Journal of Engineering and Applied Sciences 12 (Special Issue 1): 5731-5734, 2017
ISSN: 1816-949X

Algorithm Development for Fault Location in Power Transmission Lines of Branched Medium Voltage Circuits

I.N. Lizunov, E.F. Khakimzyanov, R.G. Mustafin, R.Sh. Misbakhov, I.F. Immamutdinov,
O.E. Naumov and A.M. Touitiyarov
FSBEI HE, Kazan State University of Energetics, Kazan, Russia

Abstract: The study proposes the algorithm to determine the locations of phase-to-phase faults at power transmission lines of branched medium voltage electrical networks. A special feature of the algorithm is the application of emergency mode calculation theory, taking into account the effect of the network load parameters and the transient resistances at phase-to-phase faults.

Key words: Distribution network, interphase damage, emergency mode parameters, fault location, transient resistance, centralized control system of 6 (10) kV switchgear

INTRODUCTION

High rates of electric network development at the reduction of operational personnel specific number, require the accelerated introduction of automation equipment including Damage Location Devices (DLD) on Power Lines (PL).

The variety of types and the nature of damage, as well as the operating conditions of electrical networks, do not allow us to obtain any universal algorithm for DLD.

Thus, the review of existing techniques at phase-to-phase faults and earth faults is reduced to a fault location determination by the use of current sensors (indicators) installed, as a rule, at line branch points. The clarification of a fault location is carried out by a line bypass using the forces of an operational-visiting brigade. The implementation of this technique requires serious financial investments (the cost of a project is proportional to the number of current indicators) and the organization of information transfer via a wireless communication channel (Eisenfeld, 1989; Artsishevsky, 1986; Kozlov and Lizunov, 2011). Therefore, such indicators can be only the “reference points” when a line route is by passed.

A review of existing DLD techniques at more complex types of ground faults (for example, double earth faults) did not give a clear idea of distance calculation accuracy. As a rule, existing DLD devices determine only the occurrence of double earth faults, without the clearing of damage features (on one or on different lines) and without the indication of distances to the points of damage. At that, depending on the nature of a double earth fault, a fault is defined as a fault or an interphase short-circuit (Anonymous, 2015ab; NAVI Ltd., 2007; Artsishevsky, 1986). Khakimzyanov (2014) and Khakimzyanov *et al.* (2014, 2015, 2016) demonstrate DLD methods and algorithms for double earth faults in an MV network with an isolated neutral, the novelty of which is in a special scheme for resistance monitoring device connection, in which the design resistance of an emergency mode is proportional to the distances to ground fault points.

At phase-to-phase faults DLD are realized as one-way or two-way measurements of Emergency Mode Parameters (EMP). As a rule, the resistance of a short-circuit loop is calculated through the symmetrical components of a line current and voltage (Artsishevsky, 1986, 1988; Arzhannikov *et al.*, 2003; Saha *et al.*, 2009). This method is successfully applied to power lines and the lines without branches. However, in branched medium-voltage networks, the accuracy of the method is reduced because of a load regime influence on network branches, as well as the values of the transient resistance at a fault site.

The use of devices based on the DLD wave method requires a special adjustment of a fault detection system, as well as a special processing of a line by high-frequency connection devices (Minullin, 2008; Kopylov *et al.*, 2015).

MATERIALS AND METHODS

Algorithm of problem proposed solution: Modern DLD methods by EMP involve the assumptions which distort the results of distance calculation to the site of

Corresponding Author: I.N. Lizunov, FSBEI HE, Kazan State University of Energetics, Kazan, Russia

damage. These assumptions include the exclusion of the load current influence or the transient resistance in a fault location. The improvement of DLD methods by EMP will reduce the error.

The developed algorithm is designed to determine the distance to a phase-to-phase Short-Circuit (SC) of a network with a complex configuration, taking into account the effect of network load resistance and the transient resistance at a fault site with the indication of a damaged network area.

In order to identify the algorithms compensating the effect of the network load and the transient resistance, we will calculate EMP using the example of a three-terminal line of the 10 kV electric network (Fig. 1) and its replacement circuit for the forward (reverse) sequence (Fig. 2) at a two-phase short circuit in the section VL2 (point K_2).

