VERIFICATION OF SIMULATION OF SIMULTANEOUS GROUND FAULTS USING PS CAD BASED ON PERFORMED EXPERIMENTS

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Abstract: The article deals with the description and verification of the mathematical model of compensated MV distribution network. The model was created for the solution of the earth faults localization using the additional earthing of healthy phase method. The above localization method was experimentally tested for different types of earth faults and the comparison of obtained measured values with the simulation results can be performed. The main goal of the network model is verification of methodology for simultaneous earth faults calculation.

Keywords: compensated distribution network, earth fault localization, PS CAD simulation

1. INTRODUCTION

The one phase to earth connection is the most common fault in compensated distribution networks and reliable way of its localization is still the subject of many studies and research. The reason for reliable and fast localization is distribution network safety. It is not only safe operation of the network itself, but also of persons located in the immediate vicinity of the fault. Department of Electrical Power Engineering BUT has been dealing with this issue for many years and during our research, we have experimentally verified the localization methods [1], safety of additional grounding for affected phase system, which can eliminate the fault current fault [2] [3], but also safety of operation of extra-large compensated network [4]. Recent experiments performed at the end of 2012 were focused on locating earth fault by means of short-term additional grounding of unaffected (healthy) phase and the subsequent determination of fault distance based on the distance protection principle. The functionality of above mentioned method was verified during these experiments, which were performed in the real distribution network [5].

2. REAL DISTRIBUTION NETWORK MEASURING

The principle of the method of short-time earthing unaffected phase is based on short time additional earthing healthy phase during earth fault in the network, which temporarily creates a second earth fault. Duration of this fault varies from 100 to 200 ms and is limited to the time set overcurrent protection in the affected outgoing feeder but should be sufficient for calculating the impedance fault, using the distance protection in the feeder. The additional earthing is provided by means three single-pole switches in supply transformer station. The functionality of above mentioned method was verified during experiments, which were performed in two different places at one of the feeder leading from the 22 kV substations, which is part of the supply 110/22kV transformer station. The earth fault has been created by interconnection between phase conductor of 22 kV line and grounding system of distribution transformer station. Different types of faults connections from the metallic through the arc to a high-resistance (up to 6 kΩ) at fault site were simulated. Moreover each experiment was repeated for different state of arc suppression coil – for full compensated network and for undercompensated and overcompensated network, to find potential effect of compensation rate on the method functionality.

The results of the experiments showed that the method of additional earthing of healthy phase is very effective for localization of low resistance and arc earth faults. The line impedance to fault was correctly evaluated by distance protection in the affected feeder during experiments, which in low resistance faults were simulated. In the case of resistive faults and that's already the order of tens of ohms, it is necessary to determine the impedance to the fault location using a different algorithm, which is based on the evaluation of currents and voltage during simultaneous earth faults.

3. THE SIMULATION MODEL

To create the medium voltage network model described above the PS CAD programme was used. The model includes a three-winding transformer Yn/d/yn 110/22 kV with a nominal output of 63 MVA. The winding's middle point on the 22 kV side is grounded over a compensating reactor. The transformer is fed on the high voltage side by a source with internal impedance which equals the system impedance at the given part of the network. To replace the real network at the affected 22 kV line, π models were used. The outlet's load is computed with total performance of 2,81 MW at the secondary side of the distribution transformers D/yn 22/0,4 kV so that it corresponds with the real situation, which took place in the distribution network at the time of measurement. In front of the transformer at the voltage level 22 kV a fault was created. It is possible to set the resistance of the fault and to choose the start time of the fault. In this simulation the phase L3 is the affected phase. Earthing of the healthy phase at the substation is simulated by a fault in the L1 phase directly at the 22 kV busbar. The resistance of this intentionally created earth fault is 10 Ω and it equals the resistance operated by the earthing automation at the 22 kV substation. By setting the timers of both faults a similarity with the real process can be achieved. Firstly the earth fault occurs at the distribution line and then the healthy phase is grounded. Further two other outlets of the MV network are connected in the model – outdoor and cable line. By setting the parameters the capacitive character of the real network can be achieved. In this case the capacitive current at the uncompensated state must reach 210 A. The network is compensated through setting suitable parameters of the reactor connected to the 22 kV middle point of the feeding 110/22 kV transformer.

