GROUND FAULT LOCATION BY ELECTROMAGNETIC FIELD EVALUATION

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ABSTRACT

The paper describes transient phenomenon evoked by ground fault origination. In most cases passive methods are applied to ground fault localization, these methods evaluate steady state or transient process evoked by ground fault. The paper is mainly focused on dynamical methods, which can be applied on transient process for obtaining ground fault location such as the first half-period method or connection of the resistor in the place of an arc-suppression coil. The methods are used by algorithm for ground fault location. For evaluation there is used a sampled signal from a ground fault indicator scanning the electromagnetic field.

1. INTRODUCTION

The operation of the network with a ground fault belongs to operations with an increased risk of the origination of heavy failures which would result in the interruption of electricity supply to customers. This also explains a great interest in performing theoretical analyses and in developing methods for assessing the place of the ground fault which could be as accurate as possible. Although many methods of the ground fault location are available, there exists no universal method which could be applied in all types of non-solidly grounded networks and to all types of ground faults. However, even appropriately chosen methods do not guarantee a sufficiently accurate location, mainly in the case of high-impedance and/or arcing ground faults. Great stress is therefore laid on a high reliability of indicating or measuring instruments. A good sensitivity can be achieved by installing indicating equipment as closely to the place of the failure as possible. This is also a reason for the expansion of indicators operating on principle of the measurement and analysis of electromagnetic fields.

2. TRANSIENT PROCESS DURING EARTH FAULT

Behavior of all faulty systems (voltage and current conditions) during earth fault can be explained by three processes, two transient phenomena and steady-state of the earth fault. All three processes start at the same time, but their duration is different. The next chapters describe only the first two transient processes with reference to the dynamical methods, which are explained bellow.

2.1. Discharge of the Faulty Line Over the Earth

We can distinguish two extremes in the process. The first extreme is that ground fault start at minimum of the faulty line to neutral voltage, in this case is an affected phase charge near zero. The second extreme is that a phase to ground voltage of the faulty line is near the maximum when ground fault starts and charge of the faulty phase gets near maximum (a discharge current oriented from faulty phase to earth is maximum). The discharge current expands into the network and close in a faulty circuit through a capacitance of faulty phase to ground (Figure 1). The value of the discharge current also depends on the value of the total capacity of the affected phase. It means that current relies on the length of the affected phase in the network including all lateral lines of feeding line. Due to high impedance of distribution transformers, the Peterson coil influence on the charging current is negligible. The discharged current is reflected at the interface between two different impedances and causes high frequency oscillation in the network. The frequency depends on topological form of a network (number of branches, feeding and distribution transformers). The whole process takes a short time (half-period) and is used for ground fault location by dynamical methods.

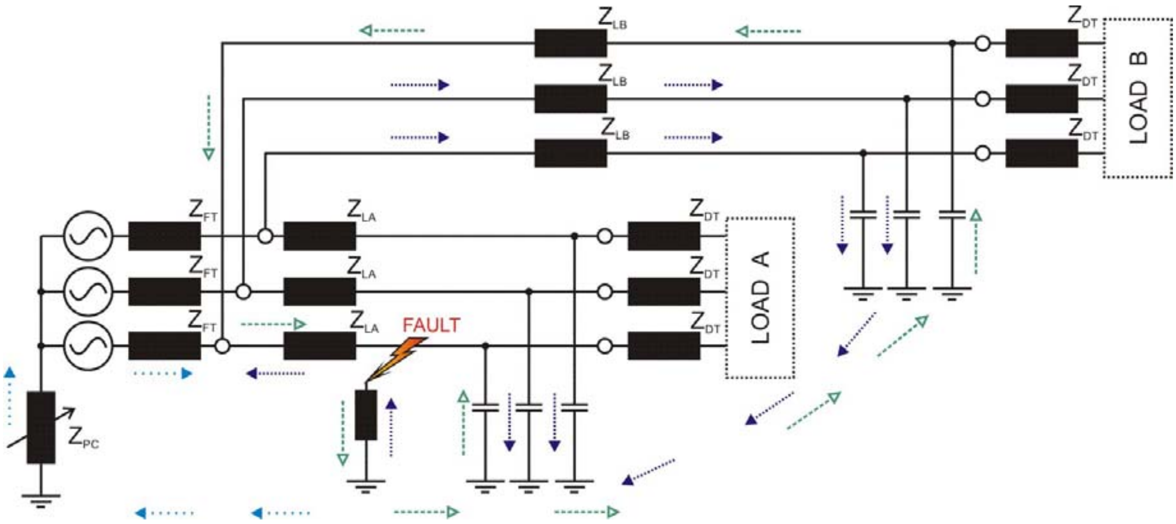


Figure 1: Charging and discharging process generated by a ground fault

2.2. Charge of the Healthy Line Over the Earth

The voltage unbalance is a result of the discharge process (distortion of a symmetrical voltage triangle). The line to neutral voltage of the affected phase falls down up to zero value and the line to neutral voltages of the healthy phases grow to a line to line voltage value as is shown on the Figure 2.

