

Practical Experience With Multiple and Evolving Faults

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Summary

Today the distance protection is the protection principle most often applied on overhead lines for the levels 220kV and 380kV. The correct fault detection and the calculation of the fault position regarding the selected zone settings depend essentially on the conformity of voltages and currents with the applied model. The distance measurement is largely known, based on the 1st order-line-model using the positive sequence impedance of the protected object. The correct selection of the faulty measuring loop is essential, especially for multiple faults and in the presence of apparent loops. Particularly the tripping scheme of an associated auto reclosure is mainly influenced by the determined type of fault. Knowing the circumstances where these requirements are not fulfilled is important. In order to compensate for measuring errors, parameter tolerances and to provide nearly undelayed tripping for 100% of the protected object, communication schemes with overreaching zones are applied. Additionally, a directional earth fault comparison scheme can be used to operate in case of high ohmic faults.

Keywords

Transmission system, line protection, distance protection, auto reclosing

1 Introduction

The contribution describes two essential topics for the application of distance protection, which were experienced at the 380kV and 220kV level. Despite both these subjects there is a number of similar items such as taped lines and multiple feed circuits, arc faults, load transport on long lines, mutual coupling and so on which have to be considered in order to apply the distance protection properly. Due to these kinds of aspects, the measured currents and voltages do not match the applied model where the calculated impedance corresponds to the line length. The paper aims at providing practical experiences regarding specific fault conditions to other protection engineers employed with the design, coordination and testing of distance protection.

Firstly the aspect of distance measurement in case of complex evolving faults during the dead time of a single phase auto reclosure cycle and secondly the issue of loop selection on phase-phase-earth faults will be discussed and analysed. Based on these analyses, recommendations and indications for the protection system design as well as relay design will be highlighted.

2 Power system fault analysis

2.1 Evolving fault during auto reclosure

The first picture shows the structure of a multiple end feed 380kV system. The aspect of mutual coupling was not to be considered on the faulty line. Single-pole and single-shot auto reclosure for line-neutral faults were enabled. The faults on the line were cleared from both ends by the zone 2 element tripping of the distance protection, although a teleprotection scheme providing fast tripping for faults at 100% of the protected object is applied. For this line, distance relays are used as main 1 and main 2.

