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Selection of Energizing Quantities for Sensitive Ground Fault Protection of MV Electric Power Networks

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Introduction

Effective detection and clearing of ground faults in MV networks particularly under high fault resistance is difficult to achieve due to too low values of both voltage and current being used as threshold for fault indication.

It must be noted that MV networks employed in mining industry operate with different neutral point arrangement i.e. isolated, compensated and ineffectively grounded via selected resistor as well.

Many scientific works were performed if about as detection, modeling and measurement as well as methodology of restoring power supply such failures [1]. Therefore after many years of experience authors have found that one of the possibility to overcome this problem can be application of argument difference detection as a criteria. Thus the argument difference between 1st and 2nd harmonic of both zero sequence voltage (U_0) and current (I_{0L}) for healthy and faulty lines were found to be convenient. However, it requires application of a suitable both voltage and current measuring units.

Paper presents and discusses simulation results of possible variations of selected quantities for different network and fault conditions. The influence of leakage (ground fault) resistance and line loading were taken under consideration. On the basis of the investigated results conclusions on reliable operation of the new developed ground fault protection are formulated.

Principle of operation of the sensitive ground fault protection

A simplified scheme of MV network with sensitive ground fault protection is presented in Fig. 1. It's operation is based on detection of 1st and 2nd harmonic arguments in both zero sequence voltage (U_0) and current (I_{0L}). Since 2nd harmonics does not exist under normal state of the network operation therefore the injection unit (UW) has been developed and applied what is described in more details in [2, 3].

Filtering of zero sequence value of both voltage (arising between neutral point and ground during ground faults) and currents of protected lines is carried out through Rogowski coils based measuring units [4].

Considering high sensitivity of developed protection a Hall sensor based unit was taken into account and tested.

The UW unit injects current harmonics into the protected network at a moment of the ground fault occurrence. The currents and voltages selected harmonics being measured are than extracted using FU_H, FI_H units. At the next step the phase comparator unit (PC) is delivered with the arguments of filtered harmonics so that it could provide initiation signal based on selected harmonics arguments difference between the protected lines.

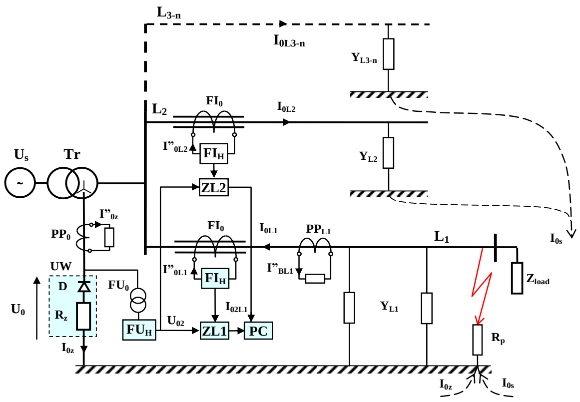

Fig. 1. Simplified scheme of MV network with sensitive ground fault protection. UW-even harmonics injection system, FU_H,FI_H-second voltage and current harmonics filters, FU_0,FI_0-zero sequence voltage and current filters respectively, ZL1,ZL2-detection measuring units, PP_{L1},PP_0-current measuring transformers, I_{0Z},I_{0S}-contribution due to injection and ground admittances of healthy line into the short circuit current, PC-phase comparator

The harmonics argument differences (obtained from PC) can be further used for signalizing of the decrease in the leakage resistance as well as for tripping faulty line.

Analysis of selected indication quantities

Respective analysis has been performed for considering content of harmonics and possibility of application of their relations when used as efficient energizing quantities for the sensitive ground fault protection for MV networks especially under the increased value of fault resistance (leakage resistance). In Fig. 2 and 3 are presented (as an example) selected secondary current wave forms I''_{BL1} provided by current transformer PP_{L1} installed at the beginning of the protected line in phase B (faulty one), and currents from the neutral conductor (I_{0z}, I''_{0z}) respectively. The simulation results obtained for unloaded as well as loaded network (I_{load}=200A) are respectively presented in Fig. 2 and Fig. 3.

