

A VALIDATION TOOL FOR THE VDIP METHOD FOR EARTH FAULTS LOCALIZATION AND ITS EVALUATION

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Abstract:

This paper describes a process of evaluation of the Vdip method for earth faults localization. For purposes of method validation, PSCAD simulation are used. In PSCAD, fault occurrences are simulated and COMTRADE format records are created. The fault records are then processed in Matlab with evaluation of the fault location. This process and can be useful for testing before the real-world application and can serve as reference.

Keywords: Vdip, fault localization, PSCAD,

1 INTRODUCTION

With rising demands for power supply continuity, a quick fault localization in distribution grids is desirable. While in solidly grounded systems the short circuit faults produce a high-level fault current, which can indicate the fault location based on loop impedance, in resonant earthed system the earth fault current is compensated and therefore is not so convenient for fault localization. To avoid the negative effects of conventional process of sequential disconnecting and reclosing of line sections at the faulty feeder, several methods based on different principles have been developed [1-3].

In accordance with trends of deploying distributed measurement systems a new method for earth fault localization based on distributed measuring was presented [4]. This Vdip method monitors negative sequence changes of voltage and current in the network to estimate the location of source of unbalance, which in resonant earthed systems is mostly single line-to-ground fault or double line-to-ground fault peculiarly. The Vdip method could increase the potential of distributed measurement systems and could prove useful mainly in such countries (e.g. Central Europe), where MV distribution networks are operated as resonant earthed with arc suppression coil.

2 VDIP LOCALIZATION METHOD

The Vdip method principle is described in European patent [5]. The evaluation process combines inputs from measured voltage changes at distribution transformer stations (DTS) and current changes in supply MV substation with numerical model of the network. To conduct a numerical model of the network, real physical parameters of network components need to be known. That involves impedances of distribution lines, superior transmission system, HV/MV transformer and current topology. Exactness of these parameters affect the localization accuracy. The negative sequence scheme of the network is created and the sections of distribution lines are divided into small elements (e.g. 100 m), to which the localization accuracy is limited. An auxiliary current source, representing the fault, is then being gradually connected to auxiliary nodes defined by the small element division. For each case an iterative load flow algorithm is carried out and negative sequence changes from measured data are compared with numerical results in corresponding measurement

node. The node, for which the differences are the smallest, is considered as the one with highest probability of fault presence.

To obtain the measured values of negative sequence voltage/current changes a monitoring system needs to be installed. The Vdip method relies on negative sequence voltage monitors (NSVM) placed at LV side of distribution transformer and on negative sequence current monitor (NSCM) placed either at MV side of HV/MV supply transformer or separately at each feeder. In the latter case, the function of NSCM can be substituted with suitable utilization of data from feeder protection relays.

3 DATA PROCESSING AND EVALUATION

To ensure correct functionality of the Vdip method a complex evaluation process needs to be established. Some of the calculation procedures are intended to be included as a functionality in the distributed measurement devices (NSVM) and the designed algorithms serve as a standard for final firmware implementation. Other processes are to be carried out in the computation centre, utilizing records from all the monitors and evaluating the fault location. The designs of related algorithms have been developed in Matlab programming language.

The evaluation process is demonstrated on one MV network referential feeder, for which field testing was already carried out [6]. The field experiments have shown some promise with the average location error around 1 km in cases of fault distances 23 and 35 km from the substation. Since the field tests execution, the designs of functionalities of NSVM and NSCM have been upgraded to reduce localization errors. The tested feeder was modelled in PSCAD to enable further testing and Vdip method validation. The combination of PSCAD simulation and Vdip evaluation process can show behaviour and validity of the method. A simplified scheme of the feeder is depicted in **Figure 3**.

A flowchart summarizing the processes of validation is shown in **Figure 1**. The flowchart is also relevant to a real-life application if the simulation blocks are substituted with real-life operation and measurement. The procedures are shortly described in following sections.

