

# Voltage Measurement Errors as a result of Multiple VT Groundings

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**Abstract.** On 12 December 2007 a distance relay tripped erroneously by zone 1 for a ground fault in an adjacent line. RTDS simulations and theoretical calculations proved that the relay had operated according to its design parameters and that the settings of the units involved were adequate. Further analysis of the fault recordings showed that the currents followed a single-phase to earth fault pattern, whereas the voltages did not follow any known pattern for the conventional types of faults.

In the paper a theoretical analysis of the problems involved with grounding the VTs in multiple locations is presented. The procedure to determine that such a problem exists and the ways to confirm it are also presented along with the calculations that have to be done to determine the real performance of the relay. Finally, the methodology and procedure expounded in this work are applied to the above mentioned fault and it is shown that, if only one VT grounding was present, the relay would have operated correctly.

## Key words

Voltage measurements, voltage transformers, multiple groundings, distance relaying, directional relaying.

## 1. Theoretical basis

When the VTs are grounded both at the VT location and at the relay location (usually in the relay housing) the situation illustrated in Figure 1 arises.

As it is shown in the paper the situation can go unnoticed since direct sequence voltages measured in the relay housing are measured correctly in spite of the multiple grounding because the  $\Delta V$  component of the voltages does not affect this measurement. In fact, only the zero sequence voltages measured in the relay housing are affected.

Due to this fact, it is only when zero sequence voltages appear that the problem really shows its effects. Usually only distance and directional relays use this magnitude and it is their performance which is more affected.

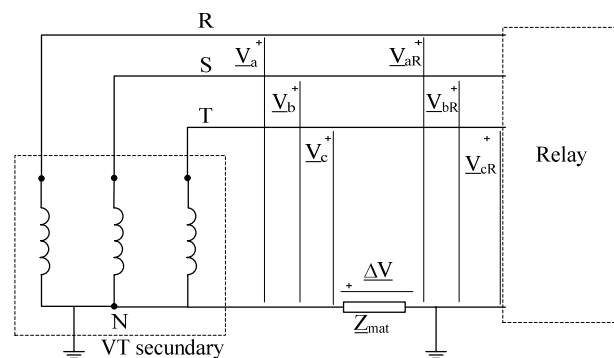


Fig. 1. Groundings in VT and relay locations.

Based on the fact that only zero sequence voltages are affected, the non existence of the fault in some phases can be checked and the really faulted phases can be determined. This can be achieved with the help of a component orthogonal to the fault that does not use the zero sequence voltage.

Once the faulted phases are determined the term  $\Delta V$  can be estimated using data from the unfaulted phases in a clever manner. In fact, the voltage displacement of the unfaulted phases must be very similar and these displacements are used to determine the neutral voltage displacement.

The grounding impedance is capacitive and resistive, but mainly resistive and, using this fact, the reliability of the  $\Delta V$  term previously calculated can be independently confirmed. In fact, the  $\Delta V$  component must be in phase with the zero sequence current due to the resistive nature of the grounding.

Then, the estimated  $\Delta V$  term can be employed to calculate the real fault voltages in the VTs location and use this information to reconstruct the signals that the relay should have received.

Again, with the reconstructed voltages, the validity of the results can be crosschecked using power system data to recalculate the system known parameters. If the system data parameters calculated from the new data are correct, then we can assure that the reconstruction of the voltages has been done correctly. To check this aspect the source impedance is calculated and compared with the expected value and both results must be similar.

## 2. Application to a real fault

The theoretical analysis previously described step by step is next applied to a real case. We conclude that, on the face of the measurements available, the relay performed correctly and that it is not the relay manufacturer but the grounding that should be held responsible for its misoperation. As it stands, we will show that had the relay been fed with the correct voltages it would have operated correctly.

The relay is located in a very short line so that small measurement errors can easily give rise to a misoperation ([1], [2]).

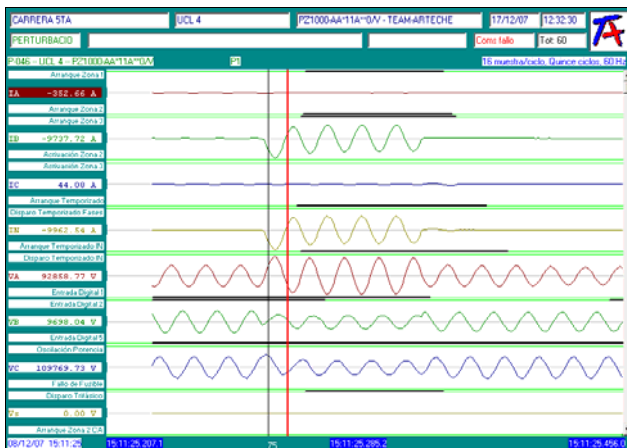


Fig. 2. Fault Data Record.

In the paper, using the data recorded by the relay and following the formerly explained procedure we calculate the correct voltages.

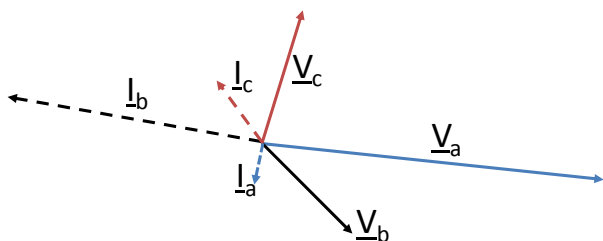


Fig. 3. Fault Phasors.

The actual fault data record is presented in Figure 2 and the corresponding phasors in Figure 3. It can be seen that the currents follow a phase B to ground fault pattern (the phase B and neutral currents acquire much higher values than load current) but the voltages show a very awkward response. The A phase voltage almost doubles the pre-fault value while phase B and C voltages shrink from

normal pre-fault values to fault voltages. In the case of the “C” phase that reduction in the voltage is not associated with a higher current in that phase. This effect can only take place in a weak infeed situation but the current of phase B clearly shows that it is not the case.

## 3. Interest of the work

The problem treated in this paper has been cited in different papers ([3],[4]) but in these works the authors simply assert that the VTs must be grounded in a single point, without further explanation. Specifically, they do not discuss the problems that arise when this recommendation is not followed. They neither explain how the incident off-line analysis has to be performed so as to determine what really happened during the fault nor how the existence of the problem can be checked when the multiple groundings are physically near from one another.

A paper like this, which fully details what has to be done and how such a problem can be treated is very much needed as a reference in the literature for professionals and researchers that have to face similar problems.

## 4. Main objectives

The main objectives of the paper are twofold and can be summarized as follows. We want

- 1) To clarify a subject of real interest for all the professionals that are involved in measuring and relaying.
- 2) To give a procedure to follow for professionals and other personnel to check if the problem treated is happening in their installations, even if to a lesser extent than in the real case shown in the paper.

## 5. Contributions

The contributions of the paper are manifest from the contents of the previous paragraphs. As a matter of fact we want:

- 1) To show a real case study where the wrong VTs groundings have provoked the misoperation of a distance relay and the outage of an unfaulted line.
- 2) To present the theoretical basis on which the fault analysis must be done in this type of situation.

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