fault existence on the 1st and 2nd harmonic was found to be higher for faulty line than for healthy one. Therefore, different angle relationship between first and second harmonics occurs.

For extraction of harmonic arguments, the Fourier filter with one cycle window was used. For each cycle, values of arguments for first and second harmonic were differentiated respectively and were compared each other for all feeders (lines) working in the protected network. Such the differential method results in high sensitivity of detection level both in isolated as well as in earthed via resistor network, up to about 100 kΩ (Figs 6, 7).

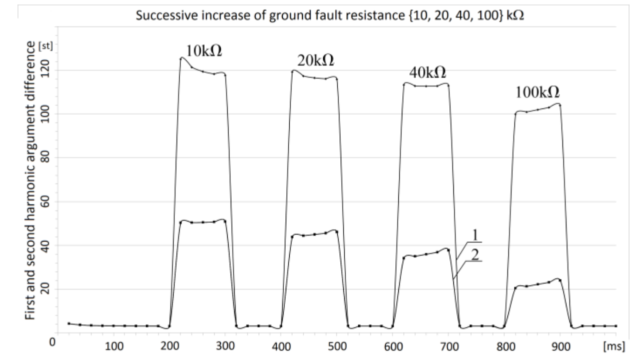

Fig.6. Phase relationship between 1st and 2nd current harmonics for healthy *(2)* and faulty *(1)* line in isolated 6 kV MV network

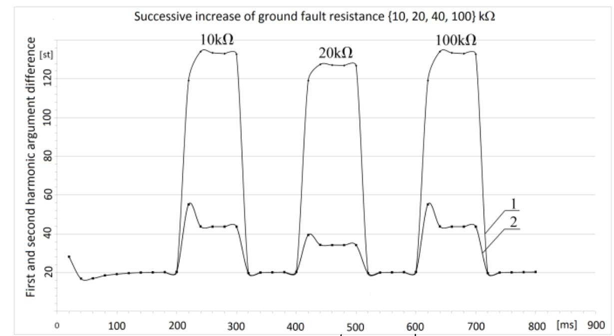

Fig.7. Phase relationship between 1st and 2nd current harmonics for healthy *(2)* and faulty *(1)* line in earthed via resistance (56 Ω) 6 kV MV network

Conclusions

The newly developed detection method basing on comparison of angle relationship between basic (1st) and injected 2nd harmonic of zero sequence current component seems to be effective for high resistive one phase ground fault detection particularly in open-cast MV mining networks operating either with isolated as well as resistive grounded neutral point. By application of second harmonic current the selective detection of decrease of isolation level is able to be performed up to about 100 kΩ.

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