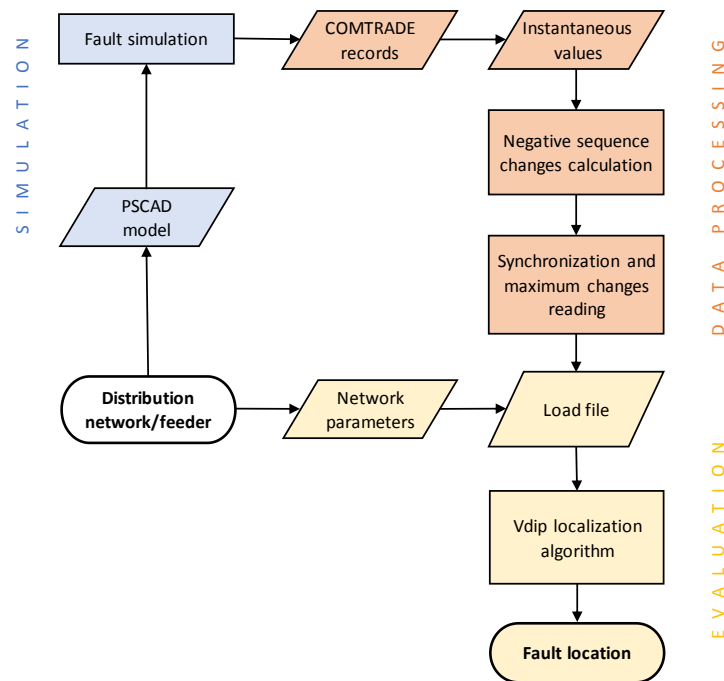


Figure 1: Flowchart of Vdip method evaluation in process of validation

3.1 COMTRADE FORMAT RECORDS – INSTANTANEOUS VALUES

The input values of the monitors functionality are either instantaneous sampled values of voltage and current in NSVM and NSCM or the values in COMTRADE format in case of using data from feeder protection. The COMTRADE format is used in the case of PSCAD simulation as well. Therefore, the conversion from COMTRADE to sampled instantaneous values needs to be completed and such module is necessary in the computation unit.

3.2 NEGATIVE SEQUENCE CHANGES CALCULATION

The problem of negative sequence changes calculation from instantaneous measured values is described in [7]. This functionality needs to be deployed in the firmware of monitors to give the right fault signal and send the records to central unit. The monitors Vdip functionality has two modes with different setting – one for earth faults and one for short-circuit faults. In this paper, only earth fault mode is described, but most of the procedures are identical for both settings.

The referential design of data processing assumes a sampling frequency of 4 kS/s. In case of fixed sampling rate in the measuring device (as in feeder protection) resampling of the records is carried out. For this purpose, the system frequency has to be estimated. In the earth fault mode digital filtering for interharmonics could be applied. For fundamental frequency phasor estimation, the full cycle Fourier transform algorithm is used as it neglects negative effects of harmonic distortion. From asymmetrical (phase) phasors, negative sequence phasors are calculated using Fortescue transformation.

The principle of calculating negative sequence changes is based on subtracting average values of negative sequence phasors in two sliding consecutive time frames (windows). The time frames have the same length and are shifted by a time lag. In each frame, the average value of negative sequence phasor can be calculated as mean average. Both the frame length and shift are settable parameters and may vary depending on the type of fault, i.e. the detection of short-circuit faults require different setting than the detection of earth faults. With optimized frame setting, negative effects of ripple control related disturbances are significantly reduced [7].

3.3 RECORDS SYNCHRONIZATION AND MAXIMUM VALUES READING

After the fault records from NSCM and NSVMs are sent to the centre, they are synchronized using a cross-correlation method. A maximum of negative sequence current change in **Figure 2**. NSCM record is found and for this time values of negative sequence voltages in NSVM records are determined. Synchronized negative sequence changes records for one measurement are depicted in **Figure 3**. When evaluating the referential PSCAD case, the synchronization is not necessary, but it is carried out anyway to check the functionality.

3.4 FAULT LOCATION EVALUATION ACCORDING TO VDIP METHOD

Besides the maximum negative sequence voltage and current changes, detail information about the network topology is required. The network parameters are stored in a user-accessible load file, e.g. an XLS file. The load file contains topology data, including information about nodes, places where the monitors are installed, impedances of distribution lines segments, positions of breakers and impedances of HV/MV transformer and transmission network. The evaluated fault location is presented via table of the most probable locations, sorted by the highest. For method validation and assessment, only the most probable location is considered.