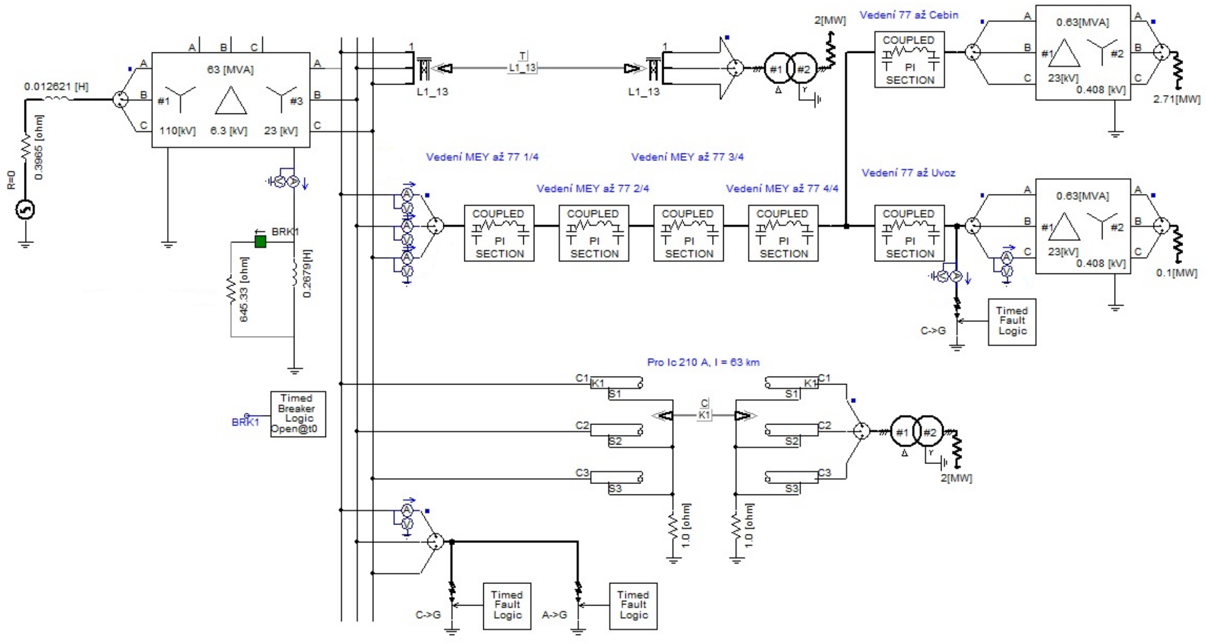

Figure 1: Network model

4. COMPARISON OF RESULTS

The waveform of each important recorded variable is compared with the waveforms of variables which were simulated using PS CAD. Figure 2 refers to the ground fault with a 0 Ω resistance, while Figure 3 relates to a fault with a resistance of 500 Ω. The waveforms on the left side describe the state during the earth fault at the distribution line, the following connection and disconnection of the resistance of the reactor and the short time earthing of the affected phase. The waveforms on the right side describe the subsequent earthing of the healthy phase. The recorded variables are the current of the affected phase I_2, the current I_0 and the fault current I_f. All figures show effective values of variables. Steady-state values are compared because transient values are different in the simulation and in the real operation. This is caused by parasitic attributes of the real network. The earth fault occurs at the time 0 s. The connections of the resistance occurs at the time 1,5 s and the earthing of the phase occurs at the time 3 s. The earthing of the healthy phase occurs approximately at the time 5,1 s. These times are not absolutely precise, the time of operation of the automation controls cannot be specified precisely.

