A New Principle For Fault Detection Technique for the Series-Compensated Line During Power Swing

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ABSTRACT

In There is an observable distinction in blame location procedure of arrangement remunerated transmission line amid common working condition and power swing condition because of specific reasons like recurrence tweak, sub-symphonious motions, homeless people and so forth. Especially amid control swing condition the recurrence of energy change is tweaked and it is twice of recurrence of voltage variety and current variety. In this way, cycle to cycle or test to test correlation isn't dependable here. Different strategies like Voltage Change, Current Change or Impedance change techniques are additionally not appropriate amid control swing condition. Drifters and sub-synchronous reverberation action in arrangement repaid line show up because of incorporation of capacitor in transmission line. Along these lines, blame location amid control swing condition in the event of arrangement repaid line is outrageous troublesome. In this paper a strategy is produced to identify blame of arrangement adjusted transmission line amid control swing condition. Here it proposes a negative-grouping current based procedure for identifying nearness of blame amid the power swing condition in an arrangement repaid line. The proposed approach is a aggregate whole (CUSUM) of progress in the extent of the negative-succession current based approach and is tried for a SMIB framework. Different sorts of shortcomings like Symmetrical, topsy-turvy, and high protection happening amid the power swing are mimicked through EMTDC/PSCAD to test calculation.

Keywords: - *Distance protection , fault detection, power swing, series compensation, negative-sequence current*

1. INTRODUCTION

The demand of electricity is increasing day by day and the cost incurred in building new transmission lines is very high. Due to this, we use series capacitor for loading and optimum working of transmission lines. But the presence of capacitor and MOV produces complex transient and this causes many problems in long transmission lines. Hence, to avoid this problem, in long transmission lines, PSB are used to avoid unintended tripping but at the time of power swing, if a fault occurs in long lines, the relay does not operate because of PSB so in this paper, we intend on using negative sequence current based method to find all types of faults during power swing.

1.1 Fault recognition challenges while there is a power swing in Series-Compensated Lines

work Series compensation imposes protection problems and are related to the level of compensation, location, and the operation of its overvoltage protection devices like MOV and air gap. The use of series capacitors in transmission lines results in various special phenomena, such as voltage/current inversion, sub harmonic oscillations, and transients caused by the MOV operation during the fault period [1]–[5]

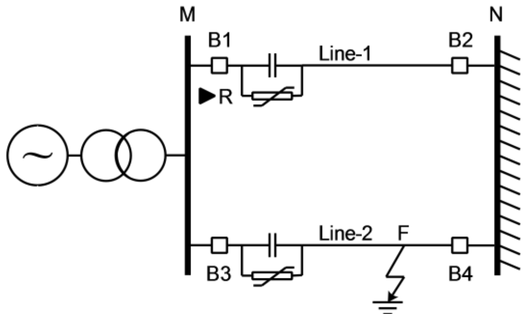

Figure 1. Single-line diagram of the 400-kv power system.

In order to demonstrate the fault detection issues during power swing in a series-compensated line, a test system [12] shown in Figure. 1 is considered. Both Line-1 and Line-2 are 40% compensated and the capacitors are placed at the relay end and the protection scheme of each series capacitor including an MOV as shown. The system details are provided in Appendix. The power angle here refers to the angle between the voltages at buses M and N. The distance relay R for breaker B1 is considered for the study. A three-phase fault is created at the middle of Line-2 at 0.6 s and cleared at 0.7 s by opening breakers B3 and B4. This causes a power swing condition in Line-1 and is observed by the relay R. During this condition, phase-a current and voltage waveforms are shown in Figure. 2(a) and (b), respectively. From the figure, it is clearly observed that during swing current and voltage waveforms are modulated with the swing frequency. As a result, the traditional fault detection techniques, such as the sample-to-sample or cycle-to-cycle comparison of current (or voltage) signals [14] cannot be reliable during the power swing.