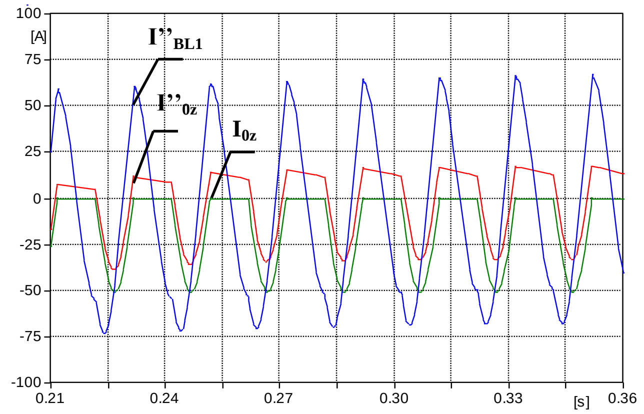

Fig. 2. Primary and secondary current waveforms in neutral conductor (I_{0z}, I''_{0z}) and secondary in faulty phase (I''_{BL1}) under one phase metallic ground fault (R_p = 0Ω), (R_z = 100Ω grounding resistance of neutral point) for unloaded line

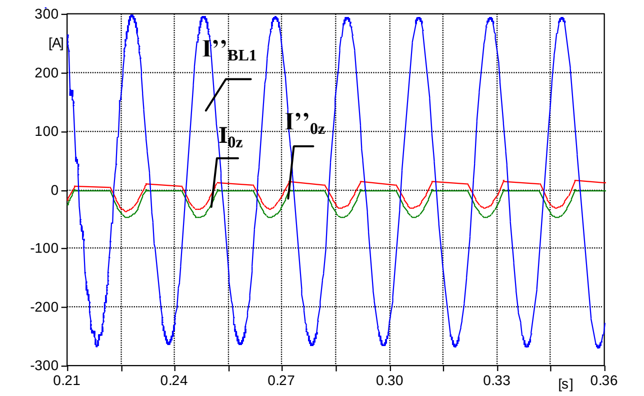

Fig. 3. Primary and secondary current waveforms in neutral conductor (I_{0z}, I''_{0z}) and secondary in faulty phase (I''_{BL1}) under one phase metallic ground fault (R_p = 0Ω), (R_z = 100Ω grounding resistance of neutral point) for loaded line

As one can observe the I''_{BL1} wave gets smoother for the loaded network and harmonics visible in the phase current (without the load) are significantly smaller.

It was found that the load inflicts the content of harmonics of the fault current what has been presented in Fig. 4.

As a result detection of selected even harmonics is made difficult what recommends the use of signals only provided by the zero sequence filters.

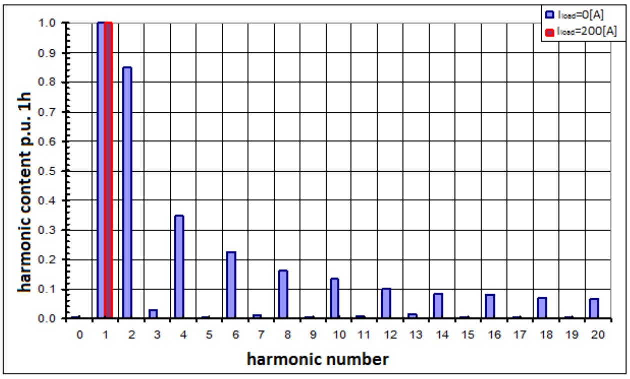

Fig. 4. Harmonics content in current I_{0z} under metallic ground fault (R_p = 0Ω), for loaded line

The zero sequence voltage is also dependent on the ground fault resistance value as indicated in Fig 5.

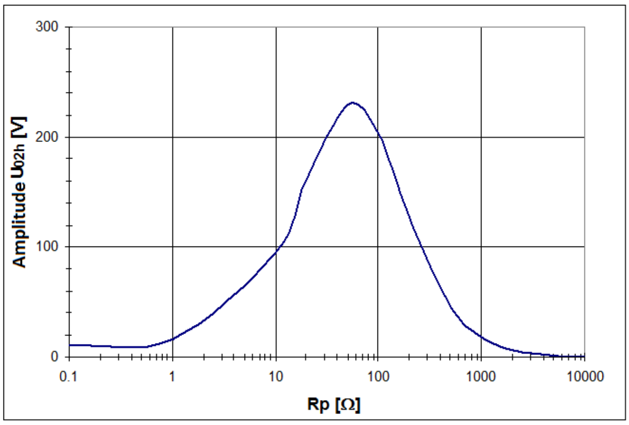

Fig. 5. Zero sequence voltage value U_{02h} versus ground fault resistance R_p

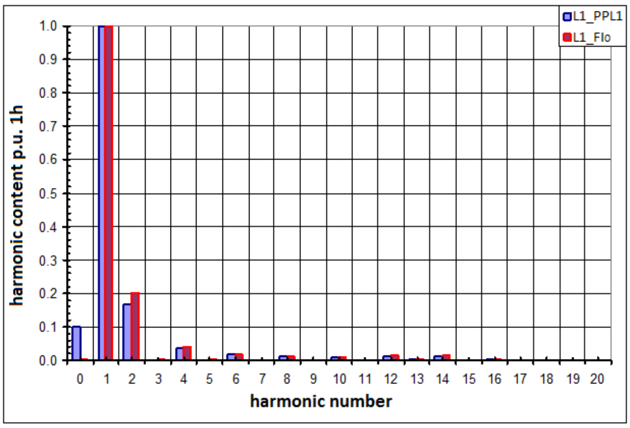

Fig. 6. Comparison of current harmonics content in faulty line (primary in faulty phase I_{BL1}) and secondary zero sequence I''_{0L1}) with use of standard CTs

