Location of Single Phase to Ground Faults in Distribution Networks based on Synchronous Transients

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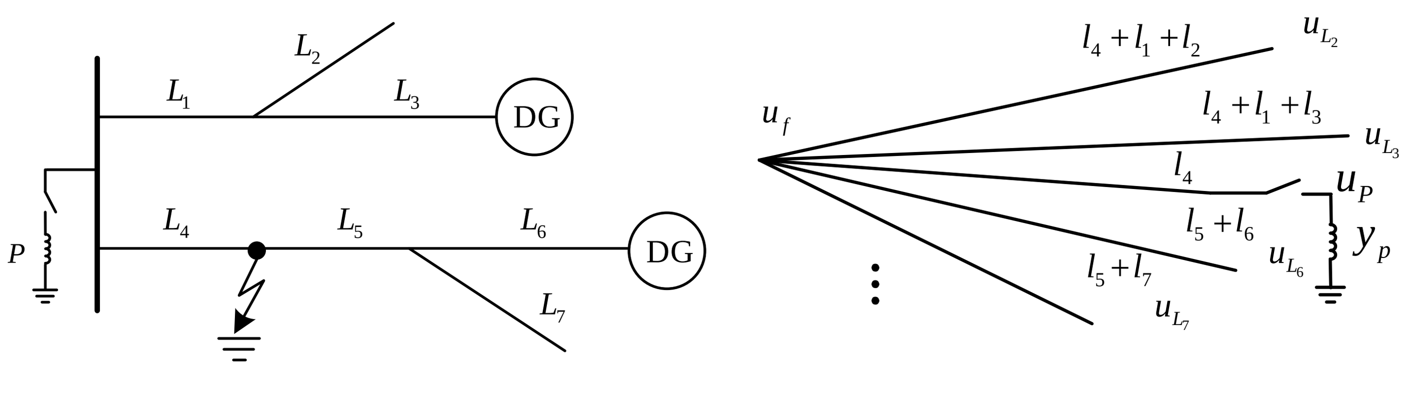
Introduction

Single phase to ground faults accounts for up to 80 percent of all the faults in distribution networks, and most of them are transient faults. Unfortunately, it is difficult to locate these faults effectively and precisely, especially for the neutral non-effectively grounded medium-voltage distribution networks because the fault signals are weak and heavily contaminated by noises. It will deteriorate the insulation of the equipment, cause short circuit faults and threaten the safety of people or property. Therefore, efficient and accurate fault identification and location are important for electric utilities.

Modelling

Considering the phase-frequency characteristics of the network, a general distribution network can be regarded as 2n+1 lines connected in parallel, n is the number of the T node with branches.



(a) The topology of the zero-sequence network **(b) The equivalent topology of the zero-sequence network**

The frequency range of the SFB for neutral non-effectively grounded system is $2\pi f_B < \omega < \omega_k$, ω_k is determined by the longest line in the equivalent network, which can be calculated via $\omega_k = \pi / 2l\sqrt{L_0 C_0}$. The relation of the zero-sequence current between faulty line section and healthy line sections within the frequency range of the SFB can be represented as

$$\begin{cases} \left| \dot{i}_{S,F}^{(SFB)} \right| = \sum\limits_{j \in M, j \neq F} \left| \dot{i}_{S,j}^{(SFB)} \right| \\ \dot{i}_{S,F}^{(SFB)} = -\sum\limits_{j \in M, j \neq F} \dot{i}_{S,j}^{(SFB)} \end{cases}, \quad j = 1, 2, \ldots M$$

