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Research Article

Smart Fault detection and classifcation scheme for Active electrical distribution networks based on Low Pass Filtering approch

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Abstract – The latest developments and trends in electrical distribution networks is the large scale penetration of renewable energy resources near consumer territory. These renewable energy-penetrated distribution networks are called active distribution networks (ADN's), which have large amount of envoi mental and economical benefits. However, the faults detection and classifcation is an issue in such ADN's due to the low current level during faults, and bidirectional power flows. This paper establishes a new fault detection as well as classification method for the ADN's, using Low Pass Filtering (LPF) approach. Initial, LPF is applied to the current signal of each phase separately, to extract the desired filtered features(DFF). Furthermore, these DFF are utilized to calculate single-phase fault detection index and classification (SPFD&CI) independently. If the SPFD&CI of any singular phase is more than a constant threshold value (T_c), the associated phase is deliberately faulty. However, the fault classification is autonomous due to phase segregation. The proposed approach is tested on the ADN's test system in MATLAB/Simulink software. Results demonstrate that the proposed approch detects and classifies all kind of faults in less than half cycle under different topologies, and worst cases.

Keywords – Active distribution networks, Faults detection and Classifcation, Low Pass Filtering, Renewable energy resources

I. INTRODUCTION

One of the paramount changes that a power system is facing is the penetration of Renewable energy resources (RERs) into distribution premisis resulting a cost-effective, an efficient and envoirment friendly power systems, so-called an ADN's [1]. The ADN's are reliable, and also provides the continuous operation of electrical power systems additionaly, improves power quality issues and reduced power losses [2].

Nevertheless, the sucessfull operation of such renewable based ADN's is linked with some major problems like fault detection and classification [3] due to reduced fault current level in islanded mode, and bi-directional power flow [4].

Protective relays often use the Fourier transform (FT) to acquire the amplitude of voltage and current signals during the fault detection procedure [5]. Moreover, different signal processing techniques like the wavelet transform (WT) and the Stockwell transform (ST) have been adopted by several researchers for defect detection [6], [7].

Because they may be used to non-stationary signals, these approaches have been reported to be more efficient than FT in the literature [8]. Furthermore, large levels of distributed generation (DG) penetration in DS might reduce the sensitivity and selectivity of overcurrent relays, affecting fault detection approaches [9], [10].

Most fault locating methods require fault categorization operations after fault detection. The fault categorization is in charge of determining the different sorts of faults [11]. Even though some articles [12], [13], [14], [15], [16] use fault type information to find problems, they do not present a classification approach.

As a result, these articles presume that fault classification is accomplished using commercial equipment or by employing a classification method that has been published in the literature.

In practice, fault categorization is based on a comparison of voltage and/or current measurements taken before and during theproblem. For this aim, most classification techniques combine a signal processing approach with a machine learning (ML) algorithm [17]. The contribution of proposed scheme includes;

- Fault detection/classification is based on a simple statistical low pass filtering approach.
- To diagnose faults, the approach merely employs current measurements at the feeder head.
- The method is applicable for active distribution networks.
- The proposed approach is independent of fault type; moreover it’s detected and classifies high as well as low impedance faults speedily.

The paper is further categorized as follows: Section II, presented the Basic principal of the proposed low pass filtering method. The suggested fault detection/classification strategy is presented in Section III. Section IV elaborates on simulation results. However, Disscussion on results and comprehensive comparision was presented in Section V. At last, the paper was concluded in Section VI.

BASİC PRİNCİPAL

A. Low pass filter

This section describes the basic principal of proposed technique, which is composed of 3 steps.

i. In first step, the input current signal is firstly squared for demodulation in the 1st step.
ii. 2nd step leads to 2 cases, if there is no interference of high-frequency components, the sampling rate of an input signal is down-sampled directly. However, with high-frequency components, a finite- impulse response low-pass filter is used.
iii. In 3rd step, to synchronize the received low-frequency signal with the original one, the signal is squared. After that, the square root is obtained to reduce scale distortion.

B. Active distribution network test system

The active distribution test system was constructed in MATLAB/Simulink software to evaluate the capabilities of the devised approach. The AND's test system, on the other hand, was designed after a minor change to the IEC standard test system. However, the established scheme has been also tested on IEEE-9 bus system. Figure 1 depicts a single-line diagram of the active