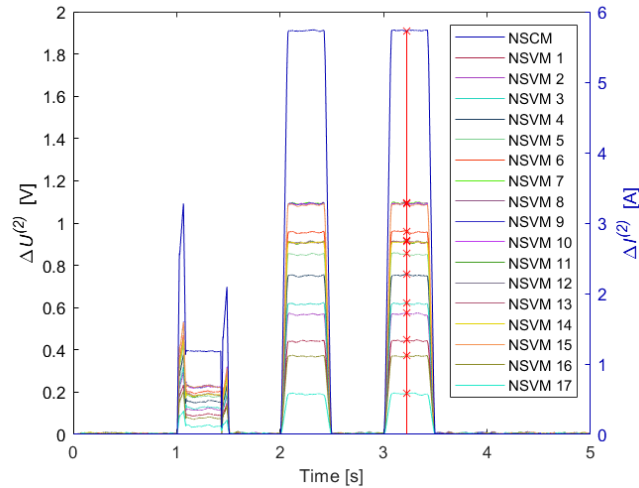


Figure 2: Synchronized records of negative sequence changes for maximum values determination

4 SIMULATION ASSESSMENT

Mentioned PSCAD model of the referential feeder was created, respecting the real physical parameters as much as possible. Distribution lines are modelled with PI sections, values of loads are fictional and modelled as constants. The network is operated as resonant earthed with an auxiliary resistor connected for 1 s to increase the fault current. The network is equipped with one NSCM at secondary side of supply transformer and with seventeen NSVMs at DTS's throughout the faulty feeder. The situation is shown in **Figure 3**, where only DTS's equipped with monitors are portrayed.

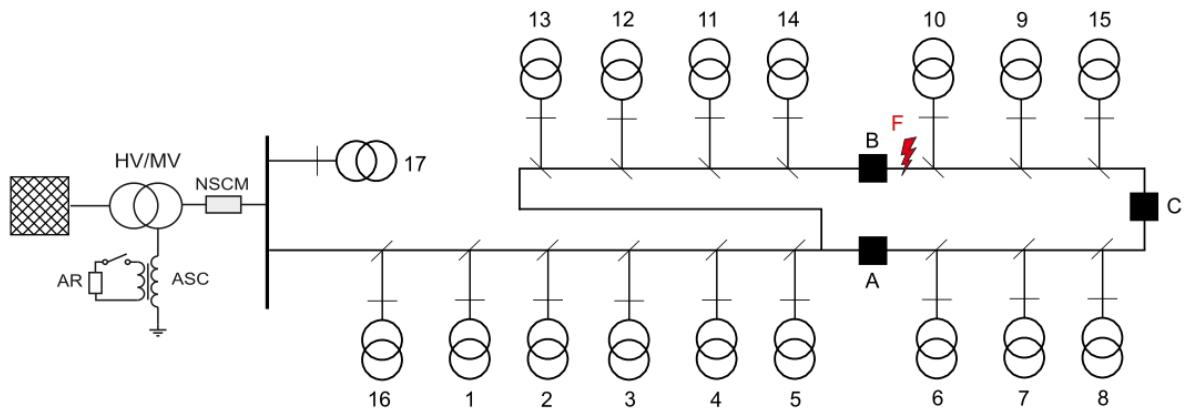


Figure 3: Schematic depiction of the referential feeder

Simulations have shown, that the Vdip method can be very accurate and locate the fault to a precision defined by network segmentation (e.g. 100 m). However, the accuracy is limited to the accuracy of input data. For instance, the localization performance is quite sensitive to impedance of transmission network, which is uneasy to estimate.

Since the method is dependent on measured data, with more NSVMs installed, better results of localization can be achieved. Also, it is important to place some NSVMs to the most distant DTS's to cover the whole feeder. For example, if the fault appears in point F according to **Figure 3**, with the breakers A and C closed and B open, the fault is localized much closer to DTS no. 10 as it has the

last NSVM in the branch. In configuration when both the breakers B and C are closed, the localization of the same fault is much more precise.

5 CONCLUSION

An evaluation referential process of the Vdip method was presented. For the method validation, a PSCAD simulation can be used, followed by data processing leading to the fault localization. This method of assessment can be useful as a trial in preparations before the real-life implementation. Simulations have shown, that with the Vdip method could be very precise and the error of fault localization can be smaller than 100 m, but the input data has to be accurate as well.

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