According to the network replacement scheme in an emergency mode (Fig. 2), the impedance Z_{kz} will be determined as follows:

$$Z_{kz} = Z_1 + \frac{\left(Z_3 + Z_{n2}\right) \times \left(Z_{21} + \frac{\frac{R_p}{2} \times \left(Z_2 - Z_{21} + Z_{n1}\right)}{\frac{R_p}{2} + Z_2 - Z_{21} + Z_{n1}} \right)}{Z_3 + Z_{n2} + Z_{21} + \frac{\frac{R_p}{2} \times \left(Z_2 - Z_{21} + Z_{n1}\right)}{\frac{R_p}{2} + Z_2 - Z_{21} + Z_{n1}}} \quad (1)$$

where Z_{kz} is the total resistance of the emergency mode, determined by the ratio of the phase-to-phase voltage to the difference in the currents of two phases (the classical circuit of the resistance measuring device inclusion reacting to the phase-to-phase faults (Ziegler and Siemens, 2000; Schneerson, 2007); Z_1, Z_2, Z_3 is the total resistance of PL sections; Z_{n1}, Z_{n2} the total load resistance of consumers (including the resistance of transformers at TS); R_p is the transient resistance at a fault location.

In Eq. 1, the unknown value is the resistance Z_{21}, whose inductive resistance by transformations will be determined with the polynomial of the third degree:

$$C_0 + C_1 x_{21} + C_2 x_{21}^2 + C_3 x_{21}^3 = 0 \quad (2)$$

Discarding the imaginary roots of the equation, we obtain the required resistance x_{21} which will be proportional with the distance to SC site in the section L2:

$$L_K = \frac{x_{21}}{x_{yd}} \quad (3)$$

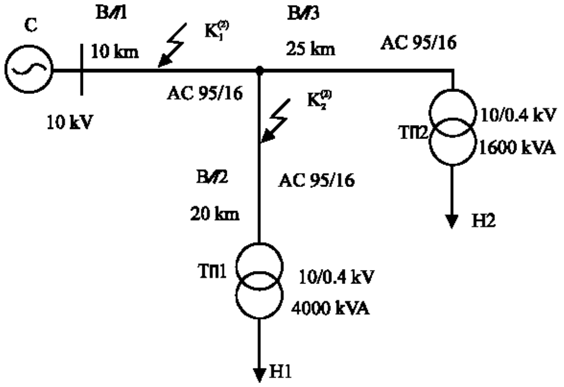

Fig. 1: The example of a single-line electrical network with the voltage of 10 kV: C-power supply system with the voltage of 10 kV, TS1, TS2 transformer substations with the low voltage of 04 kV, VL1-VL3 the sections of the line under consideration; H1, H2 the load of consumers

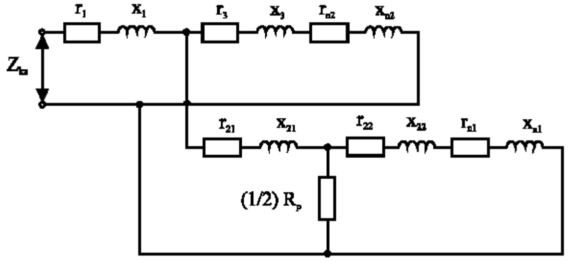

Fig. 2: The scheme of direct (reverse) sequence replacement of 10 kV network design scheme in emergency mode (small inscriptions)

where, x_{yd} is the specific resistance of power line direct sequence. The verification of the proposed DLD algorithm was carried out in the MATLAB Simulink Software package in which the circuit was modelled shown on Fig. 1. PL parameters of VL1-VL3: r_{yd} = 0.33 Ω/km, x_{yd} = 0.37 Ω/km; loads: S_{H1} = 4000 kWA, S_{H2} = 1600 kWA, cosφ = 0.6.

The point of two-phase short-circuit (K_2) on the section of the line VL2 is set at a distance of 10 km from the beginning of unsoldering (20 km of the line), the transition resistance R_P is assumed to be 20 Ω.

RESULTS AND DISCUSSION

The analysis of the current and voltage oscillograms in the emergency mode showed the following results: the short-circuit current is 0.9 kA, the voltage on the feeding substation buses is 9.2 kV.

The distance to a fault location according to the Eq. 1-3 was determined as 10.8 km after the unsoldering which makes 4% of DLD calculation error.

The detection of a damaged network segment is carried out by the criterion of active load capacity decrease as the result of network mode parameter change. Thus, a short-circuit occurred on the section VL2 and the active power of the load H1 at the specified connection was reduced to 1648 kW and at the load of H2 it reduced to 1077 kW. Thus, the deepest decrease in active power on H1 load indicates the damaged section of VL2. The power change can be fixed by the analysis of the electrical energy metrics using digital meters.