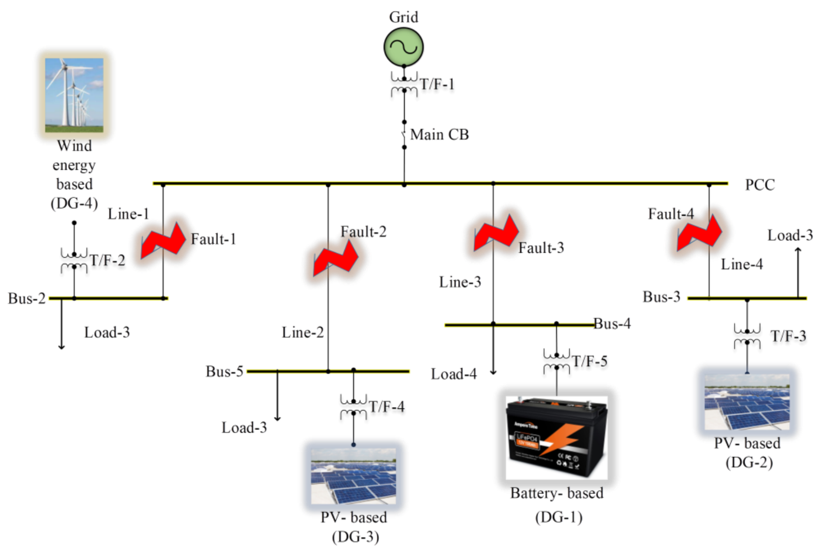


Figure 1. Active distribution network (AND’s) test system.

distribution network's (AND's) test system. The test system comprises of six buses and 4 DGs whereas, three of them are inverter-based DG and one of them is synchronous-based DG. One wind- based DG, two solar-based DGs, and one battery storage system, to be exact. For the validation ofthe proposed approach, four incipient faults F1 to F4 are produced at different places on differentlines.

II. Proposed Detection/Classification Method

This section describes in detail the steps ofproposed scheme. The flow chart of the method is shown in Figure 2. The proposed scheme consists of 3-steps.

A. *Data recording*

The Current transformer at the considered buses is used to measure the current signal. However, the measured values contain a lot of harmonic content and measurement error due devices in accuracyand other arbitrary noises. In addition, thesemeasured current signals are analogy in nature whereas, the relays need discrete data.

B. *Pre-Processor stage*

In this stage the current signals recorded in previous stage are initially converted from analogue to digital via 16 bit analogue to digital (ADC) converter. Furthermore the LPF approach isutilized to extract desired filtered features. However, the LPF is applied to the current signalof each phase separately, to extract the DFF.

C. *Fault detection/classification logic*

The DFF computed in previous stage from discrete current signals are deployed in this step for fault detection/classification index calculation.

Hence, these DFF are utilized to calculate single-phase fault detection and classification index separately on each phase from eq 1.

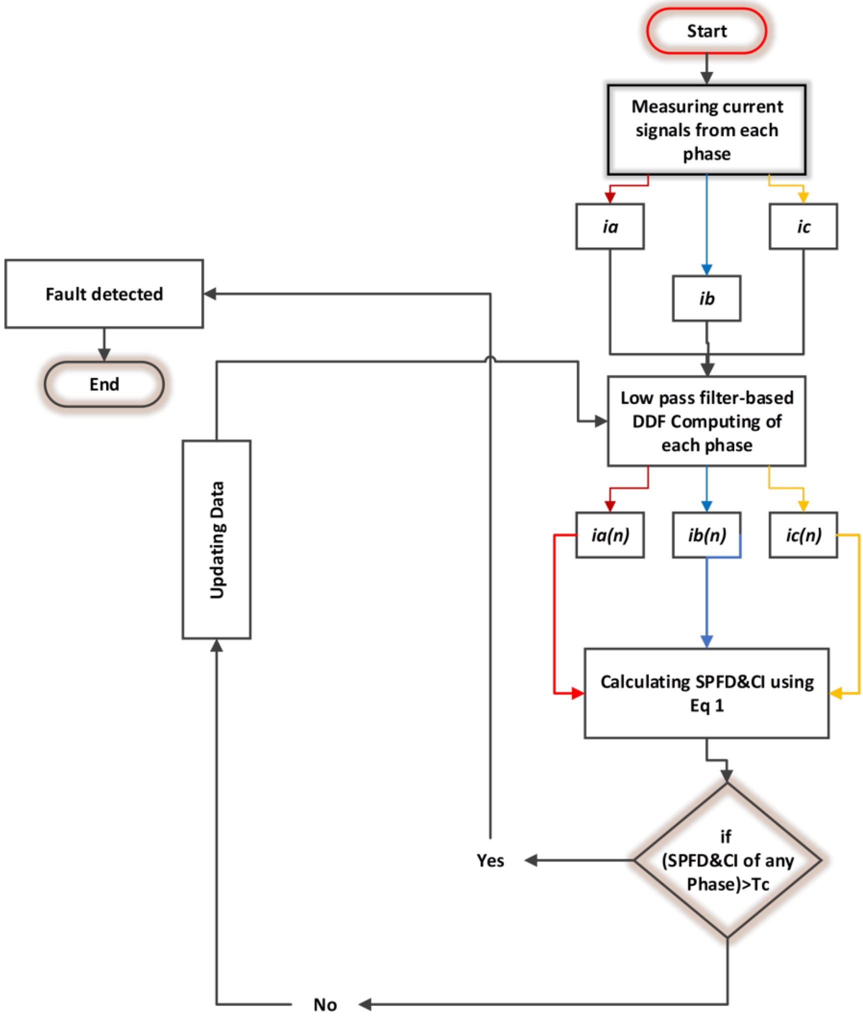


Figure 2. Proposed Faults detection/Classification strategy work-flow diagram.

