

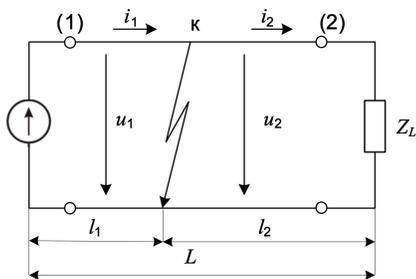
USE OF INFORMATION INFRASTRUCTURE TO DETERMINE THE LOCATION OF DAMAGE TO CABLE AND OVERHEAD LINES

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One of the challenges facing electric power systems is failure of overhead and cable transmission lines. Short circuits pose a particular danger. Damage to air and cable lines leads to a decrease in the reliability of electricity supply and the quality of electricity supplied, as well as to under-supply of electricity. At present, various devices and techniques have been developed to determine the location of damage to cable and overhead lines but all of them have their shortcomings and large errors. This fact requires increasingly faster information acquisition and processing for estimating a system state and making preventive measures to ensure sustainable power supply with minimum loss of time. This paper is devoted to the problem of on-line determination of coordinates of a short circuit point in the transmission line. The suggested methods are based on the assumption that the short circuit current at the transmission line beginning depends on the distance to the short circuit point.

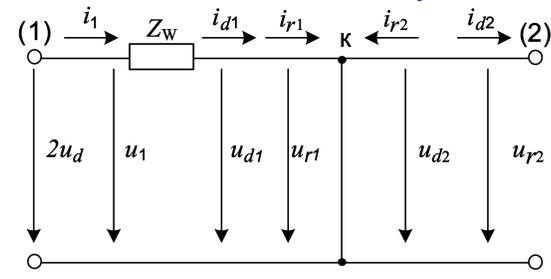
The first method for determination of coordinates of short circuit point

Design scheme of a short circuit in a line



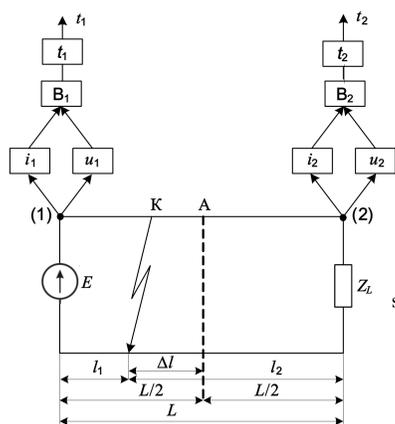
L - length of the line; l_1, l_2 - distances from the short circuit point to the source and load ends of the line, respectively; i_1, i_2, u_1, u_2 - current and voltage of the first and second sections of the line, respectively.

Model of the line for calculation of transient process in the line



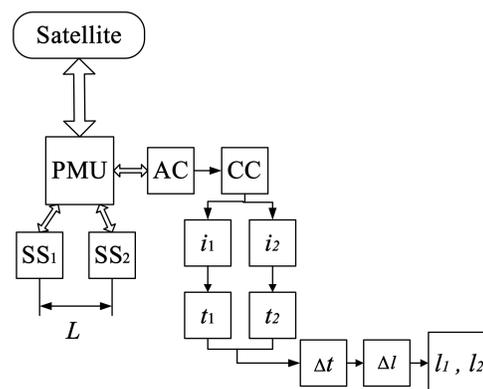
Z_w - wave impedance of the line; i_{d1} - incident current wave of the first section, i.e. from the source end to the short circuit point; i_{r1} - reflected current wave of the first section; u_{d1} - incident voltage wave of the first section; u_{r1} - reflected voltage wave of the first section; i_{d2} - incident current wave of the second section, i.e. from the short circuit point to the load end of the line; i_{r2} - reflected current wave of the second section; u_{d2} - incident voltage wave of the second section; u_{r2} - reflected voltage wave of the second section.

A scheme of devising an algorithm for determining the place of point K



(1), (2) are the sites at which the chronometers (t) and primary current (i) and voltage (u) sensors are installed; A - geometric center of the line; B - modules for processing the data from current and voltage sensors; ΔL - distance from the center of Line A to the short circuit point K.
 t_1 - express time of the signal (response) arrival at the source end of the line through the short circuit time;
 t_2 - Time of the response arrival at the load end of the line.

PMU infrastructure

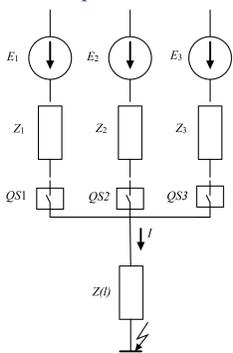


SS1 - feeding substation; SS2 - receiving substation; L - length of the line; AC - atomic clock; CC - control centre; SS1, SS2 - network substations; t - time pulse of the atomic clock; h - height of the satellite above the Earth in the area, where the substations are located; Q_1, Q_2 - angles at which the satellite is seen from SS1 and SS2, respectively.

