Earth Fault Location based on Evaluation of Voltage Sag at Secondary Side of Medium Voltage/Low Voltage Transformers

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Abstract - Due to requirement of more and more energy in the world and increased threat of global worming 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. The reason for installation of power quality meter specially in substation is monitoring and networking of power connection for smart grid. This contribution proposes the possibility of earth fault localization using synchronized data recorded on the low-voltage side of medium voltage/low voltage transformers in compensated neutral distribution. The disclosed approach locates the damaged region by utilizing voltage sags caused by connecting the auxiliary resistor. The suggested technique is validated using a numerical model that depicts a portion of the distribution network.

I. INTRODUCTION

The most prevalent form of Czech distribution network is the resonant earthed network, whose goal is to compensate for network capacitive current during an earth fault (EF) and to restrict the EF current level. Because the residual current level is relatively low, an impacted network can be operated without interruption of power supply and the possibility of hazard voltages occurring. However, due to the low fault level and the independence of fault current magnitude from fault place, quick and accurate EF location in distribution networks is a very difficult task. This is why several approaches for EF localization in resonant earthed systems have been offered.

All known methods for EF location may be divided into active and passive approaches based on their principles. Active techniques employ a specialized active signal that is introduced into the distribution system for EF location by signal tracking to the fault spot. The fundamental drawback of these active approaches is the requirement for an active source to generate the characteristic signal. The other category of passive approaches discussed is based on evaluating voltages and currents inside the affected network. Because this is the most common group, this chapter will concentrate on listing passive approaches.

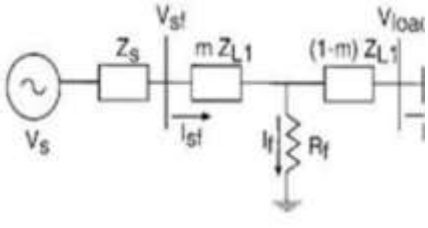


Figure 1. Simple schema of the network model used for

The serial disconnection of the afflicted line by the system operator is one of the most important and practical procedures for delimitation of the problematic segment of the line in Czech medium voltage (MV) networks. This process is used to identify the defective region, after which a technical team is dispatched to locate the particular issue site. The downsides of this procedure include the amount of time required and the operational difficulties. In many circumstances, it also necessitates several power outages.

Another approach for EF localization is based on the redistribution of zero-sequence (residual) current to both feeders when the defective feeder is linked to a loop. However, this link cannot always be realised in the distribution network's extra-urban areas. The second issue is inhomogeneity of MV lines, which is difficult to solve owing to the large number of various types and small sections of line.

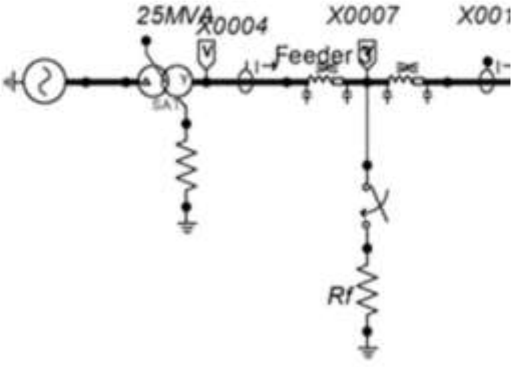


Figure 3. Schematic diagram of simple power networ

II. FAULT LOCATION ALGORITHM

According to based on the equivalent circuit shown in Figure 4, fault location estimation (1) is developed.

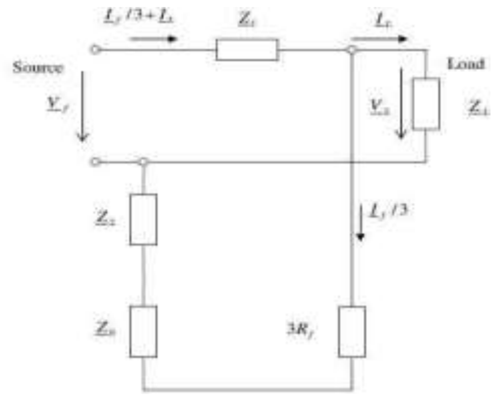


Figure 4: The symmetrical component model of a radially operated network for the conventional fault location method

$$Fault\_Location \quad \frac{\frac{V_f}{I_f} R_f}{\frac{1}{3} \; Z_0 \; Z_1 \; Z_2 \qquad \frac{I_L}{I_f} Z_1} \qquad (1)$$

Vf is the fault phase voltage, If is the fault current, IL is the load current, Z0, Z1, and Z2 are the zero-, positive- and negative- sequence impedances of the line per km, and Rf is the fault resistance. In [13], a fault resistance value can be determined by using (2). Rf is the fault resistance, Vs is the fault phase voltage and Is is the fault current.

