An Accurate Approach for Detecting and Classifying the HIF in Distribution Systems

نهج دقيق لتحديد وتصنيف الأخطاء عالية المعاوقة في نظم التوزيع

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ملخص

الأخطاء عالية المعاوقة هي الأخطاء التي يصعب استشعارها بأجهزة الحماية ضد زيادة التيار. هذا البحث يقدم نهج دقيق لتحديد وتصنيف الأخطاء عالية المعاوقة في نظم التوزيع. النهج المقترح يستطيع التعرف على التشوه في موجة التيار الناتج عن القوس الكهربي المصاحب دائما لذلك النوع من الأخطاء. وقد تم استخدام أسلوب DWT لتحليل موجة التيار. وعندها يتم إيجاد المجموع المطلق للمعاملات الناتجة من ذلك التحليل باستخدام MSD خلال دورة واحدة. خطأ الخط الواحد مع الأرض والخطين مع الأرض و الثلاث خطوط مع الأرض تم تحديدهم وتصنيفهم باستخدام ثلاث دوال منطقية.

هذا النهج تم إثبات صحته بإجراء عدة سيناريوهات لعدة أخطاء على نظام قياسي IEEE-13 node. النتائج أثبتت أن هذا النهج يمكنه تحديد وتصنيف الأخطاء عالية المعاوقة بدقة وسهولة.

ABSTRACT

The High Impedance Faults (HIF) are the faults which are difficult to detect by the overcurrent protection relays. In this paper an accurate approach for detecting and classifying the HIF in distribution systems is presented. The proposed approach recognizes the distortion of the current waveforms caused by the arc usually associated with HIF. The Discrete Wavelet Transform (DWT) based pattern recognition is used for extracting the current signals. DWT detects the fault using the absolute sum value of coefficients in Multi-resolution Signal Decomposition (MSD) over one cycle. The single line to ground, the double line to ground, and the three lines to ground faults are classified using three simple logic functions. The proposed approach is verified by applying several fault scenarios on IEEE-13 node test system. The results confirm that the proposed approach can accurately detect and classify HIF in the distribution systems.

Keywords - Fault Detection, Fault Classification, HIF, DWT, Distribution Systems

1. INTRODUCTION

Detection of high impedance faults (HIF) still presents important and unsolved protection problem, especially in distribution networks [1]. This type of fault usually occurs when a conductor touches the branches of a tree having high impedance or when a broken conductor touches the ground. In the case of an over-current relay, the low levels of current associated with HIF are below the sensitivity settings of the relay [2].

In recent years, many researchers represented various techniques in the HIF detection. The application of two Artificial Neural Networks (ANN) based algorithm for HIF detection in multi-grounded medium-voltage (MV) networks is presented in [3], where two signals are used to detect HIF in the system through the power calculation. An intelligent approach for HIF detection in power distribution feeders using Probabilistic Neural Network (PNN) and Forward Neural Network (FNN) is used in [4]. This technique uses the harmonic components of fault currents during HIF as an input to an estimated Kalman Filter. In [5] an approach to protect the radial power system against faulty conditions using fuzzy-logic scheme is introduced. In this approach the signals of both voltage and current are used for detecting the HIF.

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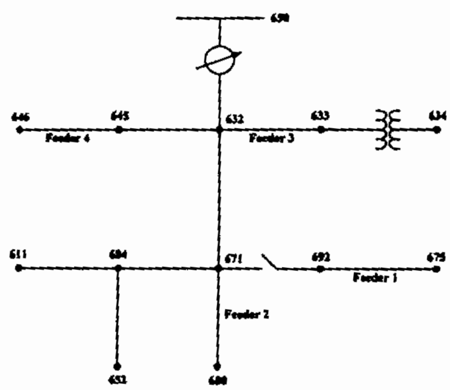