It must be noted that use of the Rogowski coil arrangement significantly improves sensitivity of the fault detection due to increased amplification rate with the harmonic number, what can be compared in Fig. 6 and Fig. 7.

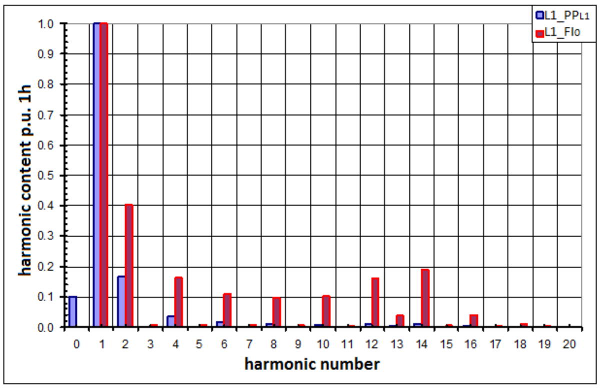

Fig. 7. Comparison of current harmonics content in faulty line (primary in faulty phase I_{BL1}) and secondary (zero sequence I''_{0L1}) with use of Rogowski coils arrangement

There was also found that content of higher harmonics in selected signals for protection depends on the leakage resistance value R_p. With the increase of the R_p value their contribution becomes more significant (Fig. 8) what is considered as a good for the protection reliability.

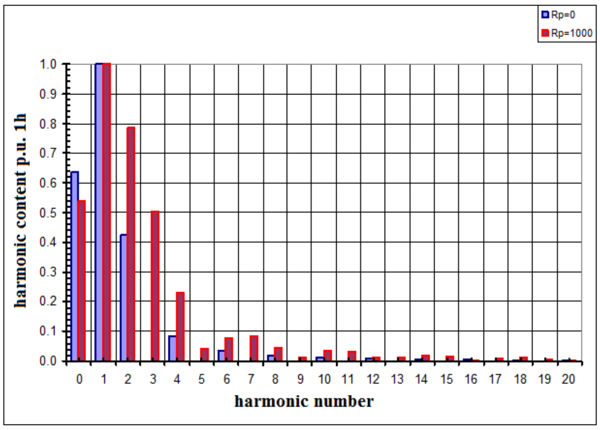

Fig. 8. Comparison of secondary current harmonics content in neutral connector under metallic $R_p = 0\Omega$ and resistive $R_p = 1000\Omega$ ground fault respectively

On the basis of comparison of higher harmonics content (Fig. 9) in the zero sequent current of both faulty and healthy lines it is clear that using above mentioned comparison as the criteria one can also discriminate the faulty feeder successfully.

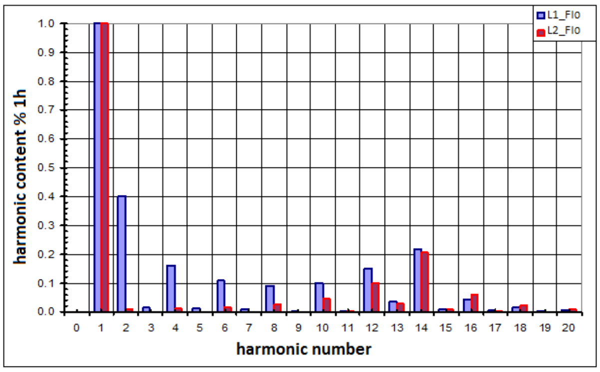

Fig. 9. Comparison of harmonics content in zero sequence current at output of faulty (L1) and healthy (L2) line filter under metallic $R_p = 0\Omega$ ground fault

It can be particularly convenient for detection and clearance of the ground faults in the MV mining networks where the short circuit currents values are significantly reduced due to safety reasons (fire and explosion hazard as well as the electric shock for servicing personal).

Efficiency of operation of the developed sensitive protection under ground faults can be deduced from Fig. 10 and 11 when compare the argument differences for various R_p value. It is seen that employment of mutual differences values results in detection of the grounding up to about 10kΩ successfully.