$$R_f \quad \frac{V_s}{I_s}$$

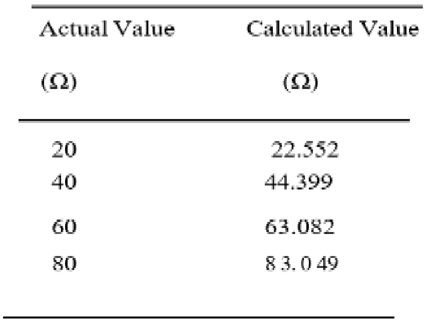
A. Correction factor

To minimize the error of fault location and fault resistance, a linear and parabolic regression is used to generate equations. From curve fitting application tool in MATLAB, under ‘APPS’ section, a statistical solution can be developed. By using method of least squares, the coefficients m (slope) and b (y-intercept) of the straight line equation can be formed.

$$y= mx + b$$

Figure 5 shows the line fit plot based on Table 1 data. The straight line is plot by using the actual value versus the calculated value. The straight line equation formed is used as correction factor in this work. It is used to minimize the earth fault location error. Table 1 shows an example data used to develop equation to minimize the fault resistance error. While Table 2 shows the summary of the fitted line plot in Figure 5.

Table 1. Sample Data of Fault Resistance



Actual Value (Ω)	Calculated Value (Ω)
20	22.552
40	44.399
60	63.082
80	8 3.0 49

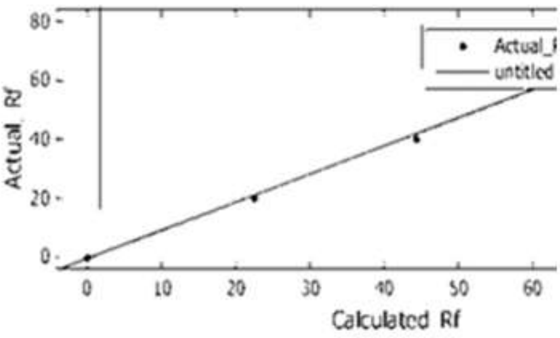
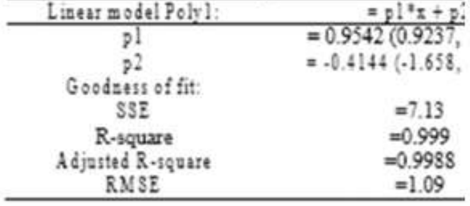


Figure 5. Line fit plot

Table 2. Summary for the Plotted Li



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

By referring to Table 2, from [14] error sum of squares (SSE) can be calculated by performing (4). Where SST is the total sum of squares, SSTR is the treatments sum of squares, while SSBL is the block sum of the squares.

$$SSE = SST – SSTR – SSBL \qquad (4)$$

R-squared is a statistical measure of how close the data are to the fitted regression line. The definition of R-squared is fairly Forward .it is the percentage of the response variable Variation that is explained by a linear model or [15]:

$$R\text{-squared} = SSTR / SST$$

R-squared is always between 0 and 100% indicates that the model explains none of the variability of the response data around its mean. While 100% indicates that the model explains all the variability of the response data around its mean.

The RMSE a way of estimating the difference between the values predicted by a statistical model and the measured values from the actual system [14].

$$RMSE \quad \frac{SSE}{k \; 1 \quad n \; 1}$$

The statistical solution for fault resistance less than 100Ω is given as:

New_Rf = (Rf*0.9542) - 0.4144

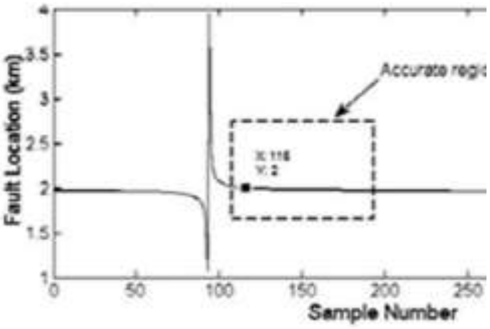


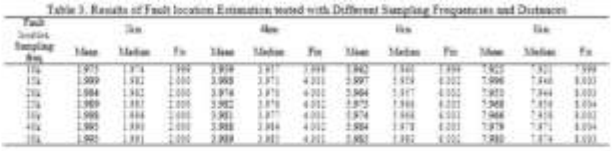
Figure 6. Fault distance estimation for fault at 2l