Fig. 3: Modified IEEE 13 Node Test Feeder System

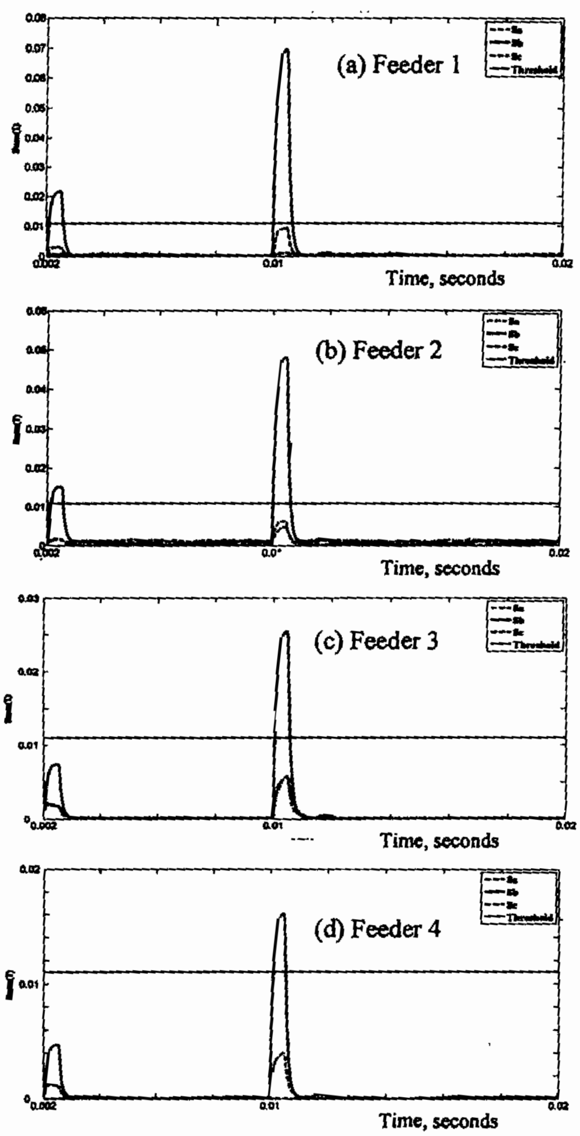
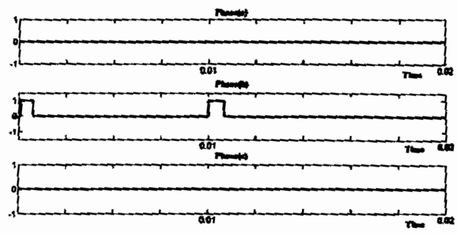
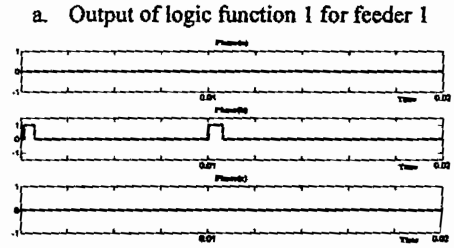


Fig. 4: Absolute Sum of d3 for Different Feeders at SLG Fault at node 675

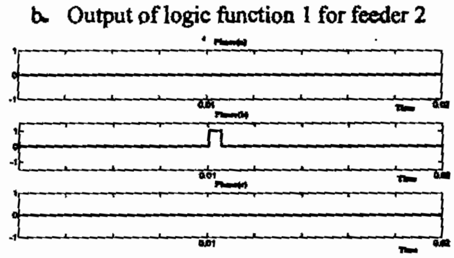
Fig. 5 demonstrates the classification logic output. It is shown that, phase b in all feeders have a logic output of "1" at arc fault instant. In order to find the faulty feeder the detector S_I of the faulty feeder is the highest when a comparison is carried out between the feeders at phase b as shown in Fig. 6. It is noted that S_{Ib} is the highest one. Therefore, the detected fault is SLG at phase b of feeder 1.