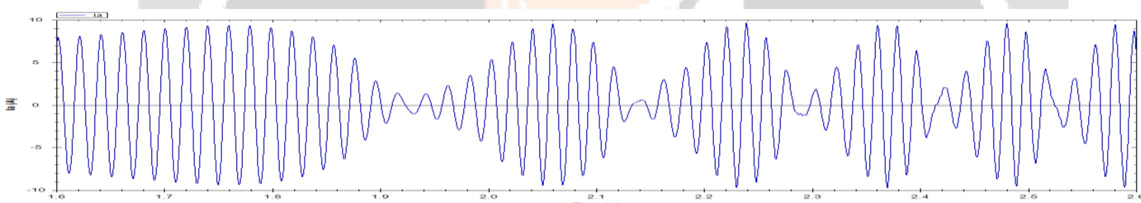

Figure 2(a). Current waveforms of phase-a at the relay bus during the power swing

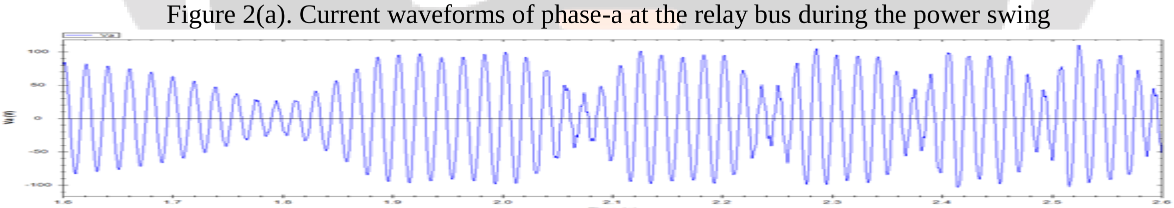

Figure 2(b). Voltage waveforms of phase-a at the relay bus during the power swing.

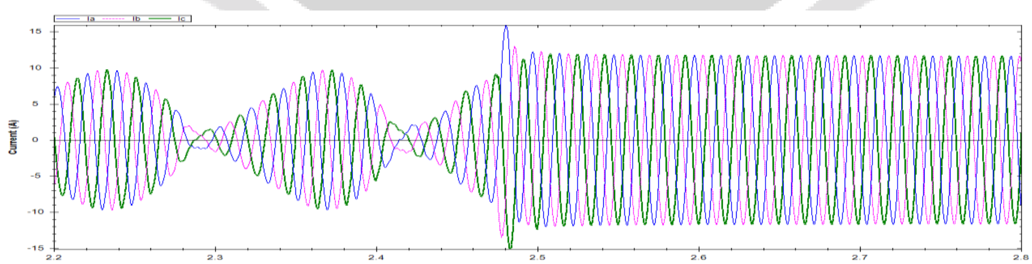

Figure 3(a). Current waveforms at the relay bus for a three-phase fault during the power swing at 2.47 s at locations of 64 km

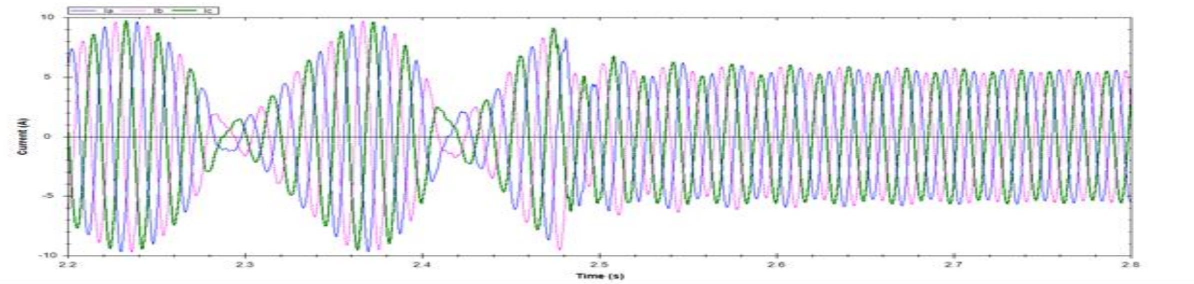

Figure 3(b). Current waveforms at the relay bus for a three-phase fault during the power swing at 2.47 s at locations of 240 km

It is clearly observed from Figure. 3(a) that in the case of the fault being close to the relay, the current level as seen from the plot is higher than the swing current which causes the MOV to operate. As a result, in most portions of the fault, the series capacitor is bypassed and no oscillation is observed in the fault current. However, in case of a fault at the far end [Figure. 3(b)], the level of fault current is lower than the swing current which does not enable MOV conduction and results in sub synchronous oscillation in the current waveforms. These issues result in more complexity to identify the fault.

