A New Method of Improving TransformerRestricted Earth Fault Protection

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Abstract: Due to requirement of more and more energy in the world and increased threat of global warming companies coming up with new Ideas to harness energy by renewal source like Solar system, windmill etc. Hence need of Zero energy meter or power quality meter has increased. Monitoring and networking of power connection for smart grid is the primary motivation for installing a power quality metre in a substation. According to the results of this study, using synchronized data from medium-voltage/low-voltage transformers with compensated neutral distribution collected on the low-voltage side, it is possible to pinpoint the precise location of earth faults. Using voltage drops brought on by the auxiliary resistor's connection, the disclosed method pinpoints the damaged area. Its efficacy is tested by simulating a section of the distribution network in a numerical model.

I. INTRODUCTION

The most common kind of distribution network in the Czech Republic is a resonant earthed network, the purpose of which is to limit the amount of current flowing through the network in the event of an earth fault (EF). An affected network may continue to function with little risk of power outage or dangerously high voltages since the residual current level is low. In distribution networks, the independency of fault current magnitude from fault site and the low fault level make it difficult to locate EFs quickly and accurately. As a direct consequence of this, a number of methods for locating EFs in resonant earthed systems have been developed.

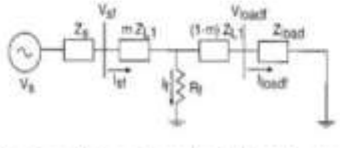


Figure 1. Simple schema of the network model used for fault distance calculation

On the basis of their underlying principles, all existing EF detection systems may be classified as either active or passive. To locate the EF precisely, active techniques inject a tailored active signal into the distribution network and follow it to the fault zone. These active methods have one major drawback: they need an active source to provide the identifying signal. Measuring voltages and currents inside the compromised network is one of the passive approaches outlined. This section will focus on enumerating passive methods since they form the bulk of the most often encountered class.

In Czech medium voltage (MV) networks, the system operator's serial disconnection of the affected line is one of the most important and useful methods for identifying the problematic section of the line. Once the faulty area has been identified, a technical team may be sent to investigate further. The downsides of this procedure include the amount of time required and the operational difficulties. In many circumstances, it also necessitates several power outages.

When the faulty feeder is connected to a loop, zero-sequence (residual) current may be redistributed to both feeders to help pinpoint the EF's location. However, in the non-urban regions served by the distribution network, this connection is not always possible. Inhomogeneity of MV lines is another problem that is challenging to resolve because of the wide variety of line types and short lengths of each kind

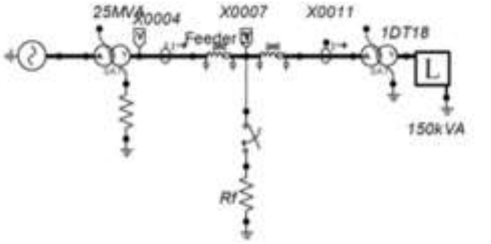


Figure 3. Schematic diagram of simple power network modeled in ATPDraw

Fault location algorithm: As illustrated in Figure 4, an analogous circuit is used to design a method for estimating the location of a problem (1).

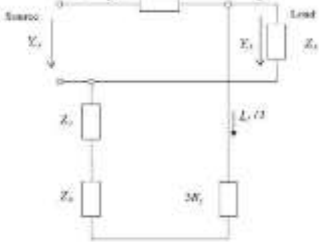


Figure 4. Traditional fault localization rategies use the radially symmetrical component model of networks.

$$\underline{V_f}\ R_f$$

Fault _ Location

Table 1. Fault Resistance Data Sample

Actual Value (Ω)	Calculated Value (Ω)
20	22.552
40	44.399
60	63.082
80	83.049

$$\frac{I_f}{\frac{1}{3}Z_0 Z_1 Z_2 \frac{I_L}{I_f} Z_1} \quad (1)$$

The fault resistance is Rf, the line's zero, positive, and negative sequence impedances, as well as the fault phase voltage (Vf), fault current (If), and load current (IL) in kilometers. [13] Provides the value of fault resistance and may be determined by (2). Fault resistance (Rf), fault phase voltage (Vs), and defect current (Is) are all quantities that indicate the presence of a fault.

$$R_f \frac{V_s}{I_s} \quad (2)$$

Correction factor: The error in fault resistance and fault localization should be reduced; equations are created using linear and parabolic regression.