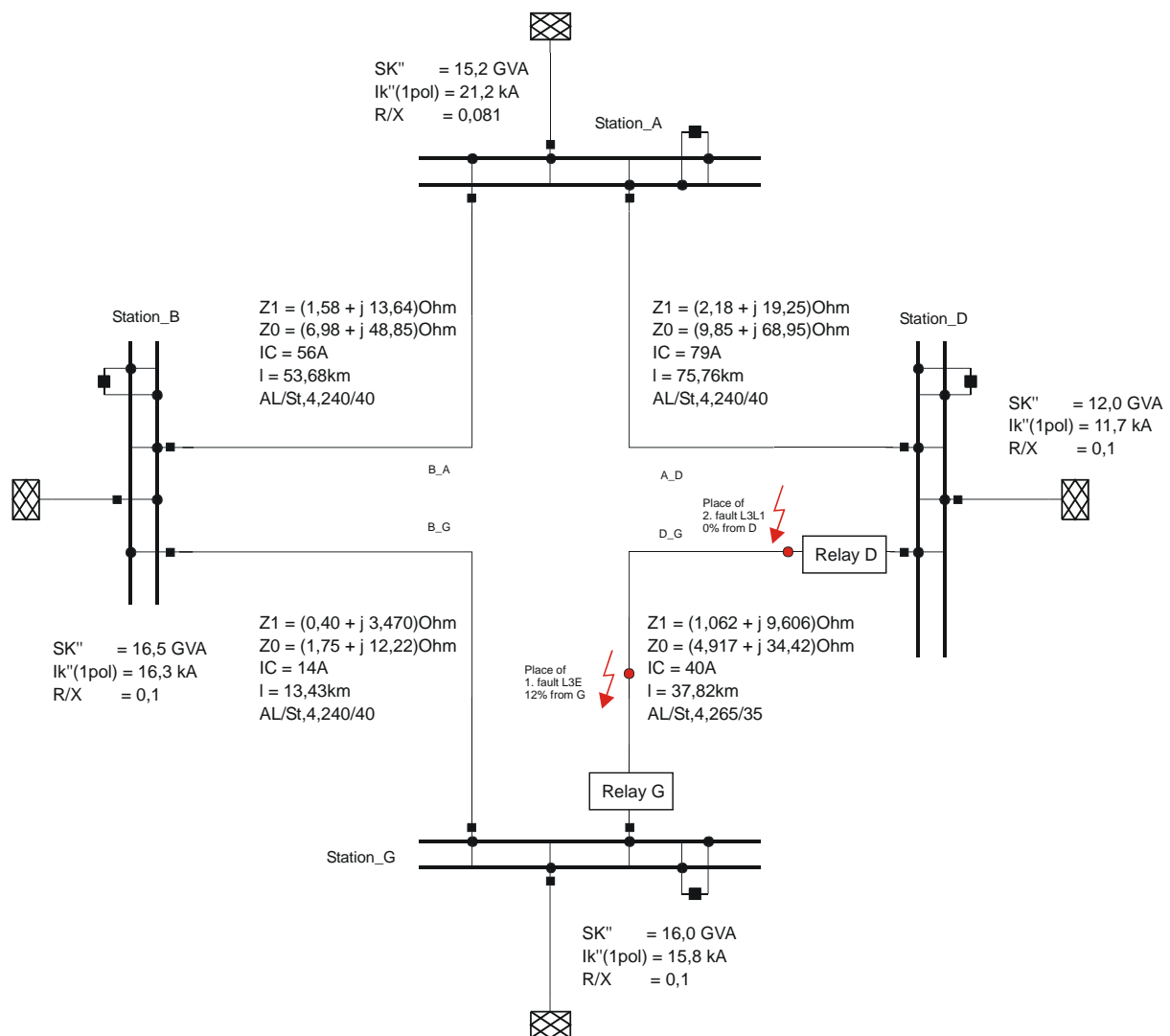


Figure 1: 380kV fault scenario

The following event sequence happened on the connection between station G and D:

- L3E fault, fault position from G appr. 11%
- Distance protection trip at D in phase L3 with a fault clearance time of 70ms
- Distance protection trip at G in phase L3 with a fault clearance time of 100ms
- Arc extinguished after 183ms
- Arcing between L3L1 at the CT in D after 425ms due to a further transient system earth fault for approx. 2ms (the fast fault extinction lead to high transient voltages especially line to line)
- Back arcing L3E fault at the initial place of the L3E fault after 580ms
- Final trip at D after 1s with zone 2 element
- Final trip at G after 1.1s with zone 2 element