2 PROPOSED FAULT DETECTION TECHNIQUE

The power swing is a balanced phenomenon [7], but a small percentage of negative-sequence components of (I 2) is found due to signal modulation and the related phase computation technique. For unbalanced faults the power swing, a significant amount of negative-sequence current is observed. In case of a three phase fault he power swing, negative-sequence current is observed at the initial period of the fault due to transients in the current signals and in the subsequent period due to the presence of modulated frequency components by the power swing. To observe the variation of I 2 during swing and fault, an ag-fault with a fault resistance of 0.1 Ω and a three-phase fault are created at 2.8 s during the power swing at a distance of 64 km from relay R toward bus N of Fig ure. 1, and the corresponding results are provided in Figures. 4 and 5, respectively. In case of the ag-fault, phase-a current only exceeds the swing current as a result MOV of only phase-a operates. For the three-phase fault, MOVs of all three phases conduct. Figure. 4(c) and 5(c) clearly show the low value of I 2 that is present during the power swing. From figure. 4(c), it is evident that during the ag-fault, I 2 becomes significant and oscillates due to modulating frequency components in the fault signals. From figure. 5(c), it is observed that during the three-phase fault, I 2 varies rapidly at the inception of the fault due to the initial transient and following that, it has a low value due to signal modulation by the swing

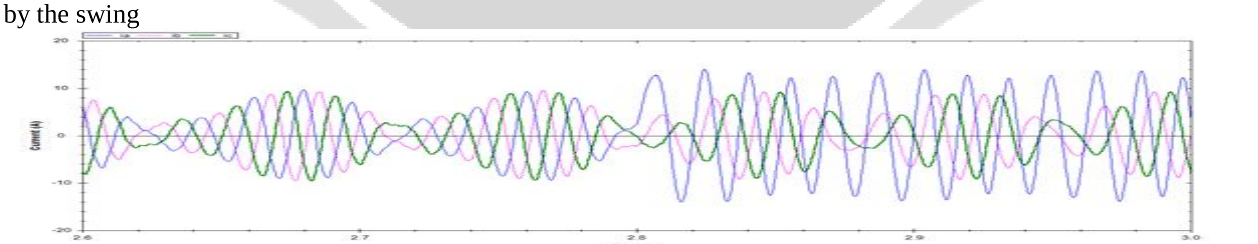

Fig. 4(a) Three-phase current waveforms for an ag-fault during the power swing at 2.8 s

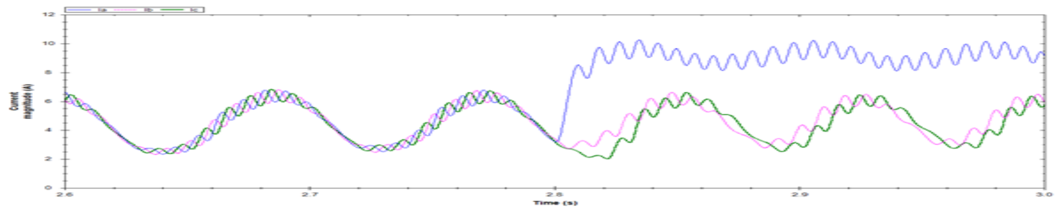

Fig. 4(b) Current magnitude for an ag-fault during the power swing at 2.8 s

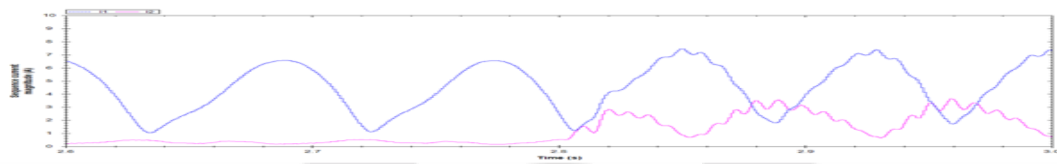

Fig. 4(c) Negative-and positive-sequence current magnitude for an ag-fault during the power swing at 2.8 s