There is an application tool in MATLAB called curve fitting (found in the 'APPS' area) that may help you get a statistical response. Least-squares methods are used to determine the slope and y-intercept of the straight-line equation, respectively.

$$y = mx + b \quad (3)$$

Data from Table 1 is used to create the line fit plot seen in Figure 5. A straight line may be obtained by plotting the actual value against the predicted value. This research makes use of the derived linear equation as a kind of correction. The mistake in pinpointing earth faults is reduced with its help. Data similar to those shown in Table 1 were utilized to build the equation used to find the minimum fault resistance error. While Figure 5 is a fitted line plot, its results may be found summarized in Table 2.

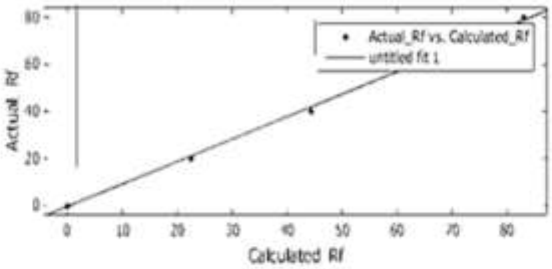


Figure 5. Line fit plot

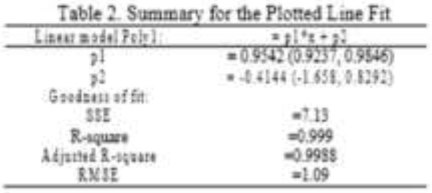


Table 2. Summary for the Plotted Line Fit

Linear model Poly1:	= p1*x + p2
p1	= 0.9542 (0.9237, 0.9846)
p2	= -0.4144 (-1.658, 0.8292)
Goodness of fit:	
SSE	=7.13
R-square	=0.999
Adjusted R-square	=0.9988
RMSE	=1.09

RMSE, SSE

k 1 n 1 (6)

You can calculate the error sum of squares (SSE) by referring to Table 2 in [14]. 4). the total sum of squares (SST), the sum of squares (SSTR), and the sum of squares (SSBL) are all examples of measures of group similarity.

SSE = SST –SSTR – SSBL (4)

R-squared is a statistical measure of the data's proximity to the fitted regression line. A straightforward method for determining how much of the response variable's variance a linear model explains and how well it fits the data is R squared. Or [15]:
R-squared = SSTR / SST (5)

The value of R2 cannot exceed 100%; it is always a positive number. A value of 0% implies that absolutely no variance in the response data around the mean is explained by the model. While a score of 100% means that the model perfectly captures the scatter in the response data around the mean, this is seldom the case.

The root-mean-squared error (RMSE) is a metric for gauging how far off the statistical model's predictions are from the actual system's measurements [14].

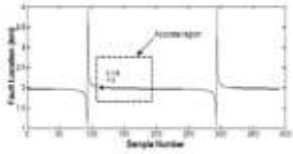


Figure 6. Fault distance estimation for fault at 2km from the measuring point

The following is an illustration of a statistical solution for fault resistance below 100:

New, $\_R_f = (R_f * 0.9542) - 0.4144$ (7)

II. RESULTS AND ANALYSIS

The algorithm's accuracy and the circuit's applicability have both been tested in a variety of ways.

