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A Novel Fault Detection Technique in Distribution System with the Penetration of DG using Mathematical Morphology

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Abstract

Objective: In this paper a Mathematical Morphology (MM) technique is implemented for detection of fault in the distribution network system with the Distributed Generation (DG) integration. **Method Analysis:** The detection capability of MM is explored for fault detection objective on IEEE 13-node test feeder and further the system configuration is augmented and being analyzed with the penetration of DG. The various common morphological filters such as dilation-erosion difference filter and Close-Open Difference Filter used in MM is exploited for accomplishment of accurate and fast detection of fault. **Findings:** The simulation studies are performed in PSCAD/EMTDC environment and voltage/current waveforms obtained at different nodes are transferred to MATLAB and analyzed by using MM for the exact detection of the fault. In order to analyze the impact of DGs on the detection of fault, above procedure is to be performed on the test system in the presence and absence of DG and the results are compared in subsequent section. **Improvement:** On the contrary to the integral transform like wavelet transform, MM is time domain approach for the said objective whose simplicity and accuracy are the attractive feature for fault detection in power system signal.

Keywords: Distributed Generation, Distribution System, Fault Detection, Mathematical Morphology

1. Introduction

Due to the presence of single source in the conventional distribution system, power flow is unidirectional[1–7]. For the protection of such networks, simple time–current graded protection is used and the protective devices can be easily coordinated in order to give discriminative clearance of faults[8–11]. In the large interconnected power systems, the consequences of development of fault may be devastating. The fault may have severe impact on the performance of power system. Therefore, for the protection of such network from such severe circumstances, protective devices are fused in the system.

However, with the integration of DGs, the distribution system converts the network into a multi-source network which causes bidirectional power flow. Therefore, the conventional schemes used for fault detection in conventional distribution system do no longer valid in DG integrated systems. This results, in unpredictable operating time of the protective devices and may result in mis-coordination between the protective devices[3,4,5,12,13]. The main reason behind it is the increased level of short circuit current due to the presence of DG. For robust and reliable distribution network, the protection scheme plays a vital role. It has been shown in previous literature that due to the integration of DG, the reliability of the distribution system is adversely affected due to the loss of coordination among the different protective devices[14–16]. The major issue caused due to DG integration includes blinding and sympathetic (false) tripping. The problem of blinding takes place due to reduction of sensitivity of protective relays. The problem of blinding reduces the fault current in an upstream devices when DG is connected in the downstream network.

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These currents do not exist in the system without DG. This problem of false tripping would not arise in a system having directional elements but mostly non directional of the overcurrent protective devices are used in the distribution network which operates for bi-directional flow of fault currents. One of the adverse impacts of integration of DG is on the fuse saving scheme[17]. Fuses are generally connected in the distribution network for the protection of lateral feeders. The fuses are supposed to operate only on the occurrence of permanent faults. Whereas, auto-reclosers are employed for the removal of temporary fault in order to save the fuse. The integration of DG changes the range of minimum and maximum fault current and hence the coordination between the devices gets affected adversely. The type of DG has also got significant impact on the performance of distribution network.

The traditional over-current protection schemes used in networks with DG depend on how significant is the influence of DG during faults. The impact of DG on protection of distribution networks has been described in many papers[18–20]. This paper proposes Mathematical Morphological Filter based approach for fault detection in DG based power distribution system. On the contrary to the integral transform like wavelet transform, for detection of irregularity of the signal, MM is time domain approach for the said objective. Simplicity and accuracy is the attractive feature for fault detection in power system signal. Although numerous literature are available for detection objective in the transmission systems, remarkably little literature are available in case of fault detection in the distribution system.

The IEEE 13 node test feeder, as shown in Figure 1, for the fault detection has been simulated in PSCAD/EMTDC and analyzed in MATLAB with proposed methodology. The current and voltage at different nodes has been used for filtering operations for detection the fault in both the cases without the penetration of DG and with the penetration of DG.

2. Morphological Filter Design and Operation

MM and its applications were first introduced systematically by[21] and[22]. It obtains object features by choosing a suitable shape as a "'probe" which is based on set theory. On the contrary to the integral transform like wavelet transform for detection of irregularity of the signal, MM is time domain approach for the said objective whose simplicity and accuracy are the attractive feature for fault detection in power system signal[23]. The occurrence of a fault on distribution system causes transient disturbances in the current or voltage waveform. The features of the disturbances can be obtained by different morphological filtering operations. Morphological operations are able to decompose the complex shapes convert them into meaningful parts and separate them from the background by preserving the main shape characteristics.