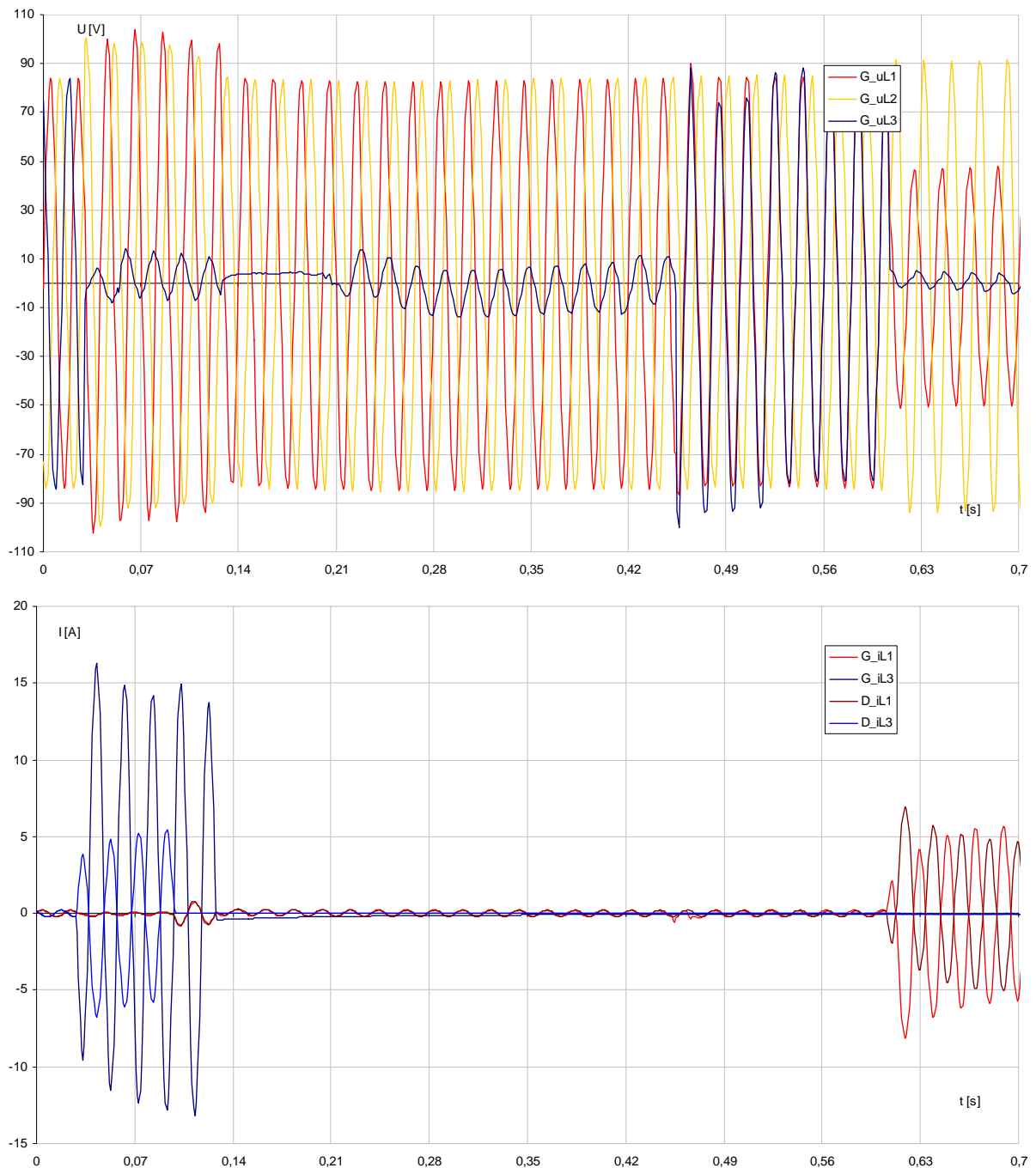


Figure 2: Transient voltages from G and currents from G and D

During the single-pole dead time, the effect of mutual coupling on the dead phase due to load current can be observed. Furthermore, the equality of the line voltages L1 and L3 refer to the contact between both these phases before the initial fault returned. Resulting from the analysis of the transient voltages and currents, the following 3-phase circuit diagram can be developed and examined.

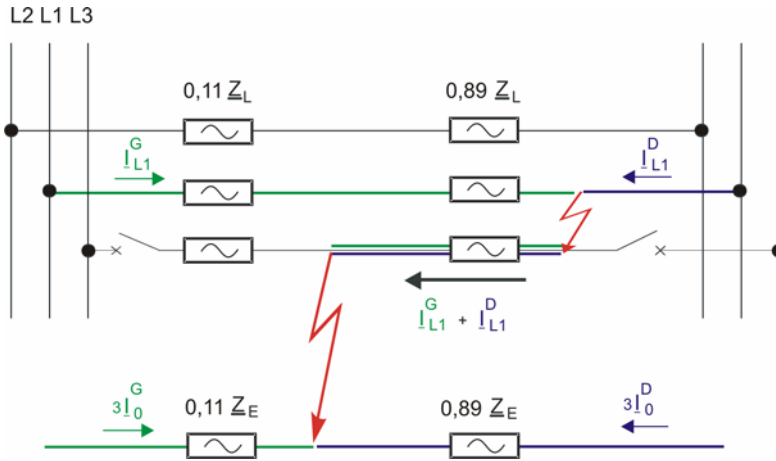


Figure 3: 3-phase short circuit diagram for the final fault scenario

A rough estimation and evaluation of the measured values gives:

Relay G

$$Z_{\text{calculated}} = \frac{Z_L \cdot (I_{L1}^G + 0,89 \cdot (I_{L1}^G + I_{L1}^D)) - 3I_0^G \cdot Z_E \cdot 0,11}{I_{L1}^G - 3I_0^G \cdot \frac{Z_E}{Z_L}} = 1,5\Omega + j13,6\Omega \quad \text{measured} \quad 2,8\Omega + j14,5\Omega$$