4.1. RESULTS OF VERIFICATION

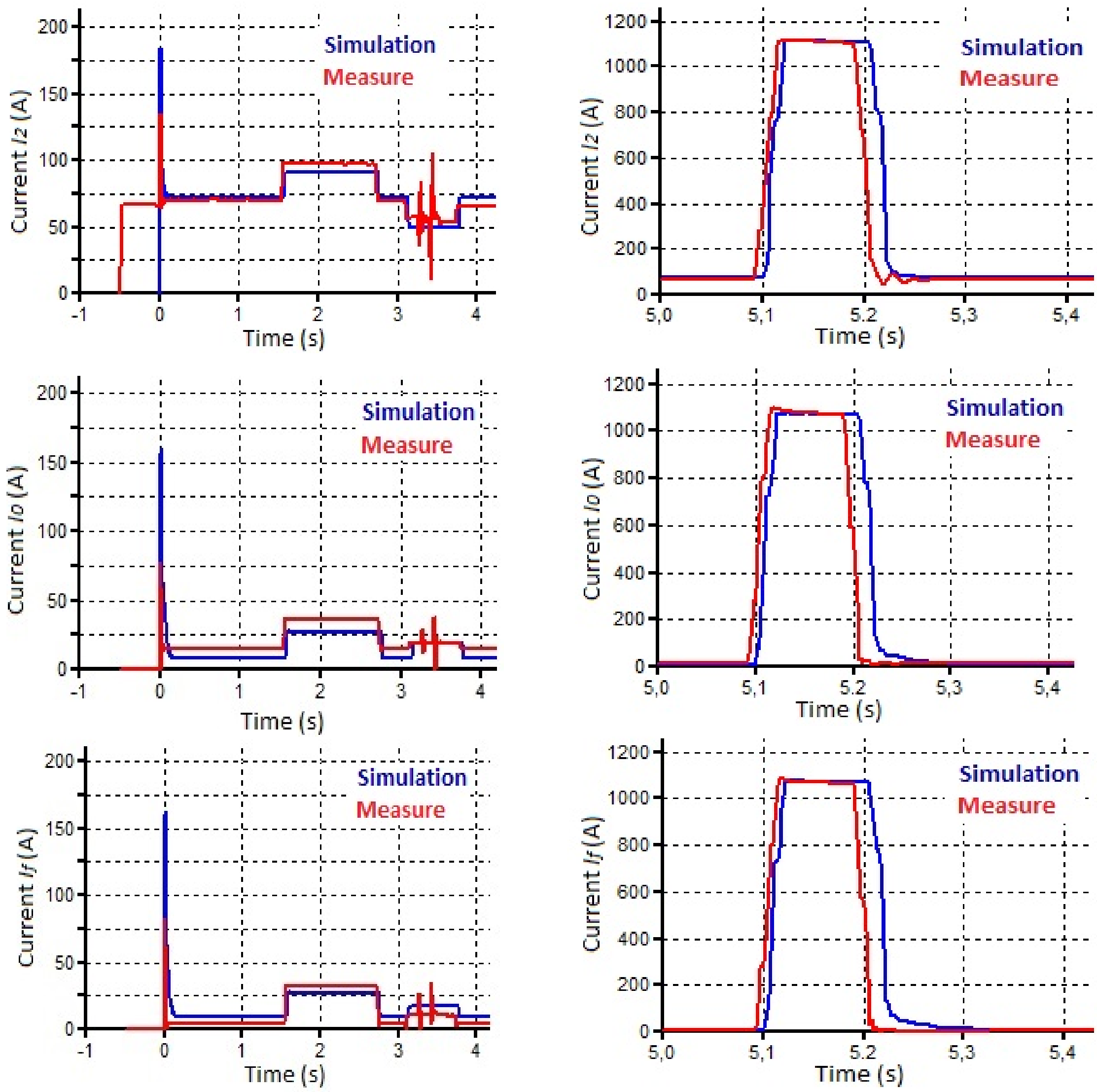

Figure 2: Current waveforms of the 0 Ω earth fault

Figure 2 shows that I_0 and I_f equal 0 before the occurrence of the earth fault, the current of the affected phase I_2 corresponds with the load of approximately 60 A. After the occurrence of the earth fault an increase of these currents can be seen. The values of the simulated and measured currents are almost equal. Steady-state values differ by 7,5 A at maximum. In some segments the simulated currents are smaller, in other segments bigger than the measured values. The deviation is in orders of Amperes which is an acceptable deviation. These small deviations of the current values are caused by small distinctions of the simulated model from the real situation. The measured waveforms from the real distribution network show significant transient phenomenom. Again this is caused by the inability to simulate the real network conditions correctly.

Figure 3 shows the current waveforms of the earth fault with the resistance of 500 Ω. Steady-state values of the simulated currents differ from the measured values more significantly. This is most obvious for the current I_0. This simulated current has an inverse trend in each state of the simulation. Steady-state values differ by up to 12 A. This issue is caused by incomplete compensation of the real network during the measurement. At higher fault resistance values the above described deviations occur. The other simulated currents show the same trend in each segment as do the measured values. Their deviations are in orders of Amperes. Again the maximum deviation reaches 7,5 A. The simulated values are again slightly higher or lower than the measured values. The reason is the same as for the 0 Ω resistance earth fault.

