High Impedance Arc Fault Detection Based on the Harmonic Randomness and Waveform Distortion in the Distribution System

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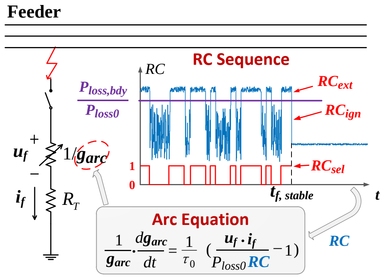
Introduction

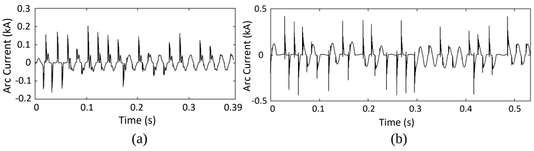
High impedance arc faults (HIAFs) happens in the MV distribution when the energized conductor poorly contacts the high-impedance grounding surfaces with continuous luminosity and electricity discharge, probably resulting in damages to devices and human security. Implementation of the intermittent arcing process is neglected for the present HIAF models. Difficulties still exist in providing reliable detection criteria when features of HIAFs vary under different situations, and meanwhile ensure the security that won't send tripping signals when normal (non-fault) events take place.

Modelling

The implementations of randomness and intermittence during the unstable arcing period are realized by adding the random coefficient RC to the Mayr arc model, defined by three variables RC_{sel}, RC_{ign} and RC_{ext}.



Schematic diagram of the HIAF model

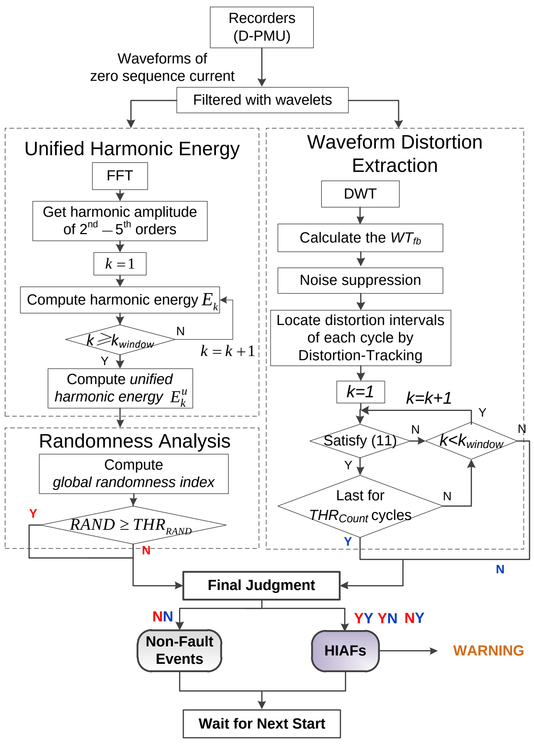


Comparison between the field (a) and simulated (b) waveforms

Detection Method

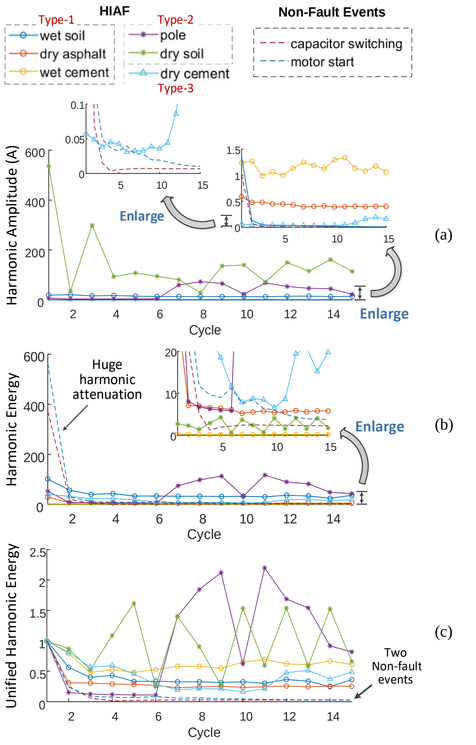
Diverse types of HIAFs and their performances make it challengeable for an algorithm to always keep high detection reliability with just single feature description and identification method.

The integrated algorithm consists of two branches. Firstly, the variations of HIAFs during unstable arcing period are identified with the unified harmonic energy and global randomness index, which can unify the scales of harmonic content in different fault situations and enlarge the disparities from non-fault conditions. Then, the waveform distortions of HIAFs during the stable arcing period are identified with discrete wavelet transform to ex-tract the detailed distribution characteristics.



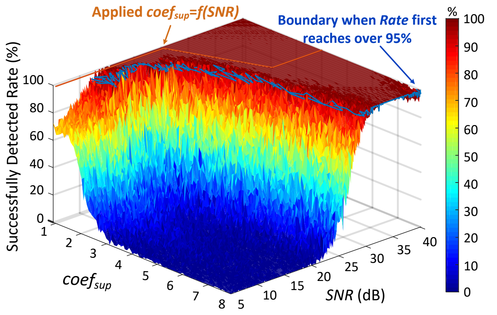
Schematic diagram of the HIAF model

Comparisons of different harmonic definitions: (a) defined with harmonic amplitudes, (b) defined with harmonic energies, (c) defined with unified harmonic energies



Non-fault events can be easier distinguished if using the unified harmonic energy for their dramatic harmonic attenuation.

Standard to apply the *noise suppression* when extract distortion features with DWT



369 simulated Type-1 HIAFs with R_T from 1Ω to 3kΩ, which are all assumed with stable arcing periods.

f(SNR) is suggested to keep the successfully detected rate of the total 369 simulated HIAFs over 95% under different noise intensities and suppression coefficients.

Results

Reliability comparisons between different algorithms

	Total	Successfully detected HIAFs				
		Method 1	Method 2	Method 3	Method 3	Ours
Type-1	12	9	11	6	12	11
Type-2A	6	6	4	3	3	6
Type-2B	7	7	0	1	0	7
Type-3	10	5	2	3	5	8
Total	35	27 (77.1%)	17 (48.6%)	13 (37.1%)	20 (57.1%)	**32 (91.4%)**

The comparisons are made with field HIAFs in a 10-kV tested. Totally 35 HIAFs are achieved with three system neutral grounding modes and several fault grounding surfaces. Detailed detection results can be seen in the paper.

Conclusions

The improved arc model can realize the description of randomness and intermittence during the unstable arcing period of HIAFs. With the classification and feature analyses for different HIAFs, an integrated detection algorithm with the combination of two detection branches can ensure the greater reliability and security at the same. The practical application of the proposed algorithm in a D-PMU based system is also introduced.

References

1. D. P. S. Gomes, C. Ozansoy and A. Ulhaq, "High-Sensitivity Vegetation High-Impedance Fault Detection Based on Signal's High-Frequency Contents," *IEEE Trans. Power Del.*, vol. 33, no. 3, pp. 1398-1407, 2018.
2. A. Ghaderi, H.L. Ginn III and H. A. Mohammadpour. "High impedance fault detection: A review." *Elec. Power Syst. Res.*, 143: pp: 376-388, 2017.