$$\begin{cases} SPFD\&CI_A = e^{I_A^2(t)} \\ SPFD\&CI_B = e^{I_B^2(t)} \\ SPFD\&CI_C = e^{I_C^2(t)} \end{cases} \quad (1)$$

D. Decision unit

Conclusively, according to designed logic, if the SPFD&CI of any singular phase is more than a constant threshold value (T_c), which is chosen to be 2. Then, the associated phase is deliberately faulty. However, the fault classification is autonomous due to phase segregation.

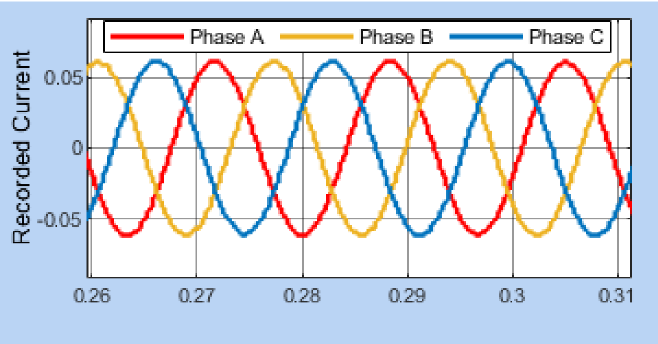
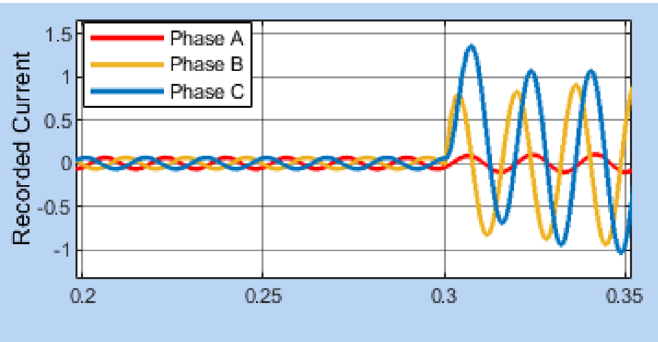
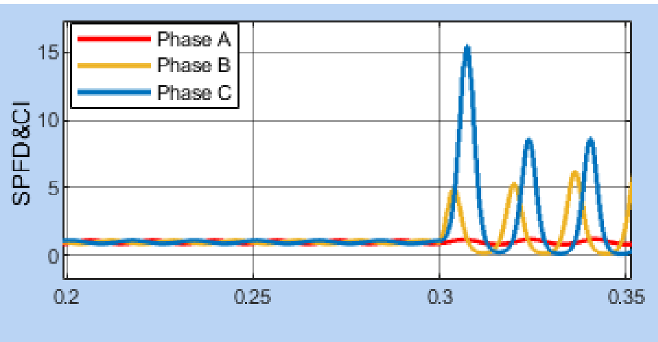


Figure 3 Fault current in healthy case.



(a)



Time(sec)

(b)

Figure 4 Double line to ground fault, (a) fault current, (b) SPFD&CI of corresponding relay.

III. Results

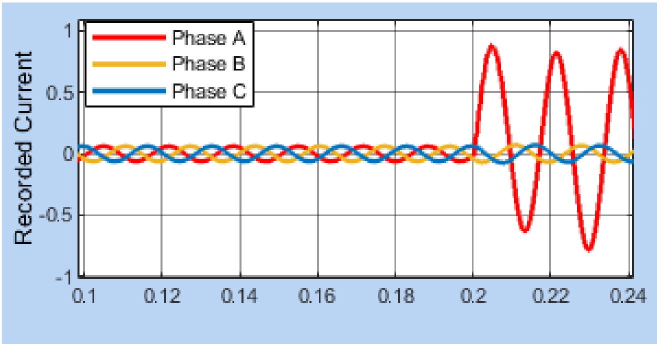
The proposed scheme was tested on ADN's test system in various case studies. Almost all types of faults are tested, under different operating conditions. However, results shows that the proposed scheme successfully detects all kind of faults in less than half cycle.

Whereas, Figure 3 represents the Recordedcurrent in health case.