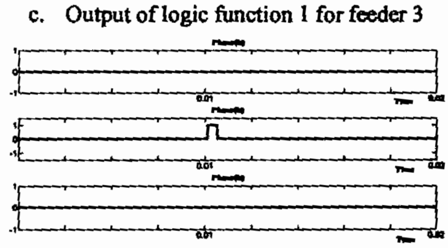
a. Output of logic function 1 for feeder 1



b. Output of logic function 1 for feeder 2



c. Output of logic function 1 for feeder 3



d. Output of logic function 1 for feeder 4

Fig. 5: Output of logic function1 for different feeders

B. Double Line To Ground Fault(DLG)

A DLG fault is implemented at node 675 for phase *b* and phase *c*. The absolute sum of d3 for three feeders (1, 2, 3) is shown in Fig. 7. It is noted that, the S_{Ib} and S_{Ic} are higher than S_{Ia} at all feeders. As expected, the magnitudes of the absolute sum of the two faulted phases (at high frequency currents) are higher than the threshold value.

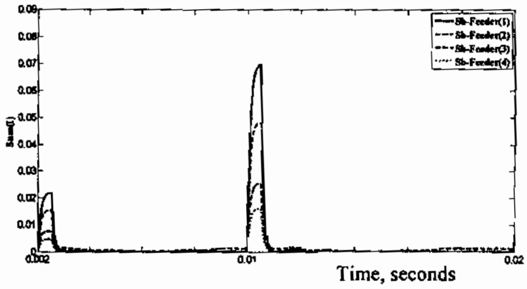


Fig. 6: Comparison between absolute sum of details for phase b at different feeders in SLG fault

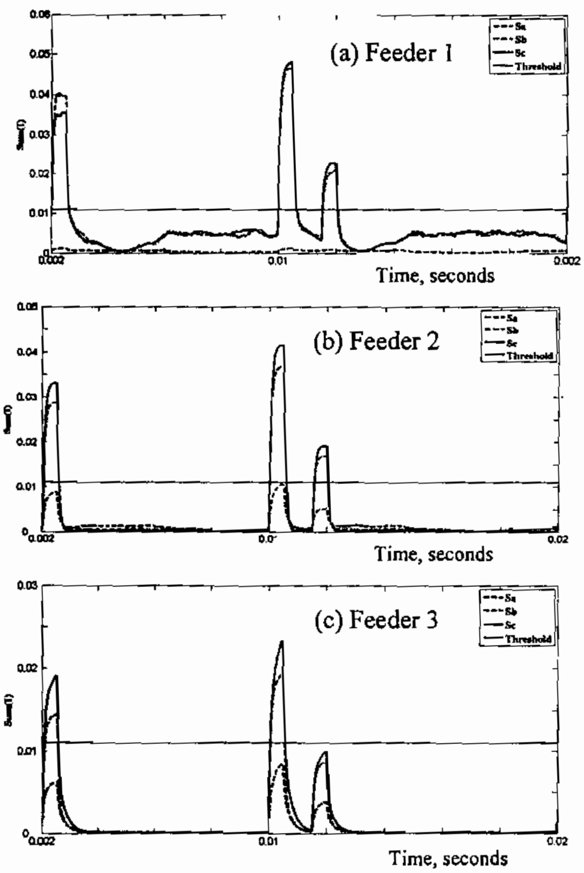
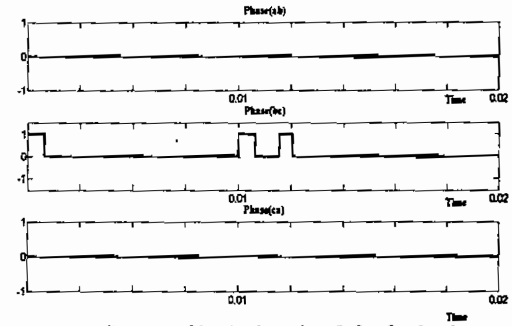
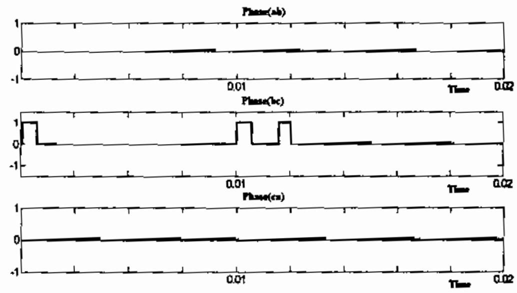