Method

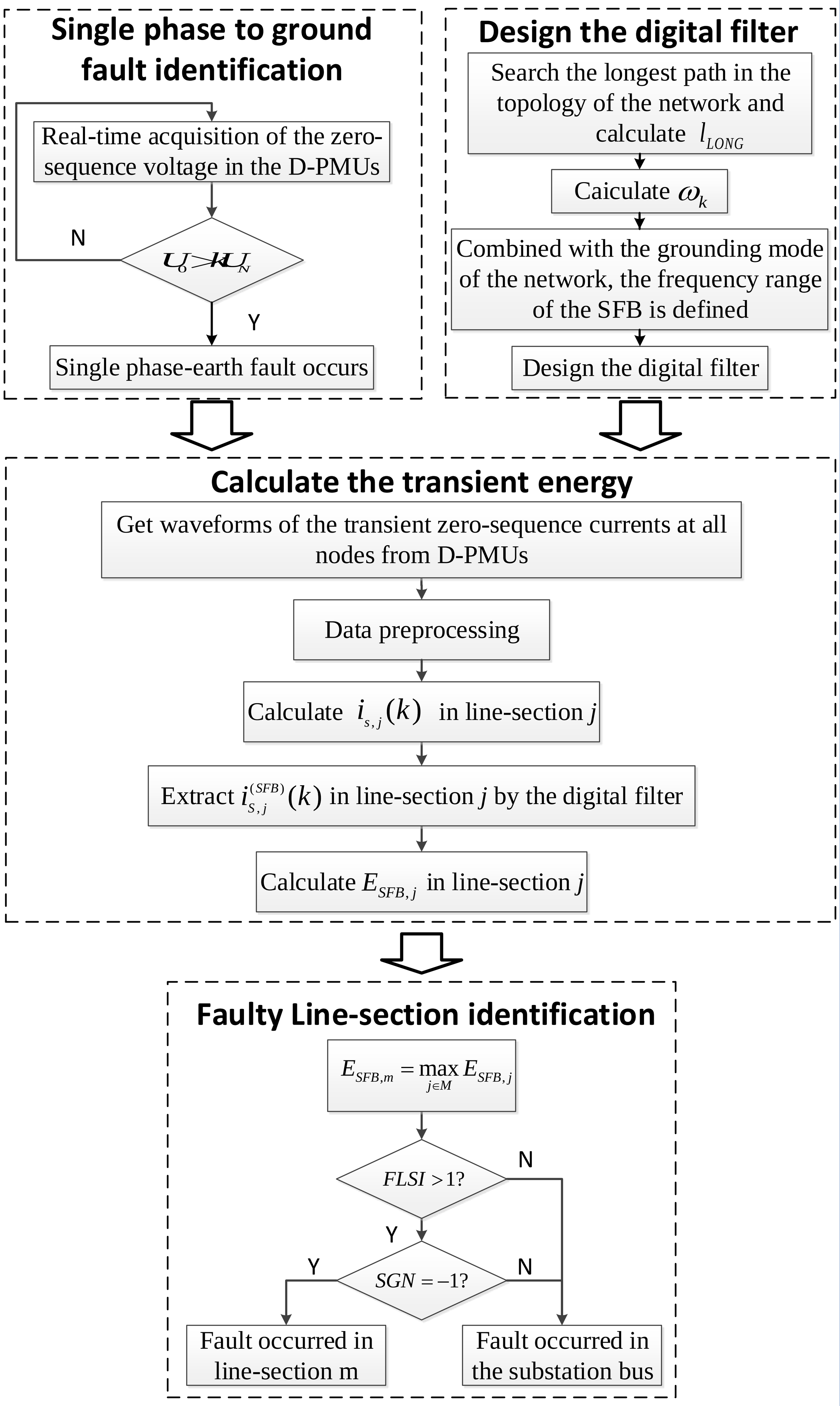
The flow chart of the faulty line section location scheme is shown in the figure, which includes the following steps:

1)Determination of the SFB.

2)Single phase to ground fault detection.

3)Transient energy calculation.

4) Faulty line section identification.