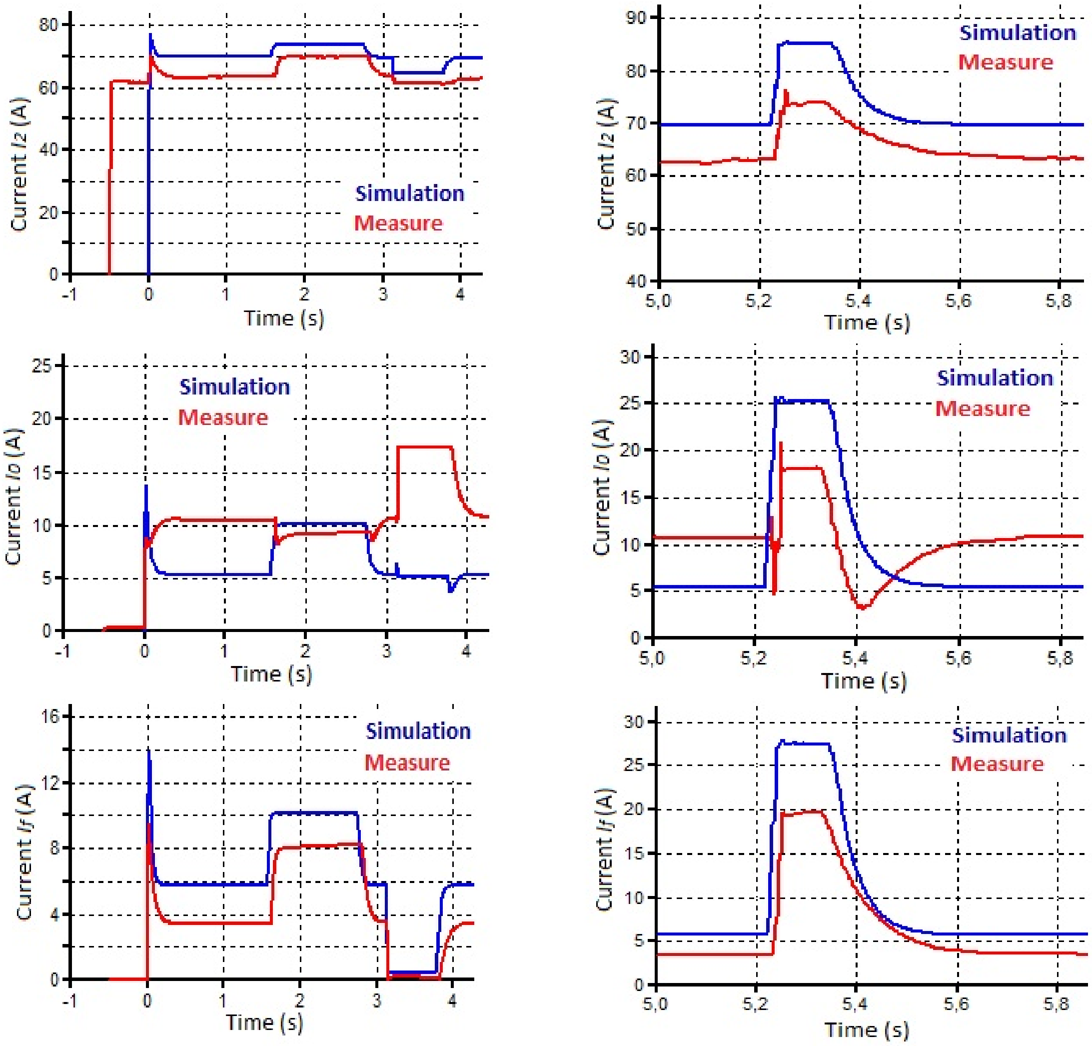

Figure 3: Current waveforms of the 500 Ω earth fault

5. CONCLUSION

By examining the simulated current values obtained from the distribution network model it can be said that the model corresponds with the real distribution network almost exactly and therefore the model is suitable for verification of the healthy phase earthing method for earth fault localization. The differences described in the previous chapters are caused by simplifying the real network in the model or by inaccurate parameterization of some circuit elements. This means:

- inaccurately setting the reactor,
- inability to set the transverse conductance of the distribution line in PS CAD,
- unknown earthing conditions of the network in the measurement location.

These failings are most apparent in earth faults with high resistance. There are more oscillations in the real measurement than obvious in the simulation. This is caused by the fact that the simulation computes with ideal values which cannot be met in real situation. Similar results are reached by examining measured and simulated values of other variables. Their reactions on network changes are small and therefore they are not shown in this paper for clarity reasons.

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