It is evident from the previous discussion that negative-sequence current is available in the computation process during the swing. But with a small amount of I 2 remaining during the swing condition, a change in the magnitude of the negative-sequence current (ΔI_2) based technique suits the purpose. With a suitable threshold, the cumulative sum of the $\Delta\left|\bar{I}_2\right|$ based technique is selected in this work for the fault detection during swing. CUSUM is a versatile technique used for abrupt change detection in various fields [11]. It is to be noted that the CUSUM-based approach is applied for transmission-line fault detection using sampled values of the current signal [14] and has limitations due to uneven variation in sample-to-sample magnitude difference of current during power swing. In this present work, CUSUM is applied to obtain a good index for fault detection during the power swing where a change in negative-sequence current is being used as the input signal.

The computation steps for the method are provided

$$\bar{I}_2 = \frac{\left(\bar{I}_a + \alpha^2 \bar{I}_b + \alpha \bar{I}_c\right)}{3} \qquad (5.1)$$

Where $\bar{I}_2$ is the sequence-sequence current; $\alpha = e^{j2\pi/3}$ and $\bar{I}_a$, $\bar{I}_b$ and $\bar{I}_c$ are the phase currents.

A derived signal s_k is obtained as

$$s_k = \Delta\left|\bar{I}_2\right| = \Delta\left|\bar{I}_{2_k}\right| - \Delta\left|\bar{I}_{2_{k-1}}\right| \qquad (5.2)$$

For $s_k > \varepsilon$, the proposed CUSUM test is expressed as

$$g_k = \max\left(g_{k-1} + s_k - \varepsilon, 0\right) \qquad (5.3)$$

Where the index g_k represents the test statistics and s_k is the drift parameter in it.

A fault is registered if

$$g_k > h \tag{5.4}$$

Where *h* is a constant and should be ideally zero. In (5.3), ε provides the low-pass filtering effect and influences the performance of the detector. When $s_k > \varepsilon$, the value increases by a factor of the difference between s_k and ε. With further current samples available, the CUSUM process provides an easy way to decide on the fault situation by applying (5.4). After each fault detection index g, is reset to zero. For only the swing situation, g_k will be zero as $\Delta\left|\bar{I}_2\right| < \varepsilon$.

3. Results

The algorithm for fault detection is tested for different conditions including balanced and unbalanced faults, high resistance faults, and close-in faults during the power swing. Using EMTDC/PSCAD with distributed parameter line model data was generated. The inputs to the relay are fed from the secondary of a current transformer with a turns ratio of 1000:5. The nonlinear CT model is considered in the simulations. Sequence components were estimated considering phase-a as reference. The convention used in this paper is such that the output of the algorithm should be 1 for fault and 0 for the no-fault situation.
In order to test the algorithm at critical conditions, all faults are created at a fault inception time of 2.54 s which corresponds to $\delta = 175^{o}$. As mentioned in Section II, faults occurring far away from the series capacitor produce current magnitude less than the swing current when MOV does not operate. At this condition, the presence of series capacitor in the circuit during the fault period results in sub synchronous oscillations which complicate the fault detection process. In order to test the proposed technique for far-end faults, all faults are created at 240 km from the capacitor toward bus *N* which corresponds to 75% of the line length.