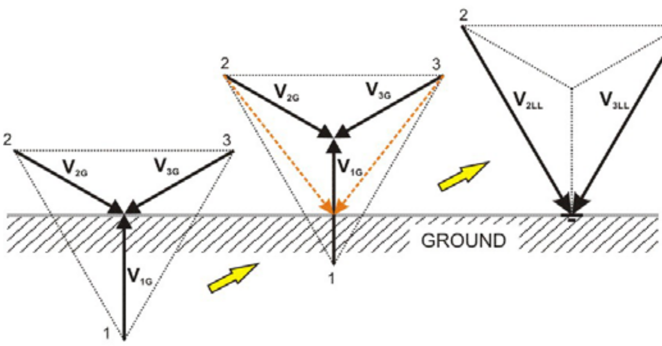


Figure 2: Change of the voltages during the charging process

Because feeding transformer keeps symmetrical voltage, the healthy phases are charged by charging current till the voltages achieve a line to line value (Figure 1). A charge current value depends on a whole healthy line to ground capacity (total healthy line length), furthermore on an impedance of a fault circuit (sum of line and fault impedance), voltage values and charge of a healthy line at the moment of ground fault ignition.

3. PASSIVE METHODS OF INDICATING THE GROUND FAULT

Passive methods are based on measured values of voltages and currents after the initiation of a ground fault. These values can be evaluated during the transient process called forth by the ground fault or after its stabilization (coming into steady state). For that reason, the passive methods may be divided into methods using the steady state signal (statical methods) and into those using the signal during the transient process (dynamical methods) [1].

3.1. STATICAL METHODS

- Method of the fifth harmonic
- Admittance principle of the zero-sequence component

3.2. DYNAMICAL METHOD

The paper is mainly focused on usage these dynamical methods of indicating the grand fault.

- First half-period method

When a ground fault becomes, a short intensive transient process is generated due to the influence of capacities of individual feeders. The capacity of the faulty phase will be discharged and the phases not affected by the failure will be charged during this process. This short discharging current is recognizable in the first half-period after the initiation of the ground fault. The method then compares the phases of the zero-sequence component of the current and of the zero-sequence component of the voltage. If the zero-sequence components of the current and of the voltage are in phase during the first half period after the initiation of the ground fault, the matter concerns the line not affected by the failure. On the contrary, if the zero-sequence components of the current and of the voltage are in antiphase, the matter concerns the line affected by the failure. The advantage of this method consists in the possibility of its application in compensated non-solidly grounded networks and it localizes even arcing ground faults well. Higher technical demands on the realization are then caused by a short interval of time for an evaluation.

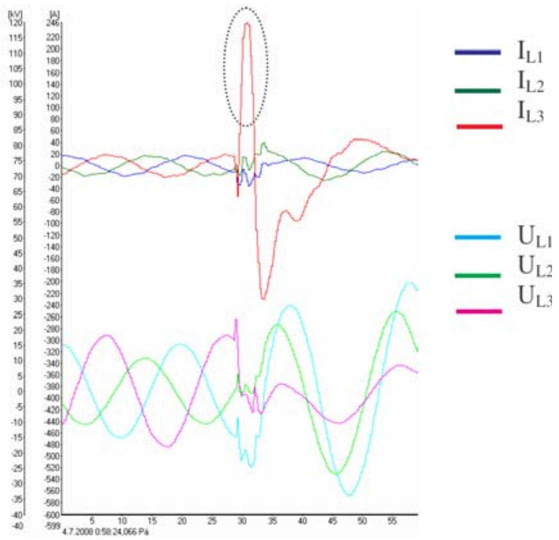


Figure 3: Oscillographically obtained shapes of voltages and currents at the ground fault – affected line

- Connection of the resistor

A resistor through which the neutral point is connected to ground for a short time is used for assessing the faulty feeder. After the origination of a ground fault, the resistor shall be connected, after a short delay, for the period of about 1 s and the changes of currents and voltages will be evaluated. If, after the resistor has been connected, the current of the faulty phase increases due to a change of the admittance of the failure loop, the matter concerns the line affected by the failure. Similarly as in the previous method, the ground fault can be localized even from the zero-sequence components of the voltage and the current. The disadvantage of this method is the increase of the current loading at the place of failure and the endangering of the public. For that reason, it is appropriate to connect the resistor only after it has been undoubtedly assessed that, e. g., the first half-period method or other methods did not identify the place of the ground fault unambiguously.