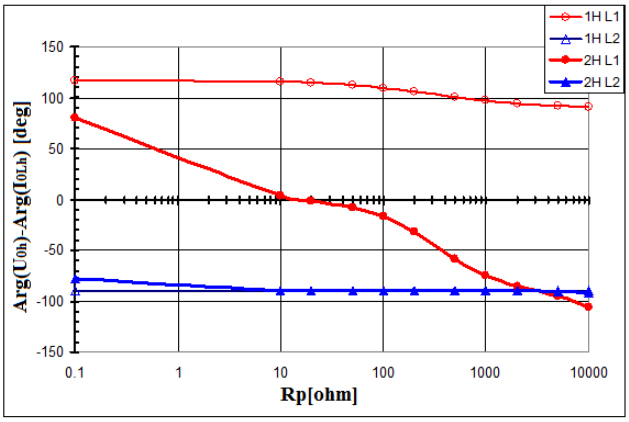

Fig. 10. Argument difference between zero sequence voltage U_0 and zero sequence currents (I_{0L2}) for healthy and (I_{0L1}) faulty line respectively with leakage resistance R_p value

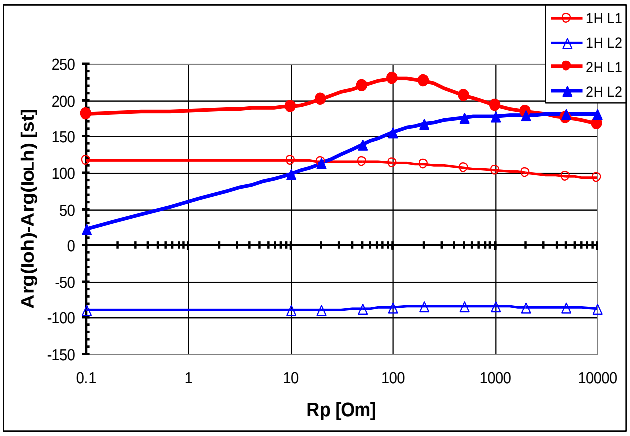

Fig. 11. Argument difference between zero sequence current I_{0z} and zero sequence currents (I_{0L2}) for healthy and (I_{0L1}) faulty line respectively with leakage resistance R_p value

Conclusions

Effective discrimination and clearing of the high resistive ground faults in MV networks is difficult due to decreased both voltage and current values provided by measuring transformers. It is particularly onerous in MV mining networks operated with isolated neutral point.

On the basis of theoretical results it was found that in such case the comparison of arguments value for selected electrical quantities (zero sequence voltage and current) when injected even harmonics under the ground faults can be used as a choice. It is recommended to apply the diode with resistor in series (as current limiter) between the transformer neutral point and grounding electrode.

There are two possibilities of providing the protection operation as follows:

- Tripping signal is due to selected harmonics argument difference between zero sequence current provided by the filters applied on protected lines and zero sequence voltage.
- Tripping signal is due to selected harmonics argument difference between zero sequence current provided by the filters applied on protected lines and zero sequence current in neutral conductor.

Both the current and the voltage zero sequence filters should be based on Rogowski coil arrangements to increase sensitivity of the protection. It must be underlined that as the difference value as well as its variation under the ground fault conditions can be used as criteria.

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In the paper an approach to selection of energizing quantities applicable for the developed sensitive ground fault protection of MV networks is presented and results are discussed. The protection is operated basing on comparison of the argument difference value between selected harmonics of zero-sequence as voltage as well as current harmonics injected simultaneously. It was found that such correlations are particularly useful for successful detection of onerous high resistive ground faults. On the basis of simulation and investigated results the suitable conclusions if about application of proper quantities for practice were formulated. Ill. 11, bibl. 4 (in English; abstracts in English and Lithuanian).

B. Miedzinski, D. Pyda, M. Habrych. Vidutinės įtampos elektros tinklų įžeminimo gedimo apsaugos dinaminių parametrų parinkimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2012. – Nr. 7(123). – P. 57–60.

Pateikiamas vidutinės įtampos elektros tinklų įžeminimo gedimo apsaugos dinaminių parametrų parinkimo metodas ir aptariami gauti rezultatai. Apsaugos funkcionavimas pagrįstas nulinės eilės įtampos ir srovės pasirinktų harmonikų bei tuo pačiu metu injektuotų harmonikų argumento vertės tarpusavio skirtumo palyginimu. Nustatyta, kad tokios koreliacijos yra ypač naudingos detektuojant didelės varžos įžeminimo gedimus. Remiantis modeliavimo ir tyrimų rezultatais suformuluotos siūlomo metodo praktinio taikymo prielaidos. Il. 11, bibl. 4 (anglų kalba; santraukos anglų ir lietuvių k.).