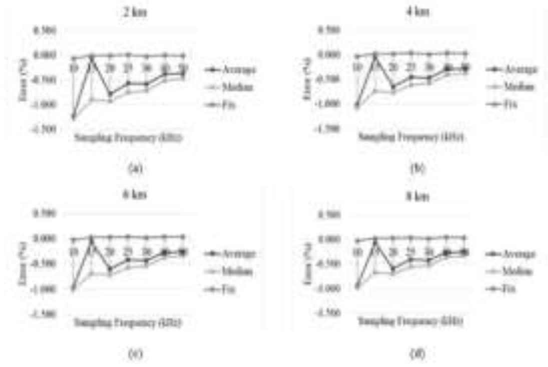
III. RESULTS AND ANALYSIS

Several tests have been conducted to test the accuracy and suitability of the algorithm to the circuit.

Sampling frequency

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





Fault resistance

The fault resistance, Rf, is another component that influences the algorithm's accuracy. The real value of fault resistance is used in this simulation to locate the defect. Table 5 displays the results of fault localization tests with various fault resistance values. The algorithm's correctness is acknowledged based on the findings in Table 5.

Table 5. Fault Location Algorithm was evaluated with various Rf values at 900 Inception angle and 50kVA load.

Distance (km)	Rf (Ohm)	Estimated (km)	Error (km)
4	0	4.010	0.010
	25	4.017	0.017
	50	4.020	0.020
	100	4.018	0.018
10	0	10.028	0.028
	25	10.030	0.030
	50	10.033	0.033
	100	10.029	0.029
16	0	16.030	0.030
	25	16.043	0.043
	50	16.046	0.046
	100	16.042	0.041

Estimated Fault Resistance

As previously stated, the fault resistance may be evaluated using equation (2). The calculated fault resistance is shown in Table 6. Demonstrates that projected fault resistance has moderate deviations from the real value, but has a large influence on predicted fault location. It appears that if the fault resistance value is greater than 100, the mistake will be enormous. 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.

Table 6. Result of fault resistence estimated

Actual Ω	Estimated Ω	Error (Ω)
20	22.552	2.552
40	44.399	4.399
60	63.082	3.082
80	83.049	3.049
200	185.866	-14.135
400	358.038	-41.962
600	551.612	-48.388
800	811.636	11.636

Based on the data obtained in Table 6, if the predicted value of fault resistance is less than 100, (8) will be utilised to determine the fault site. However, if the anticipated fault resistance is equal to or more than 100, (9) will be employed. Table 7 displays the calculated fault resistance with correction factor. Table 7 displayed the revised estimated New Rf in (8) and (9)

$$New\_Rf = (Rf*0.9567) + 43.85$$

Table 7. Result of Fault Resistance Estimated with Correction Factor

Actual (Ω)	Estimated (Ω)	Error (Ω)
20	21.105	1.105
40	41.951	1.951
60	59.778	-0.222
80	78.831	-1.169
200	221.668	21.668
400	386.385	-13.615
600	571.577	-28.423
800	820.342	20.342

Based on results in Table 7, the difference of fault resistance decreases. The smallest error is - 0.222Ω and the largest is - 28.423Ω.

Without fault resistance

If the failure resistance in (1) is minimal, the algorithm is also tested. The load was set to 50kVA for this test, and the fault resistance was set to 0. Table 8 illustrates the predicted fault distance when the fault resistance is insignificant. The projected earth fault distance is nearly identical to the real fault distance.

Table 8. Results of Estimated earth Fault Distance Without Fault Re

Actual (km)	Estimated (km)	Error (km)
2	2.005	0.005
3.7	3.709	0.009
4	4.010	0.010
5	5.013	0.013
6	6.015	0.015
7.2	7.218	0.018
8	8.020	0.020
9.6	9.624	0.024
10	10.025	0.024
12	12.029	0.029
12.5	12.531	0.031
14	14.035	0.034
15	15.036	0.036
16	16.038	0.038
17.2	17.241	0.041
18	18.044	0.044
19.4	19.447	0.047
20	20.049	0.049

IV. CONCLUSION

The voltage and current faulty signal can be used to establish fault localization. The sampling frequency (fs), fault resistance, and suddenly can provide the algorithm a little error effect. Running multiple simulations to discover which fs is the most stable when tested at various distances can be used to decide sampling frequency. Several tests have been performed to determine if the inaccuracy of estimated distance rises or decreases. It has been demonstrated that the value of predicted fault resistance has an effect on the accuracy of the distance algorithm. This implies that a corrective method is required to reduce the predicted earth fault distance inaccuracy. Overall, the findings suggest that the distance algorithm and correction approach may be utilized to find the position of an earth fault.

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