Relay D

$$Z_{\text{calculated}} = \frac{0,89 \cdot Z_L \cdot (I_{L1}^G + I_{L1}^D - 3I_0^D \cdot \frac{Z_E}{Z_L})}{I_{L1}^D - 3I_0^D \cdot \frac{Z_E}{Z_L}} = 1\Omega + j14,3\Omega \quad \text{measured} \quad 4,3\Omega + j14,2\Omega$$

As the comparison underlines, the fault reconstruction is in accordance with the measurement. Due to the remote infeeding over the common impedance $0,89Z_L$, the fault is seen too far away i.e. out of the overreaching zone which is used for the overreaching scheme and usually set to 120% of the protected line. Making use of an additional insensitive directional earth fault comparison scheme would not provide a solution for the problem experienced because this type of fault does not agree with the commonly used zero sequence model.

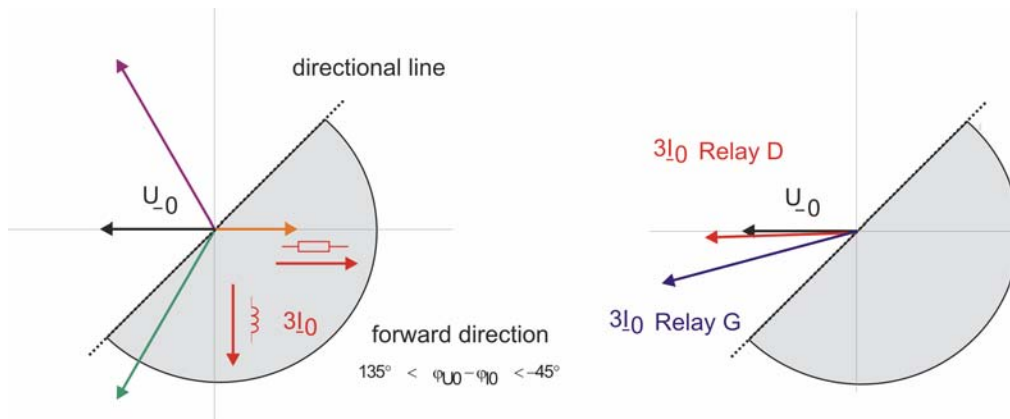


Figure 4: Zero sequence components for the zero sequence directional comparison scheme

2.2 Double phase to earth fault

The second subject of this paper deals with the loop selection of numerical full scheme relays. The record below shows the currents and relay behaviour at a L1-L2-E fault where the phase L1 became approx. 2ms later involved in the fault.