Flow chart of the proposed fault location scheme

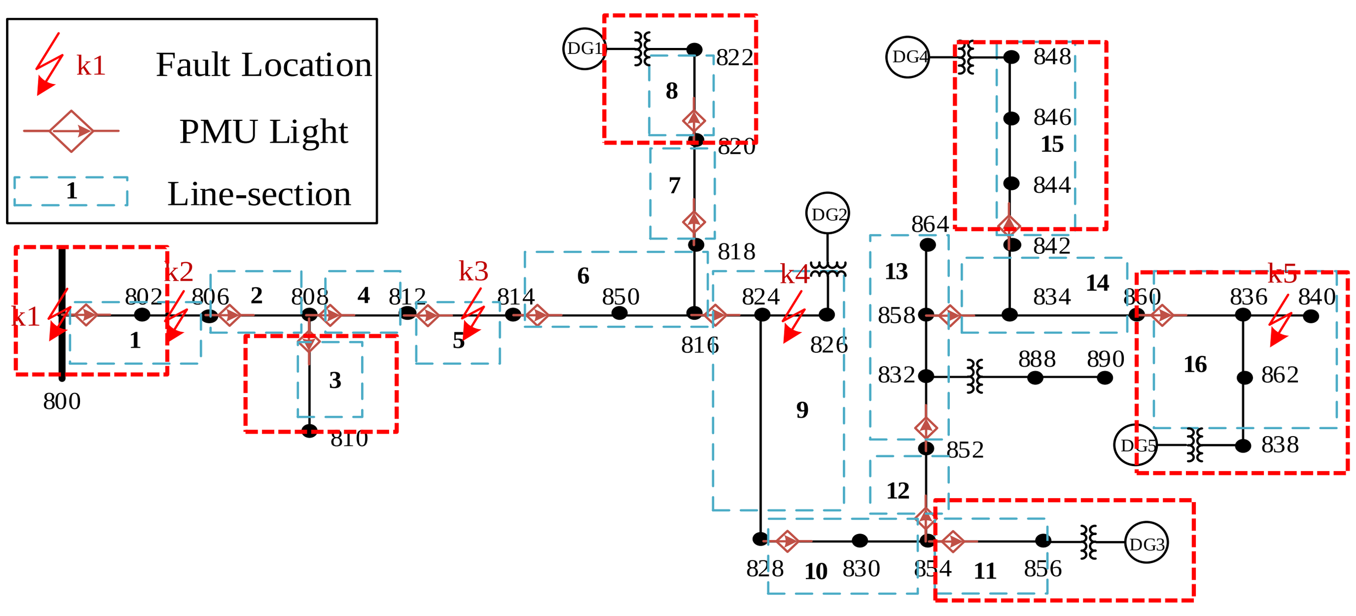
Comparisons of other methods

Method A: It uses the amplitude and phase of the zero-sequence admittance of the line section to identify the faulty line section.

(a) Accuracy Comparison for Different Location and F_R			
Faulty Line section	$F_R(\Omega)$	Accuracy of Method A	Accuracy of the proposed Method
5	0	100%	100%
	500	100%	100%
16	0	100%	100%
	500	100%	100%