Fig.7: The absolute sum of d3 for different feeders at DLG fault at node 675

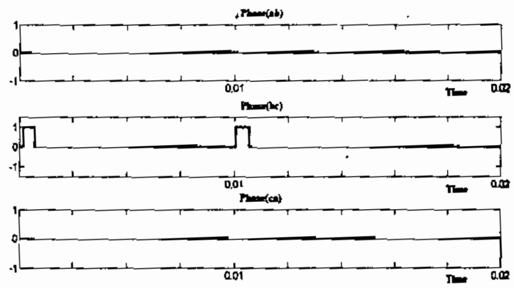
Fig. 8 illustrates the classification logic output. It is shown that, both phase b and phase c at all feeders has a logic output of "1" at instant of arc fault. To find the faulty feeder the detector S_I of the faulty feeder has the highest value of the detector when a comparison is carried out between the feeders at phase *b* and *c*, as shown in Fig. 9. It is shown that, the S_{1b} and S_{1c} have the highest values of the detector. This means that, the fault of DLG fault is detected at phase b and c of feeder 1.



a. Output of logic function 2 for feeder 1



b. Output of logic function 2 for feeder 2



c. Output of logic function 2 for feeder 3

Fig. 8: Output of logic function1 for different feeders

C. Three Phase Fault(3LG)

A 3LG fault is implemented at node 675. The performance of detector S_I for different phases and feeders is shown in Fig. 10. As expected, the magnitudes of all phases (at high frequency currents) are much higher than the threshold value.

Fig. 11 illustrates the classification logic output. It is shown that, three phases in all feeders have a logic output of "1" at instant of arc fault. In order to find the faulty feeder for the detector S_I of the faulty feeder has the highest value compared to the feeders at certain phase as shown in Fig. 12. This means that, the fault is 3LG fault detected at feeder 1.

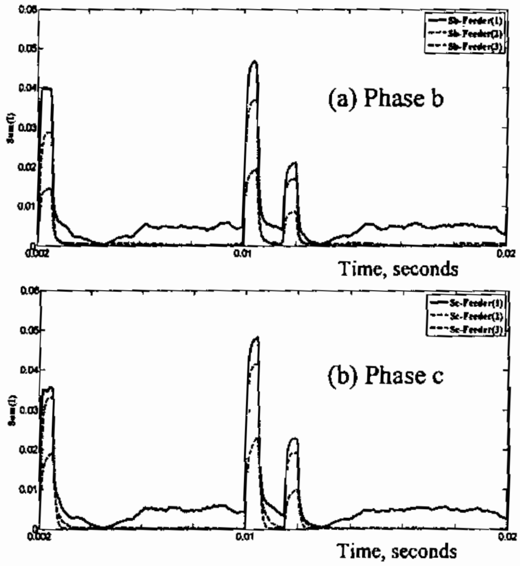


Fig. 9: A Comparison between absolute sum of details for phase b and c at different feeders for DLG fault

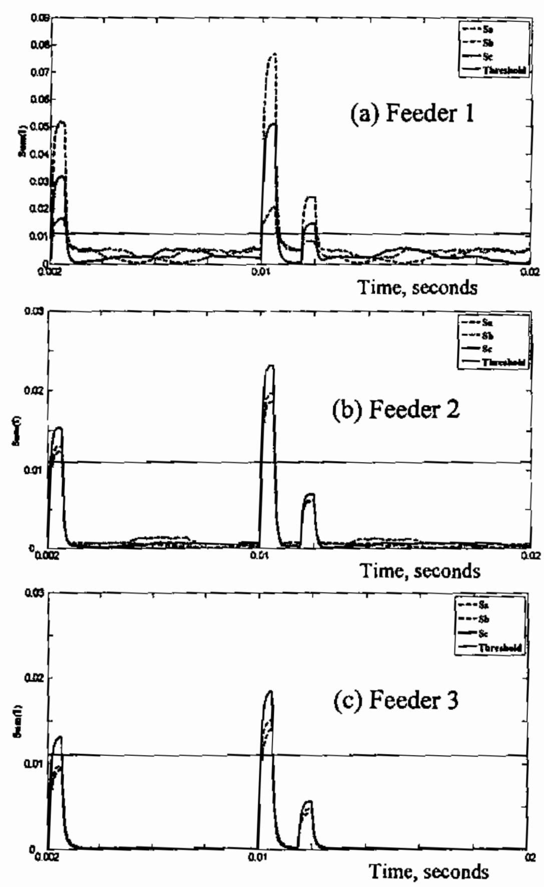
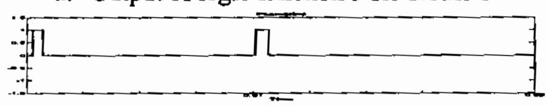