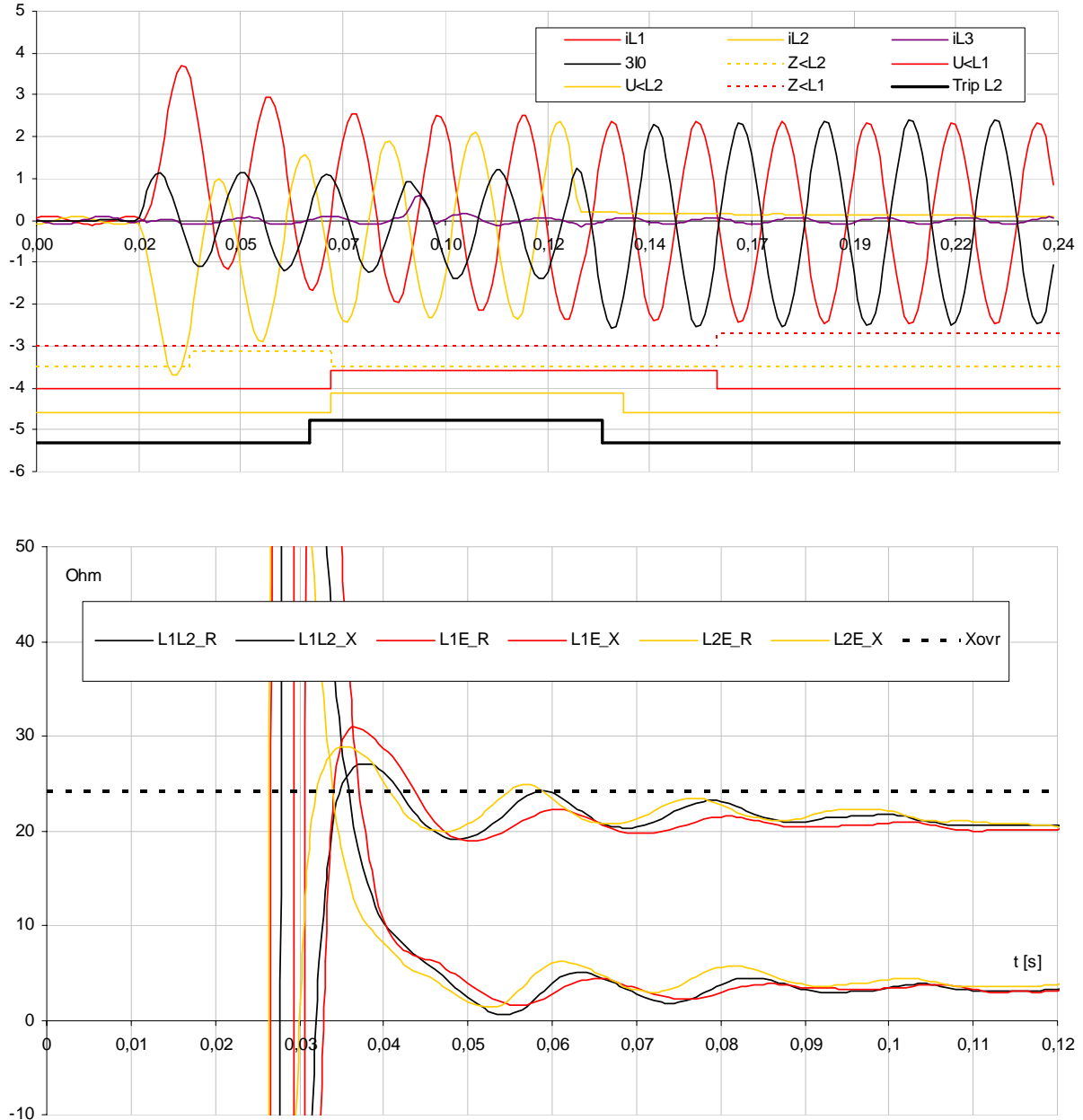


Figure 5: Currents and status signals for a multiple earth fault

From the impedance calculation using FFT, all three measuring loops involved are seen in the overreaching zone by taking notice of a time displacement of approx. 1ms. The relay is set to measure only line to neutral loops in case of phase-phase-earth faults. The question arising from this event is why the L1E element did not also trip and resulted in a final three phase tripping.

3 Setting recommendations and requirements for implementation

Corresponding to the first subject of the paper, two consequences can be derived. At first the setting of the overreaching zone should be increased to twice the protected object impedance in order to detect such kinds of faults. Secondly the application of a different protection principle which is not affected by the current infeeding from the remote end is recommended. The fault experienced underlines the usage of the current differential principle as one of the two redundant working protection systems for the high voltage level.

The second subject of the paper which can be seen much more frequently happen looks at the internal logic of phase separation or parallel computing of the three or six measuring loops. As far as is known, the calculation of all loops should run in parallel all the time. Consequently, the three phase final tripping is expected for the fault experienced and applied relay setting. Based on the analysis of the R and X values, it seems that the impedance calculation of the other line-neutral-loops was blocked because of the single phase tripping of one phase. An interesting aspect to be considered is that neither acceptance tests nor commissioning nor periodic tests of course usually look after the aspect of different fault inception times for the involved loops in such a short time as described. The relay behaviour is normally tested by simulating evolving faults during the dead time of an auto reclosure after the initial fault has already been cleared. Such kinds of tests can definitely only be done by applying transient test quantities coming from a transient power system simulation.

4 Summary

In this paper two experienced real world faults at the 380kV and 220kV level were introduced. The purpose of the paper is to put sensibility on the application and design of distance protection in case of multiple or evolving faults in HV systems. The availability of the protection system especially under circumstances which do not match the used fault model is an issue which should not be underestimated. Particularly the usage of the differential protection with fast and secure communication links via fibre optic should be prioritized. Making use of the phase-selective differential protection scheme and distance protection scheme especially under the aspect of back-up protection for the remote bus is the recommended application for that voltage level.

Literature

- [1] VDN Ringbuch „Schutztechnik“
- [2] Transmission Code –Netz- und Systemregeln der Übertragungsnetzbetreiber. Ausgabe August 2003, Verband der Netzbetreiber VDN e.V. beim VDEW