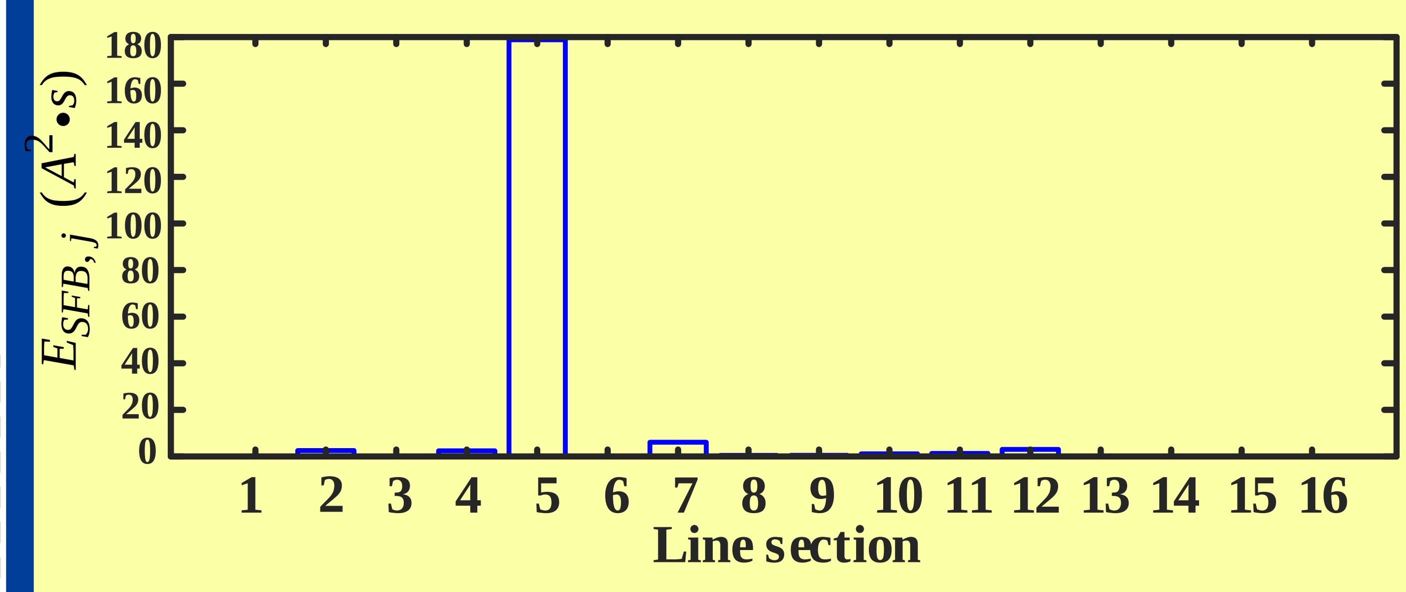
(b) Accuracy Comparison for Different Location and C_p			
Faulty Line section	C_p(%)	Accuracy of Method A	Accuracy of the proposed Method
5	5	97.1%	100%
	8	97.2%	100%
16	5	66.1%	100%
	8	64.9%	100%

Method B: It uses the corrected correlation coefficient of the transient zero-sequence currents to identify the faulty line section, of which the threshold is 0.5. Method B cannot work if a fault occurs in the red box in this figure. Compared with method B, the proposed method is suitable for more fault scenarios, and needs less measuring equipment.



Results

Faulty Line Section	F_0 (°)	$F_R(\Omega)$	SNR (dB)	FLSI	SGN	Location Results
5	0	0	5	9.26	-1	5
	0	0	-1	9.15	-1	5
	0	50	5	8.92	-1	5
	0	500	5	9.05	-1	5
	0	500	-1	9.31	-1	5
	60	0	5	8.73	-1	5
	90	0	5	9.17	-1	5



Both the simulation and on-field fault experiment results show that the proposed method is not affected by strong background noise, fault locations, load types, grounding resistances, inception angles, locations and power supply of DGs. And the method is also robust to line parameters and outliers.

Detailed detection results can be seen in the paper.

Conclusions

This paper proposes an integrated technique based on the D-PMUs to identify the faulty line section for neutral non-effectively grounded MV networks. The paper investigates the determination of the SFB within which the transient energy of the monitored signal is far greater than the energy of the noise, the transient energy of faulty line section is proven to be greater than the energy of the healthy line sections. A method based on a combined criterion is proposed, and the implementation of the scheme is illustrated. And the method is also robust to line parameters and outliers. Three methods are compared with the proposed method to prove that the proposed method is more accurate and applicable.

References

H. Zhang, Z. Jin and V. Terzija, "An Adaptive Decomposition Scheme for Wideband Signals of Power Systems Based on the Modified Robust Regression Smoothing and Chebyshev-II IIR Filter Bank," IEEE Trans. Power Delivery, vol. 34, no. 1, pp. 220-230, Feb. 2019.