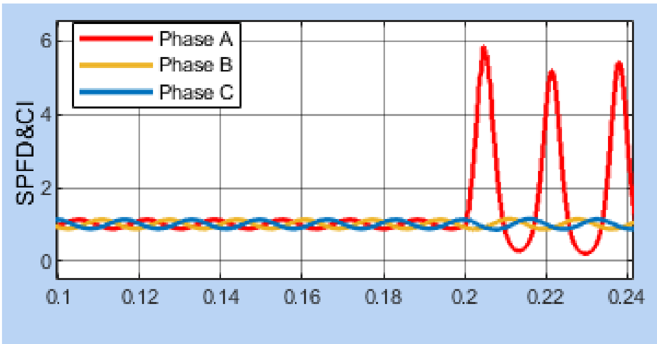
A. Case 1

Figure 4 (a,b) shows double line to ground fault occured at phase B&C at time instant of 0.3 sec which is cleared from the recorded fault current.

Therefore, the fault detection and classification index SPFD&CI of phase B, and C at 0.3 sec is more than T_c value of 2. Hence the BC-g fault is clearly, and timely detected by proposed scheme.



(a)



Time(sec)

(b)

Figure 5 Single line to ground fault, (a) fault current, (b) SPFD&CIof corresponding relay.

B. Case 2

Whereas, Figure 5 (a,b) single line to groundfault occured at phase A at time instant of 0.2 sec, as cleared from the recorded fault current.

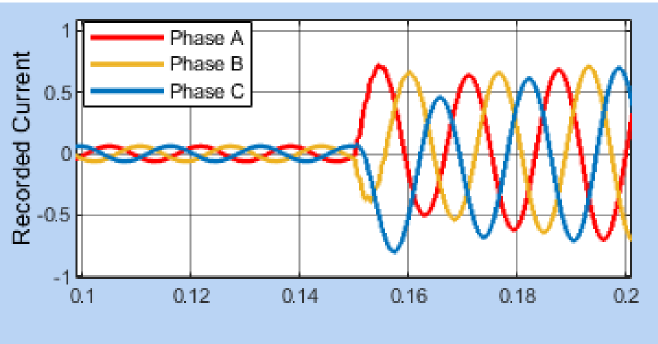
Therefore, the fault detection and classification index SPFD&CI of phase A at 0.2 sec is more than T_c value of 2. Hence the A-g fault is clearly, and timely detected by proposed scheme.

C. Case 3

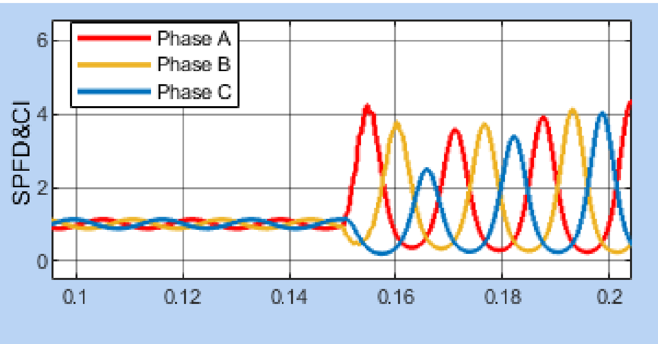
Figure 6 (a,b) shows three-phase to ground fault occured at phases ABC at time instant of 0.15 sec as cleared from the recorded fault current.

Therefore, the fault detection, and classification index SPFD&CI of phase A, B, and C at 0.15 sec is greater than T_c value of 2. Hence the ABC-g fault is clearly, and timely detected by proposed scheme.

However, due to phase segregation of implemented SPFD&CI, fault classification is by default.



(a)



Time(sec)
(b)

Figure 6 Single line to ground fault, (a) fault current, (b) SPFD&CIof corresponding relay.

IV. DISCUSSION

In this paper, a novel method for detecting and classifying all types of power system problems in active distribution networks is presented. The suggested scheme has a number of advantages, which are listed below.

- Only the postfault current signal is used in the suggested approach. As a result, it is more efficient than certain traditional designs that require both voltage and prefault current.
- Because voltage isn't required, the proposed technique can be used in situations where there isn't a potential transformer accessible (like in the conventional distribution networks).
- Compared with the other current-based methods, the proposed scheme has low computational burden.
- The proposed design works effectively in a wide range of operational scenarios. The effects of fault resistance and fault initiation angle were compared. Moreover, simulation trials in distribution networks, including DGunits, have validated its effectiveness.
- As a result, the proposed technique represents a significant advancement in current-based directional relaying.

V. CONCLUSION

To deal with the potentially serious consequences with faults in ADNs, we employed low pass filltering in this research. SPFD&CI was developed to help in fault detection and classification. To validate the efficiency of the proposed technique, extensive simulations are performed. The results show that in the worst-case scenario, the proposed technique protected the ADNs from all forms of faults..

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