The second method for determination of coordinates of short circuit point

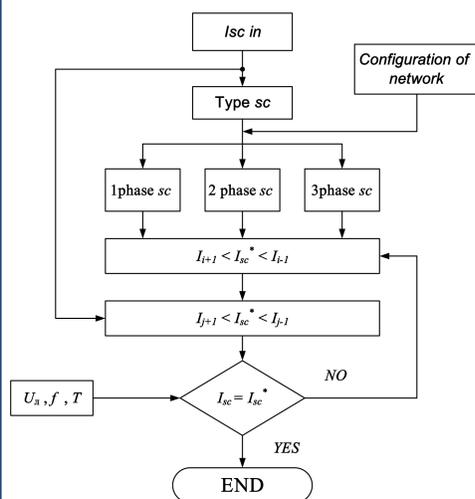
E_G - system EMF (electromotive force); r - internal resistance of the system; $Z(N)$ - resistance from the short-circuit point to the nearest ground wire; $Z(l)$ - resistance of the line section from its beginning to the short circuit location; $I_{sc}^{(3)}, I_{sc}^{(2)}, I_{sc}^{(1)}$ - initial effective values of short-circuit currents at three-phase, two-phase and one-phase short circuits, respectively.

Final equivalent circuit



E_1, E_2, E_3 - sources that have a considerable impact on the short-circuit current of line, Z_1, Z_2, Z_3 - equivalent resistances of a circuit section from sources to the beginning of the considered line, $QS1, QS2, QS3$ - circuit breakers, $Z(l)$ - resistance of the line section from its beginning to the short circuit point located at a distance l from the beginning of the line.

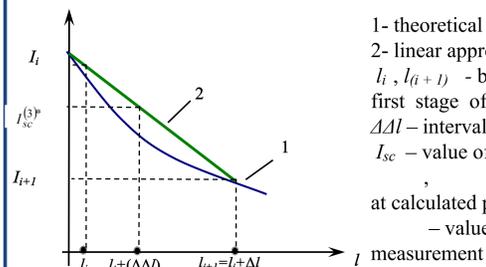
The algorithm for on-line determination of short circuit point in the transmission line



Fault location detection

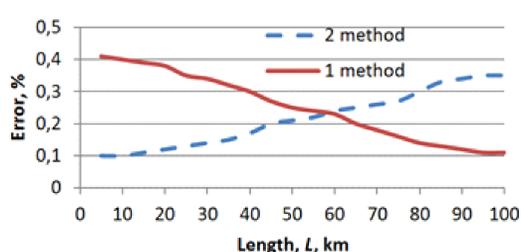
i	$l_i = i \cdot \Delta l, m$	$I_i^{(3)}$ kA	$I_i^{(2)}$ kA	$I_i^{(1)}$ kA
1	$l_1 = \Delta l$	$I_1^{(3)}$	$I_1^{(2)}$	$I_1^{(1)}$
2	$l_2 = 2 \cdot \Delta l$	$I_2^{(3)}$	$I_2^{(2)}$	$I_2^{(1)}$
...
$i-1$	$l_{i-1} = (i-1) \cdot \Delta l$	$I_{i-1}^{(3)}$	$I_{i-1}^{(2)}$	$I_{i-1}^{(1)}$
i	$l_i = i \cdot \Delta l$	$I_i^{(3)}$	$I_i^{(2)}$	$I_i^{(1)}$
$i+1$	$l_{i+1} = (i+1) \cdot \Delta l$	$I_{i+1}^{(3)}$	$I_{i+1}^{(2)}$	$I_{i+1}^{(1)}$
...
n	$l_n = n \cdot \Delta l$	$I_n^{(3)}$	$I_n^{(2)}$	$I_n^{(1)}$

i - number of calculated point of a possible short circuit on the interval;
 Δl - distance from the beginning of line to the fault location;
 n - the total number of points to be calculated;
 Δl - sampling step (in meters).



1 - theoretical dependence of $I(l)$;
2 - linear approximation of $I(l)$;
 l_i, l_{i+1} - beginning and end of the interval at the first stage of determining the place of a short circuit;
 $\Delta \Delta l$ - interval of second stage of determining;
 I_{sc} - value of short-circuit current;
 I_{i+1}, I_i - calculated values of short-circuit current at calculated points and, respectively;
 $I_{i+1}^{(3)}$ - value of short-circuit current obtained from

Comparison of the accuracy of determining the fault location



Conclusions

Two methods are suggested to on-line determine the short circuit point in transmission lines. In the first method the short circuit point is determined based on the application of time factors associated with the final velocity of power transmission (electrical signal) along the transmission line and by the moments of response arrival at the line beginning and end.

The second method is based on preliminary theoretical calculation of short-circuit currents at different line cutsets and on determination of the initial effective values of short-circuit currents. The method applies the matrices of theoretical calculations of short-circuit currents. The measured values of short-circuit currents are compared with the rated currents. The coordinates of the short circuit location are exactly determined at two stages: approximate and accurate.

It is suggested that the moments of time and information transmission to the processing center should be determined with the help of PMU, up-to-date tools of digital communication and UT system.

We propose that the structural schemes of auxiliary devices, which are not foreseen in PMU, should be added to the available tools.