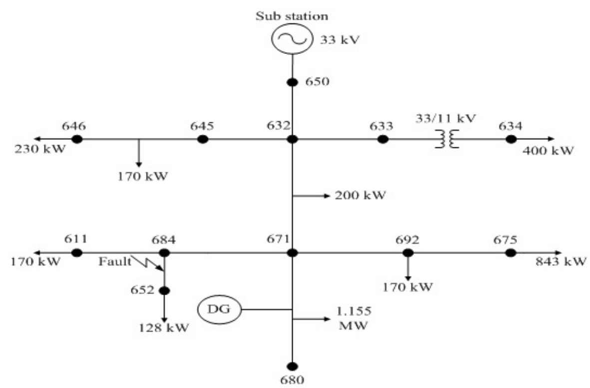


Figure 1. IEEE 13 node distribution system with DG.

Dilation and erosion are two basic operations in MM. If $f(p)$ is the signal to be treated, belonging to domain $D_f = \{x_0, x_1, x_2, \cdots x_p\}$, and $s(q)$ is the structuring element belonging to domain $D_s = \{y_0, y_1, y_2, \cdots y_q\}$, with $p > q$, p and q being integers, then the dilation of $f(p)$ by $s(q)$, denoted by $(f \oplus s)$ is defined.

$$y_d(p) = (f \oplus s)(p) = \max \begin{cases} f(p-q) + s(q), \\ 0 \le (p-q) \le p, \quad q \ge 0. \end{cases} \quad (1)$$

The erosion of $f(p)$ by $s(q)$ denoted by $(f \Theta s)$ is defined.

$$y_e(p) = (f \Theta s)(p) = \min \begin{cases} f(p+q) - s(q), \\ 0 \le (p+q) \le p, \quad q \ge 0. \end{cases} \quad (2)$$

Based on dilation and erosion, two composite operations known as opening and closing are defined. The opening of $f(p)$ by $s(q)$, denoted by $(f \circ s)$, is defined as dilation of the eroded signal by s

$$y_o(p) = (f \circ s)(p) = (y_e \oplus s)(p) = ((f \Theta s) \oplus s)(p) \quad (3)$$

Similarly, closing of $f(p)$ by $s(q)$, denoted by $(f \bullet s)$, is define as erosion of the dilated signal $(f \oplus s)$ by s

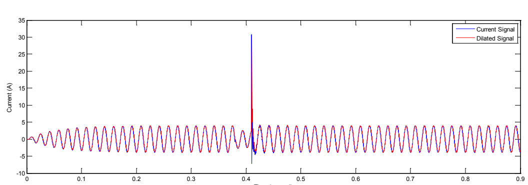
$$y_c(p) = (f \bullet s)(p) = (y_d \oplus s)(p) = ((f \oplus s)\Theta s)(p) \quad (4)$$

The basic function of morphological filtering is a known as structuring element. The choice of structuring element plays a vital role for the accurate detection performance of morphological filter[24]. However in the present study the linear structuring element is used for open as well as close operation. The improper selection of structuring element as well as normal open and close operation derived from dilation and erosion may not lead to accurate detection objective. In this context, to enhance the filter performance the generalized open and close operation is implemented in the view of better detection objective. The sudden change in the shape of the voltage and current waveform due to fault can be detected by morphological filter such as dilation-erosion difference filter and Close-Open Difference Filter (CODO).

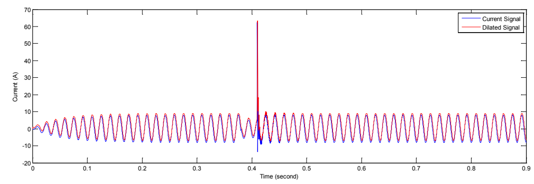
3. Result and Discussion

In this paper, a comparative assessment of the filter performance is carried out on IEEE-13 node test system, as shown in Figure 1, in presence and absence of DG. The simulation studies are performed in PSCAD/EMTDC environment and voltage/current waveforms obtained at different nodes are transferred to MATLAB and analyzed by using MM for the exact detection of the fault. To analyze the impact of DGs on fault detection, different MM operation procedure is performed on the test system in the presence and absence of DG and the results are compared in subsequent section.

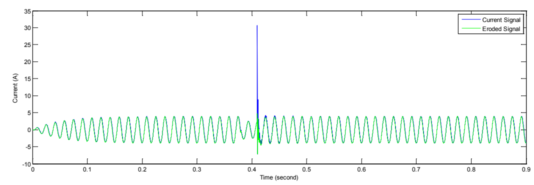
MM filtering operators like dilation and erosion is applied on current waveforms of each bus. Figure 2 shows the dilation and erosion operation on the fault current signal in the presence and absence of distributed resource.