3.1 Line-to-ground fault in the series-compensated line

The algorithm is tested for a line-to-ground fault of ag-type with a fault resistance of 0.1 Ω initiated at 2.54 s at a distance of 240 km from the relay location, and the results are shown in Figure. 5(a)

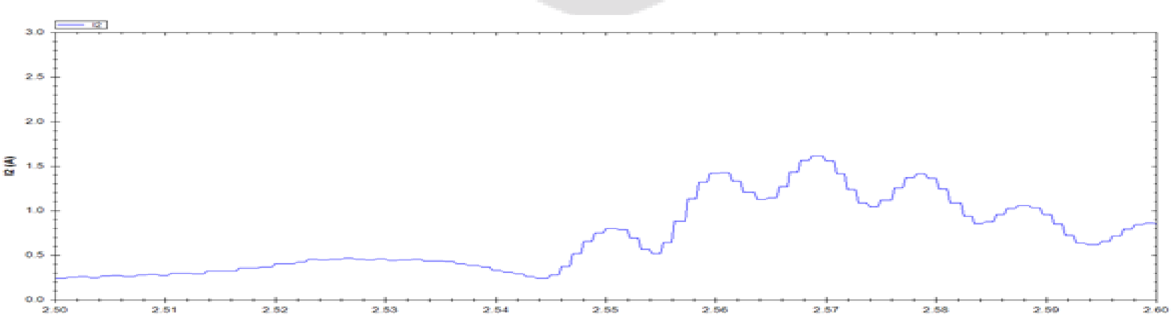

Figure 5(a). Negative-sequence current magnitude during the line-to-ground fault

With the fault being unbalanced, the observed during the fault is significant and oscillating in nature due to signal modulation. The index *g* , which decides the output of the algorithm, is zero before the inception of the fault. The output “1” clearly shows that the fault is detected after 6 ms of fault initiation.

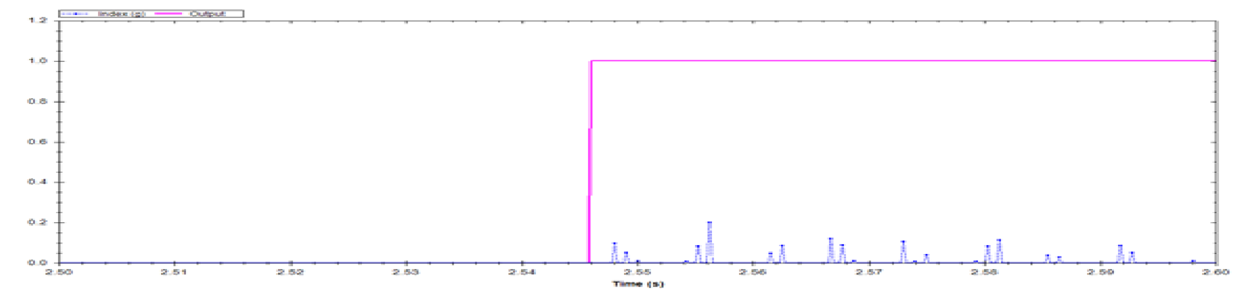

Figure 5(b). Performance during the line-to-ground faul

3.2 Performance during the close-in fault

Three-phase close-in faults apparently bypass the capacitor due to the MOV operation. This may lead to voltage collapse at the relay bus. Due to the subsidence transients in the coupling capacitor voltage transformer (CCVT), the fault detectors based on voltage phasors, for example, the rate of change of impedance or the rate of change of swing-center voltage will be affected.