4. THE RECORDED DATA USAGE FOR PARAMETERIZATION OF INDICATORS

The ground fault indicator is device for identification of ground faults according to the analysis of electromagnetic fields of MV lines. Each indicator saves the records about the originated ground fault into internal memory. The operator reads out the data from this memory in certain intervals of time or the stored data can be instantaneously transmitted to the operator at the dispatch centre who can analyse them. All data, after having been read out, are processed and they may be used for the prediction of electrically weak places in the MV system. The operator may then be sent there for performing visual inspection. An indicator has to be set up in relation to requirement and operation parameters of the monitored network for its correct function. It means that there have to be chosen useful localization methods, sequence of the methods during evaluation and defined limit value for each useful method. The parameterization is difficult and circuitous in practice, because this setting has to be verified by a actual fault in the protected network. Because a ground fault is not frequent phenomenon it is better when the chosen parameterization is applied to a data of a fault in the network recorded by the indicator. The designed algorithm which is described bellow can be used to this purpose. The algorithm, which imitates the ground fault indicator, uses for assessment a stored data recorded by the indicator scanning the electromagnetic field of the line during the ground fault.

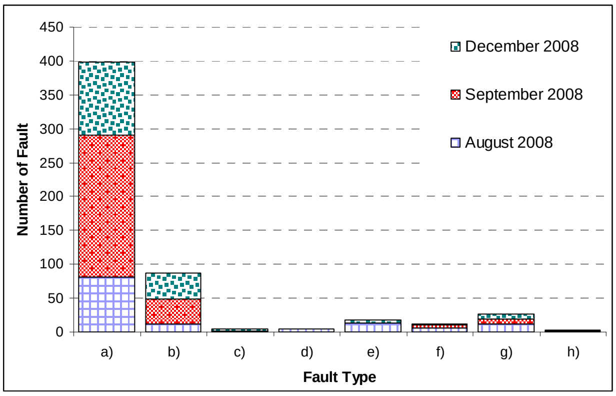
4.1. THE ALGORITHM FUNCTION DESCRIPTION

- Sequence of the location method is specified in the first step of the algorithm with respect to protected network operating conditions. In the compensated networks which are most frequent in our country, there is used the first half period method for ground fault location at first. If its' using for evaluation is not possible (e.g. high-resistance ground fault), then the connection of the resistor method is applied and finally the fifth harmonic (also inclusive 3. and 7. harmonic) and admittance principle of the zero-sequence component method.
- In the second step the algorithm parameterization is executed for the tested network. There are set initiating zero sequence values of voltage and current and the other limit values for evaluation of the fault as chapter 3 described.
- Then the algorithm loads a sampled signal which was recorded into the faulty network by the ground fault indicator, after that a fault type and fault parameters are determined and finally a fault position is located. These results are assessed, How they correspond to an actual fault progression. If not it is necessary to change the applied parameterization, in the opposit case a pre-set is transferred to the ground fault indicator unit.

5. IMPROVEMENT OF THE RESULTS FROM GROUND FAULT INDICATION

The ground fault consequences can even lead to the interruption of the electricity supply (outage) and to economical losses on the side of the supplier as well as of the consumer. The suppliers of electricity therefore apply available means for preventing such losses. One of these means is the prediction of the place where the ground fault could appear. The indicators have been installed at a chosen locality of ČEZ, a. s. since the year 2005 and at a chosen locality of ZSE, a. s. since the year 2007. The data from the installed indicators are read out and evaluated regularly. As it is evident from the results, failure states originate mostly at random and in correlation with meteorological conditions. The applicability of the data as a help for managing the failure states is given by their timely presence at the control centre. For that reason, the telecommunication and the data transmission to the centre is the necessity for all indicators installed outside the object of the substation.

A quarterly frequency of failures inside the network being tested as given by the MEg60 and MEg61 indicators will be shown as an example bellow.



a) Ground Fault (up to 5s)

b) Permanent Ground Fault

c) Voltage unbalance

d) Overvoltage

e) Ground Fault (up to 0,5s)

f) Shut-down impulse indication

g) Reclosure impulse indication

h) Short-circuit

6. CONCLUSION

There exists no universal method which would be applicable to all types of networks and ground faults and which would be able to locate the ground fault in these networks safely. For that reason, the most appropriate solution consists in combining more methods so as to restrain their deficiencies, respecting at the same time the frequency of origination and the importance of various types of ground faults. Thanks to the combination of methods presented in this paper and to a convenient topological dislocation of indicators, a very accurate location of the ground fault can be achieved. Whole accuracy of the ground fault location is also influenced by good choice of ground fault location method, its sequence for evaluation of fault location and correct parameterization of ground fault indicators. Because verifying of correct parameterization and indicator function is not easy and circuitously workable in the ordinary working network. Therefore is necessary fast check on the correct indicator parameterization and function with the help of an algorithm which imitate the ground fault indicator. This verified set-up is transferred to the indicator unit.

REFERENCES

[1] Xinhui Z., Bingyin X., Zhencun P., Peiyu W., 2008, “Study on Single-phase Earthed Faulty Feeder Selection Methods in Non-Solidly Grounded Systems“, *IEEE Xplore*, DRPT2008, Nanjing China, 1836-1840