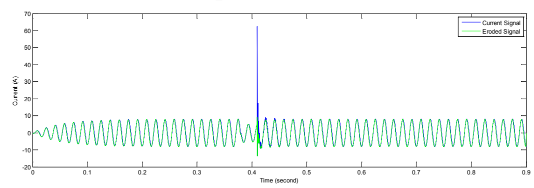
a) Dilation operation without DG.



b) Dilation operation with DG.



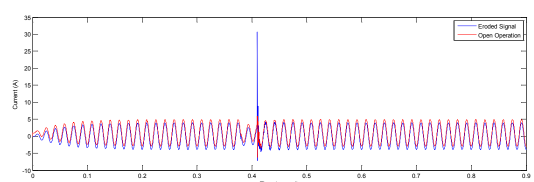
c) Erosion operation without DG.



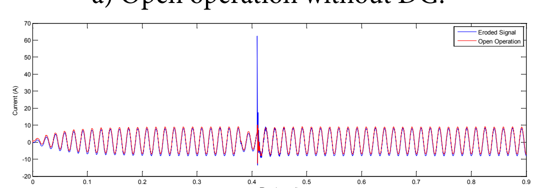
d) Erosion operation with DG.

Figure 2. Comparison of dilation and erosion operation in absence and presence of DG.

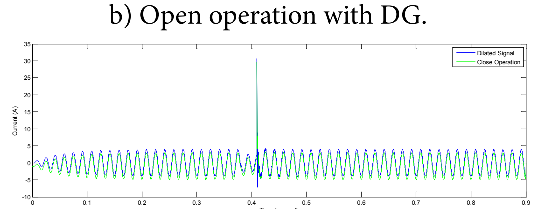
Followed by dilation/erosion, open (dilation of eroded signal) and close (erosion of dilated signal) operation is performed on the waveform as shown in Figure 3.



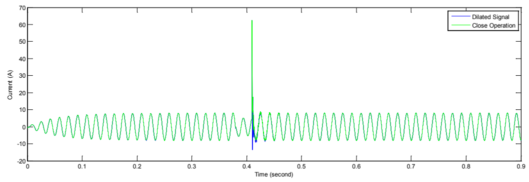
a) Open operation without DG.



b) Open operation with DG.



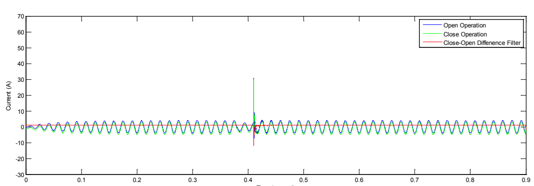
c) Close operation without DG..



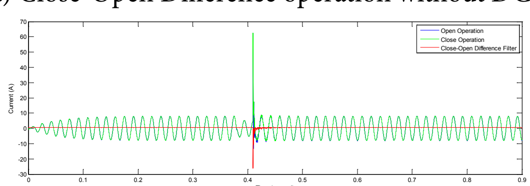
d) Close operation with DG.

Figure 3. Comparison of open and close operation in absence and presence of DG.

The choice of structuring element plays a vital role for the accurate detection performance of morphological filter. However in the present study the linear structuring element is used for open as well as close operation. The sudden change in the shape of the voltage and current waveform due to fault can be detected by morphological filter such as dilation-erosion difference filter and Close-Open Difference Filter (CODO). The signature of voltage and current in the presence of strongly penetration of DG may be strongly affected i.e. the size, location and nature of penetration are also another vital factor. The CODO filtering operation in both the cases (presence and absence of DG in the power system distribution network) has been shown in Figure 4.



a) Close-Open Difference operation without DG.



b) Close-Open Difference operation with DG.

Figure 4. Comparison of CODO morphological filtering of current waveform in presence and absence of Distributed Generation (a) CODO operation in absence of DG and (b) CODO operation in presence of DG.

The output of Close-Open Difference Filter for event detection is shows that the magnitude of wave shape of the CODO will remain constant in normal condition whereas there is a sudden change in magnitude of current on the occurrence of fault, which can be observed by the abrupt change in magnitude of CODO. The impact of DG on fault detection is shown in Figure 4, which signifies that there is a huge change in the magnitude of current.

4. Conclusion

A comparative study using mathematical morphological operation has been shown in presence and absence of DG, to analyze the effect of DG penetration on fault detection in power distribution system. The output of CODO demonstrates that DG makes a significant impact on fault detection. An MM based tool is proposed and implemented in presence and absence of DG. The detection method uses current waveforms sampled at the substation.

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