An additional criterion which allows to determine a damaged unsoldering is the control of the negative sequence voltage. The consumer of a damaged site will have higher voltage of the reverse sequence in comparison with the consumers on the undamaged sections of a network (Khakimzyanov *et al*., 2016).

Let's compare the results of DLD calculations using the Eq. 1-3 with other methods used in practice. Thus, the built-in DLD function of Oscillogram analysis in FastView program indicates the distance to the fault location which makes 16.8 km (the error is 16%). Besides, this technique does not provide information about the location of SC point.

The patent solution is the closest one to the developed algorithm. The calculation according to the presented technique indicated the distance to the fault site which made 13.9 km from the beginning of the unsoldering, the error makes about 20%.

Thus, DLD algorithm was developed in medium voltage networks, based on EMP control which differs from other DLD methods by the fact that the tree topology of a network is taken into account during the calculation of the distance to a fault site, as well as the short-circuit transient resistance.

Let's carry out a series of model studies concerning the influence of a load power value, as well as the value of the transient resistance at a fault location, on the accuracy of DLD process according to the proposed procedure and according to the calculations by Eq. 1-3. The results of DLD calculation errors are shown on the diagram (Fig. 3) from which it can be seen that with a maximum load power of consumers (8 MVA) and at 25 Ω transient resistance, the error of DLD does not exceed 9% which is lower than other methods used in practice.

Let's show the calculation of EMP using the example of the same electric network with the voltage of 10 kV (Fig. 1) in two-phase short-circuit mode at K1 point within the section VL1 (the distance to the SC site is 5 km, the transitional resistance is set to 20 Ω). The scheme for the forward (reverse) sequence replacement in the emergency mode is shown on Fig. 4.

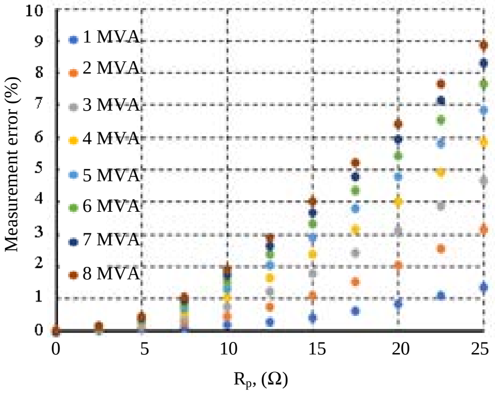

Fig. 3: Relative errors depending on transient resistance and load

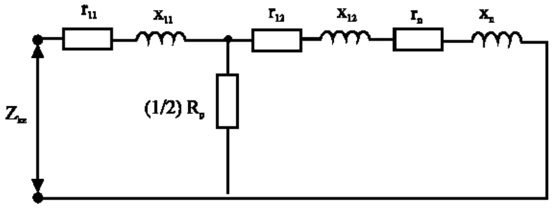

Fig. 4: The replacement scheme for the direct (reverse) sequence of 10 kV network design scheme in emergency mode

In this case, the impedance Z_{kz} will be determined as follows:

$$Z_{kz} = Z_{11} + \frac{\frac{R_p}{2} \times \left(Z_1 - Z_{11} + Z_n\right)}{\frac{R_p}{2} + Z_1 - Z_{11} + Z_n} \tag{4}$$

Where,

$Z_1 = Z_{11}+Z_{12}$ = The impedance of the power line head section

Z_n = The total load resistance of consumers (including the transformer resistance at the TS)

The lines determined by the following equation:

$$Z_n = r_n + jx_n = \frac{\left(Z_2 + Z_{n1}\right) \times \left(Z_3 + Z_{n2}\right)}{Z_2 + Z_{n1} + Z_3 + Z_{n2}} \tag{5}$$

Then, the solution of the DLD problem is similar to the first example.

Summary: The algorithm was developed to determine the distance to two-phase short-circuit, taking into account the influence of load currents and the transient resistance at a fault point, the error of which is 10% lower on the average as compared to the existing and practiced DLD methods.

CONCLUSION

The calculation of DLD by the Eq. 1-5 showed the following results: the distance to the fault site made 5.1 km, the relative error was 1.6%. The built-in DLD function of Oscillogram analysis in FastView program, as well as the method, indicates the distance to the fault site of 5.5 km (the error makes 10.7%).