Sampling frequency

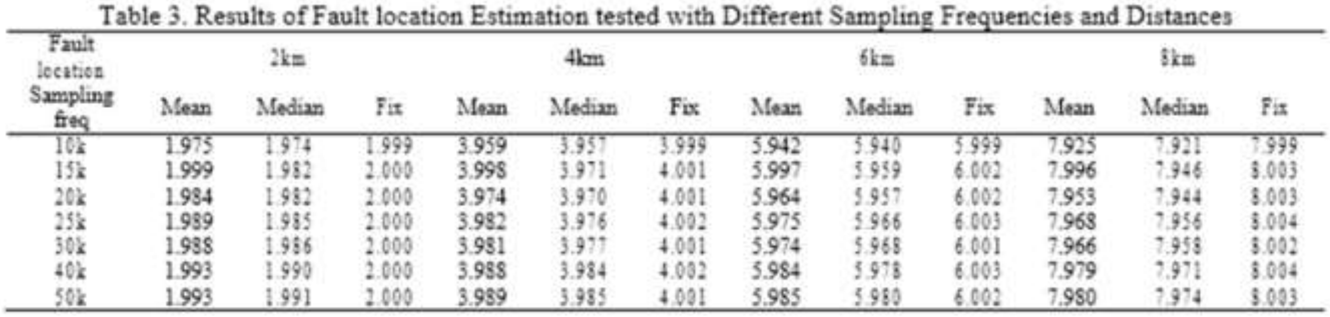
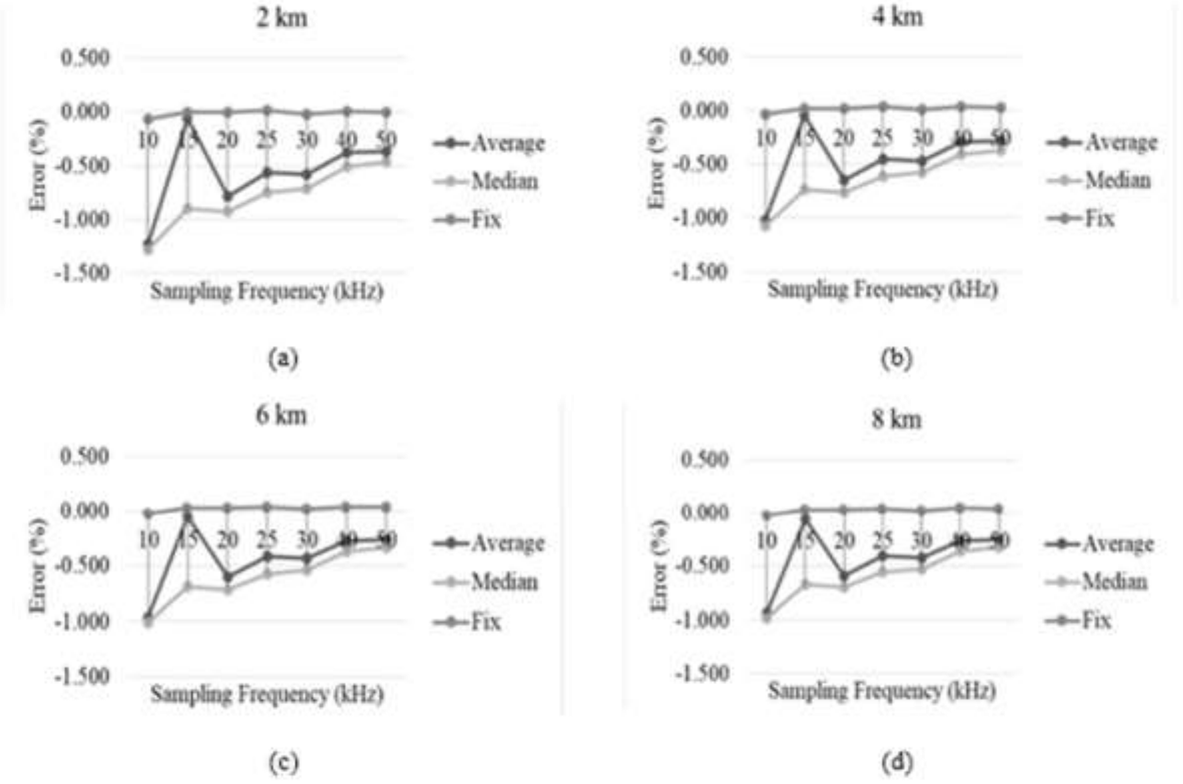


Table 3. Results of Fault location Estimation tested with Different Sampling Frequencies and Distances

