Research of the Remote Fault Location Algorithm Based on Sampled Values for Measured Primary Electrical Quantities

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ABSTRACT

Digital current and voltage transformers are designed to large-scale transformation of voltage, alternating and/or direct current. Then they transmit the results of transformation to electricity metering systems, devices for measuring, relay protection, automatics, alarm, and control.

There was developed the remote fault location method using data (instantaneous values of primary quantities) from innovative current and voltage sensors, which are included in the digital transformer structure. The results of the research of algorithm performance in cases of the influence of different distorting factors are presented.

INTRODUCTION

Remote fault location on overhead power lines with the voltage of 110 kV and higher using recording devices (indicators), disturbance recorders, microprocessor-based devices for relay protection and automatics became an integral part of maintenance electrical grid service.

[1] requires fault location devices to be installed on overhead power lines with the voltage of 110 kV and higher; the maximum value of examination zone on overhead power lines and fault location using topographical methods after output receiving from fault location devices are also regulated.

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Nowadays these values of examination zone on overhead power lines cannot be considered as satisfactory, especially for overhead power lines with the length over 100 km.

The most important issue in remote fault location is the cases of self-removing short-circuit when it is impossible to find a fault visually during the examination. The effectiveness of fault location on overhead power lines in cases of unsustainable short-circuits was about 40% of examined power lines with such type of fault [1]. Thus, the development of the remote fault location algorithms with higher accuracy is considered a pressing challenge.

There was developed the remote fault location method using emergency-mode parameters and based on one-sided measurement [2, 3]. The advantages of this method are the absence of special generating equipment (in contrast to, for example, locating methods [4]), the absence of necessity in measurement synchronization, the simplicity of usage [5]. Also, the remote fault location methods based on measuring emergency-mode parameters have large (about 10-20%) error caused by errors of current and voltage sensors [6].

Usage of the data from digital current and voltage transformers can potentially increase the remote fault location accuracy. But the application of these converters for meeting the challenge of remote fault location requires additional research.

REMOTE FAULT LOCATION ALGORITHM BASED ON SAMPLED VALUES

Ivanovo State Power Engineering University (Russia) conjointly with scientific and production enterprise “Digital Measuring Transformer” developed digital current and voltage transformers and also combined transformers applied for the voltage classes of 6(10), 35, 110 and 220 kV. The developed transformers were included in the register of measuring instruments.

The usage of transformers as primary converters for connecting with remote fault location devices helps to improve the accuracy of fault location thanks to their advantages [7]. Presence of several current sensors (including the Rogowski coils) allows one to determine the values of alternating and direct currents and also, physically, the derivative of the input current.

Figure 1 represents the block diagram of the developed remote fault location method.

The developed remote fault location method using data from digital current and voltage transformers consists of such basic operations: calculation of module and argument of phase currents and voltages complex vectors, calculation of symmetrical components for primary quantities, determination of faulty phase (or phases) and short-circuit type, determination of the beginning and the end of the transient process in emergency mode (in case of short-circuit), calculation of inductance to the fault, and determination of the distance to the fault.
Design equation (in Distance Calculator) corresponds to the expression of the transient process for instantaneous values in cases of different types of short-circuit. The calculation is made in the moments of short-circuit current zero-crossing.

Expression (1) represents the calculation of the distance to the fault in the case of phase-to-phase short-circuit (A-B) using instantaneous values of electrical quantities.

\[
L_f(t_{0i}) = \frac{u_{AB}(t_{0i})}{L_1^{(1km)} \frac{d(i_A - i_B)}{dt}(t_{0i})}, \tag{1}
\]

where \( t_{0i} \) – the moment of current \((i_A(t) - i_B(t))\) zero-crossing, sec; \( u_{AB}(t_{0i}) \) – the phase-to-phase voltage in the moment \( t_{0i} \), kV; \( \frac{d(i_A - i_B)}{dt}(t_{0i}) \) – the current \((i_A(t) - i_B(t))\) derivative value in the moment \( t_{0i} \), kA/sec, \( L_1^{(1km)} \) – the specific positive (negative) sequence inductance of overhead power line.

Design equation (and design inductance) was determined in accordance with the boundary conditions for a certain type of short-circuit.

**METHODOLOGY OF ALGORITHM RESEARCH**

The research and refinement of the algorithm and the related computer simulation models (including data processing models) were made in two steps. During the first step, the design expressions were tested in Simulink, where the models of electrical grids and the algorithm itself were implemented. [7]. Then there were researched various options of algorithm realization (using different
sensors like Rogowski coil or traditional electromagnetic current transformer with further digitization) and algorithm performance in cases of various distorting factors (e.g. transient fault resistance) [7].

![Diagram of remote fault location algorithm]

**Figure 2.** Refinement of computer simulation models for the implementation of the remote fault location algorithm:

- **a** – step 1;
- **b** – step 2.

During the second step, refinement of the computer simulation models consisted of taking into account the influence of analog-digital converter and frequency filters. Errors of developed primary converters in case of usage of the hybrid (field-based and chained) Rogowski coil model were also taken into account. The calculation of the distance to the fault using computer simulation models demonstrated the virtual absence of the influence of the developed current sensors on the method accuracy.

Taking into account conducted research and refinement of the software realization of the algorithm there was developed the code written on programming language MATLAB. This code includes all of the basic operations given above and provides the performance of the remote fault location algorithm with the error lower than 5%.

**DEMONSTRATION OF ALGORITHM PERFORMANCE**

As an example, there is given the demonstration of the algorithm performance in the case of phase-to-phase short-circuit (A-B) located 100 km from the head of the power line (measuring point).
Figure 3. Primary currents (a) and voltages (b) oscillograms (in short-circuit mode).

Figure 4. Symmetrical currents components (1 – positive sequence, 2 – negative sequence, 3 – zero sequence).
1. Figure 3 represents phase currents and voltages oscillograms, which illustrate initial data sets from the analog-digital converter model in Simulink.
2. Figure 4 represents the results of the calculation of symmetrical currents components.
4. Calculation of the distance to the fault in the moments of current $(i_a - i_b)$ zero-crossing using equation (1) – determination of the inductance in phase-to-phase short-circuit mode.

The arithmetic mean of the calculated distances to the fault is 101.53 km. The remote fault location algorithm error – 1.53%.

CONCLUSION

The developed remote fault location algorithm was researched in cases of the influence of different distorting factors: methods of current derivative calculation, the presence of fault transient resistance, the distance to the fault, the electrical load, the presence of fault voltaic arc, the phase-to-phase capacitance in power lines, the parameters of analog-digital converter.

Primary algorithm debugging was made with the usage of computer simulation models of electrical grids, which included the primary converters models. Algorithm performance in the case of phase-to-phase short-circuit is demonstrated.

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REFERENCES