At the same time, the analysis of change comparison concerning the active power of the load H1 and H2 shows a small discrepancy between them which is also the criterion of damage at the head section of a line. The active power of the load H1 was 1684 kW and the active power at the load H2 made 929 kW.

The calculation of the distance to the fault location according to the presented method in the networks with a large number of taps (of any configuration) will be similar to two examples presented above.

The developed algorithm for a fault determination can be implemented both on the existing microprocessor element base (on a terminal) and in the central server of the centralized control system of 6 (10) kV switchgear.

ACKNOWLEDGEMENTS

The research was financially supported by RF Ministry of Education and Science in the framework of the federal target program "Research and development in priority areas of scientific and technological complex of Russia development during 2014-2020", the agreement on subsidy provision No. 14.577.21.0194 issued on October 27, 2015-the 2nd stage, the unique identifier of applied scientific research (of the project) is RFMEFI57715X0194.

REFERENCES

Anonymous, 2015a. Indicators of short-circuit ICS by LLC, MNPP antrax: Electronic resource. Antrax Flames Group SIA, Fryazino, Russia.

Anonymous, 2015b. Software fast view 4.2: Electronic resource. Mekhanotronika, Saint Petersburg, Russia. http://www.mtrele.ru/pro/dlya_raboty_s_bmrz100/programma_dlya_prosmotra_i_analiza_oscillogramm_fastview/.

Artsishevsky, Y.L., 1986. Determination of Power Line Fault Location in the Networks with Isolated Neutral: Textbook. Moscow High School, Moscow, Idaho,.

Artsishevsky, Y.L., 1988. DLD of power lines in the networks with a grounded neutral. Master Thesis, Moscow High School, Moscow, Idaho.

Arzhannikov, E.A., V.Y. Lukoyanov and M.S. Misrikhanov, 2003. Determination of a Short-Circuit Point on High-Voltage Power Lines. Energoatomizdat Publisher, Moscow, Russia, Pages: 272.

Eisenfeld, A., 1989. Fixing Indicators of Current and Voltage LIFP-A, LIFP-B, FPT and FPN. Energoatomizdat Publisher, Moscow, Russia, Pages: 86.

Khakimzyanov, E.F., 2014. The behavior of resistance measuring device with double earth faults in the distribution networks of 6-35 kV. Relay Prot. Autom., 1: 18-21.

Khakimzyanov, E.F., A.I. Fedotov, R.G. Mustafin and R.U. Galeeva, 2016. Determination of the distribution network damaged section in the regime of double earth fault. News Higher Educ. Institutions Prob. Energy, 8: 3-8.

Khakimzyanov, E.F., R.G. Mustafin and A.I. Fedotov, 2015. Determination of the distances to the places of double earth faults on a power line of medium voltage network. Univ. News Prob. Energy, 4: 132-137.

Khakimzyanov, E.F., R.G. Mustafin and R.G. Isakov, 2014. The unit for resistance measuring, revealing a double earth fault in the distribution networks of 6-35 kV. Relay Prot. Autom., 3: 29-35.

Kopylov, A.M., I.V. Ivshin, A.R. Safin, R.S. Miesbachov and R.R. Gibadullin, 2015. Assessment, calculation and choice of design data for reversible reciprocating electric machine. Int. J. Applied Eng. Res., 10: 31449-31462.

Kozlov, V.K. and I.N. Lizunov, 2011. The centralized microprocessor system of relay protection and automatics with remote control. Russian Federation-Eurasian Patent Organization, Russia.

Minullin, R.G., 2008. Locational Diagnostics of Overhead Transmission Lines. Kazan State Power Engineering University, Kazan, Russia, Pages: 202.

NAVI Ltd., 2007. Fault indicators for LineTroll air lines: Product assortment. NAVI Ltd, Saint Petersburg, Russia. http://www.navi-spb.ru/files/linetroll.pdf.– Screen heading.

Saha, M.M., J.I. Jozef and R. Eugeniusz, 2009. Fault Location on Power Networks. Springer, Berlin, Germany, Pages: 424.

Schneerson, E.M., 2007. The Digital Relay Protection. Energoatomisdat, Moscow, Russia, Pages: 549.

Ziegler, G. and A. Siemens, 2000. Numerical Distance Protection: Principles and Application. Publicis MCD Verlag, Erlangen, Germany, ISBN:9783895781421, Pages: 321.