Fault location	2km			4km			6km			8km		
Sampling freq	Mean	Median	Fix	Mean	Median	Fix	Mean	Median	Fix	Mean	Median	Fix
10k	1.975	1.974	1.999	3.959	3.957	3.999	5.942	5.940	5.999	7.925	7.921	7.999
15k	1.999	1.982	2.000	3.998	3.971	4.001	5.997	5.959	6.002	7.996	7.946	8.003
20k	1.984	1.982	2.000	3.974	3.970	4.001	5.964	5.957	6.002	7.953	7.944	8.003
25k	1.989	1.985	2.000	3.982	3.976	4.002	5.975	5.966	6.003	7.968	7.956	8.004
30k	1.988	1.986	2.000	3.981	3.977	4.001	5.974	5.968	6.001	7.966	7.958	8.002
40k	1.993	1.990	2.000	3.988	3.984	4.002	5.984	5.978	6.003	7.979	7.971	8.004
50k	1.993	1.991	2.000	3.989	3.985	4.001	5.985	5.980	6.002	7.980	7.974	8.003



(a) (b)

(c) (d)

Fault resistance

The fault resistance, Rf, is another component that influences the algorithm's accuracy. The simulation uses the real value of fault resistance to zero in on the problem. Table 5 displays the results of fault localization tests conducted on a range of fault resistances. The algorithm's correctness is acknowledged based on the findings in Table 5.

Table 5. Multiple Rf values were tested at an inception angle of 900 degrees and a load of 50kVA to see how well the fault location algorithm performed.

Estimated Fault Resistance

Table 6. Result of fault resistance estimated

Actual Ω	EstimatedΩ	Error Ω
20	22.550	2.550
40	44.398	4.398
50	53.088	3.088
70	73.054	3.054
180	175.876	-4.124
400	356.096	-43.906
500	512.088	12.018
600	568.098	-31.902
800	811.646	11.646

An evaluation of fault resistance using equation has already been described (2). As can be seen in Table 6, the predicted fault resistance has been accounted for. Anticipated fault resistance is shown to deviate only little from the true value, however, to have a major effect on the expected fault location.

Table 7. Result of fault resistance estimated with Correction Factor

Actual Ω	EstimatedΩ	Error Ω
20	21.550	1.550
40	41.398	1.398
50	49.088	-0.912
70	68.054	-1.946
180	201.876	-21.876
400	388.096	-11.904
500	492.088	-7.912
600	588.098	-11.902
800	818.646	18.646

It seems the error will be quite large if the fault resistance value is larger than 100. This has a significant influence on the fault estimation process. A statistical approach is constructed using 2.2 to obtain the best accurate estimation value.

Distance (km)	Rf	Estimated (km)	Error (km)
4	0	4.010	0.010
	20	4.015	0.015
	45	4.018	0.018
	95	4.016	0.016
10	0	10.014	0.026
	20	10.025	0.028
	45	10.030	0.032
	100	10.020	0.028
16	0	16.025	0.029
	20	16.030	0.040
	45	16.044	0.044
	100	16.042	0.040

If the fault resistance's predicted value is less than 100, the data in Table 6 will be used to determine where the fault is. (8). However, (9) will be used if the expected fault resistance is 100 or above. Table 7 displays the calculated fault resistance with correction factor. Table 7 displayed the revised estimated New Rf in (8) and (9)

New Rf= (Rf*0.9567) + 43.85

If Table 7 is to be believed, the gap in fault resistance is closing. Inaccuracies range from- 0.222Ω to 28.423Ω.

Without fault resistance

If the failure resistance in (1) is minimal, the algorithm is also tested. This test was conducted with a 50kVA load and a fault resistance of 0. Table 8 displays the calculated fault distance under the assumption that the fault resistance is small. The calculated distance between earth faults and actual faults is quite close.

III. CONCLUSION

Analysing the voltage and current of the faulty signal might help pinpoint the location of the fault. The method may be given a little error impact by the sampling frequency (fs), fault resistance, and abruptly. Several simulations may be done to establish which sampling frequency (fs) is most stable at certain distances, and this information can be used to guide the decision-making process. The accuracy of estimated distances has been studied in a number of different ways to see whether it improves or worsens with time. It has been shown that the distance algorithm's precision changes depending on the value of projected fault resistance. A correction approach is required to reduce the inaccuracy in the projected earth fault distance. The findings suggest that an earth fault could be found using the distance algorithm and correction method

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