Fig. 10: The absolute sum of d3 for different feeders for 3LG

a. Output of logic function 3 for feeder 1



b. Output of logic function 3 for feeder 2

c. Output Of logic function 3 for feeder 3

Fig.11: Output of logic function 3 for different feeders

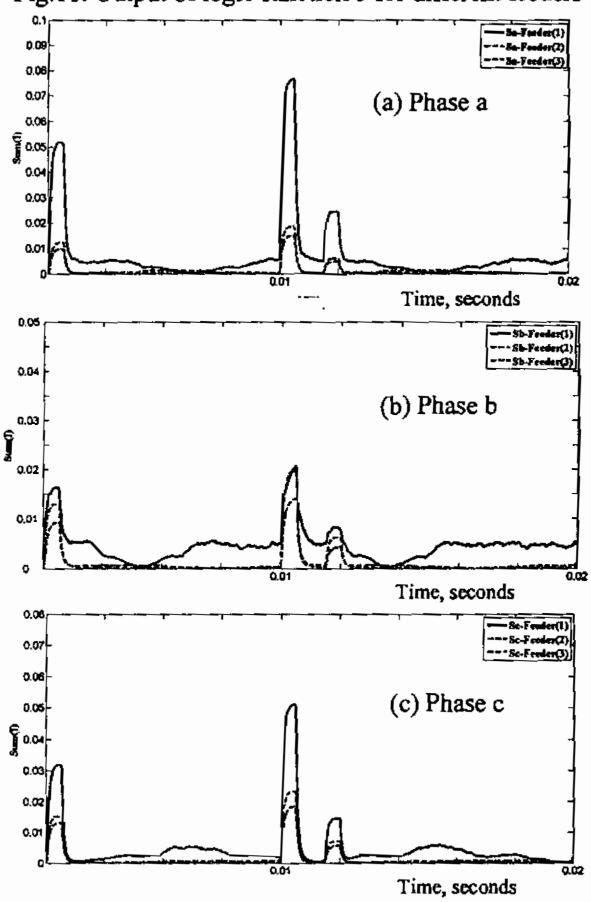


Fig.12: The performance of detectors S_I for different feeders at a certain phase for 3LG.

It is clearly seen that, the proposed approach successes to detect and classify the HIF location as well as the fault type in all cases; single line to ground fault, double lines to ground fault, and three phases fault. The scenario of applications proves the simplicity and accuracy of the proposed approach. Add to that, the proposed approach is independent on the load type or the load balance.

IV. CONCLUSION

This paper introduces an accurate approach for detecting and classifying the HIF in distribution systems. The proposed approach recognizes the distortion of the current waveform caused by the HIF arc using DWT. The intelligence of the proposed approach is based on three simple logic functions. The logic functions are designed to classify not only the fault location, but also the fault type.

The IEEE 13-node benchmark distribution system is used for the proposed approach validation. Different scenarios using Matlab-code simulation have been efficiently applied three fault types; SLG, DLG, and 3LG.

It is clearly seen that, the proposed approach has been applied accurately and successes to detect and classify the fault location as well as the fault type in a simple way. Furthermore, the proposed approach is independent on the load type or the load balance.

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