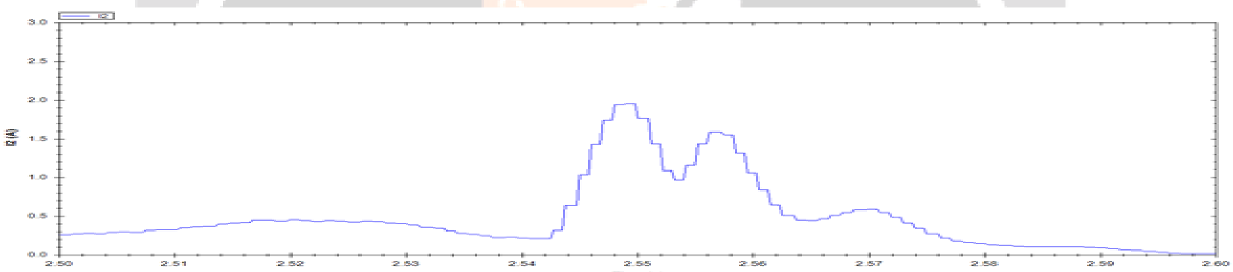

Figure 6(a). Negative-sequence current magnitude during the close-in fault

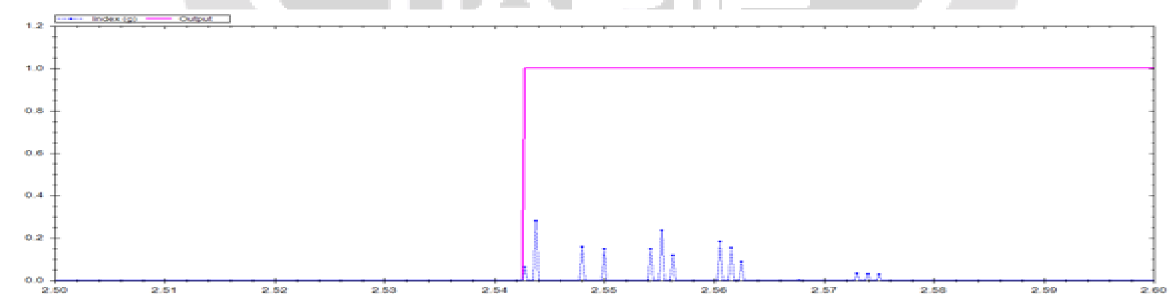

Figure 6(b). Performance during the close-in fault

In the proposed technique as the current signal is used to detect fault during the power swing, such a close-in fault is not an issue. To test the algorithm, a three-phase fault is created at 2.54 s ($\delta = 175^0$) at a distance of 1 km behind the series capacitor, and the results are provided in Figure.6. The observation on I 2 in the present fault case is similar to that of case-C. The observation on index *g* clearly shows that during the power swing, its value is zero and it grows quickly to a high value after the inception of the fault. The output of “1” is consistent, and fault detection is possible within 2 ms

4. CONCLUSIONS

A novel fault detection technique for the series -compensated line during the power swing is presented in this paper. It uses a cumulative sum of change in the magnitude of negative-sequence current to detect faults. The performance of the proposed algorithm is applied for balanced and unbalanced faults for different series-compensated systems. Conditions, like high-resistance fault and close-in fault are considered to test the algorithm. The proposed method, as a current based technique, is not affected by issues like close-in fault. This method is precise and fast in detecting faults during the power swing in a series compensated line

6. REFERENCES

[1] R. J. Marttila, “Performance of distance relay mho elements on MOV protected series -compensated lines,” IEEE
Trans. Power Del., vol. 7, no. 3, pp. 1167–1178, Jul. 1992.

[2] H. J. Alture, J. B. Mooney, and G. E. Alexander, “Advances in series compensated line protection,” 2008. [Online].
Available: www.selinc.com/20081022, TP6340-01

[3] A. Newbould and I. A. Taylor, “Series compensated line protection: System modeling and relay testing,” in Proc. 4th
Int. Conf. Develop. Power Protect., 1989, pp. 182–186.

[4] D. Novosel, A. G. Phadke, M. M. Saha, and S. Lindahl, “Problems and solutions for microprocesso r protection of
series compensated lines,” in Proc. Conf. Develop. Power Syst. Protect., 1997, pp. 18–23

[5] D. Novosel, B. Bachmann, D. Hart, Y. Hu, and M. M. Saha, “Algorithms for locating faults on series compensated
lines using neural network and deterministic methods,” IEEE Trans. Power Del., vol. 11, no. 4, pp. 1728–1735, Oct. 1996.

[6] IEEE Power System Relaying Committee of the IEEE Power Eng. Soc., Power Swing and Out -of-Step
Considerations on Transmission Line. Rep. PSRC W G D6, Jul. 2005. [Online]. Available: http://www.pes-psrc.org
[7] S. Lotfifard, J. Faiz, and M. Kezunovic, “Detection of symmetrical faults by distance relays during power swings,”
IEEE Trans. Power Del., vol. 25, no. 1, pp. 81–87, Jan. 2010.

[8] P. K. Nayak, A. K. Pradhan, and P. Bajpai, “Detecting fault during power swing for a series compensated line,” presented at the Int. Conf. Energy, Autom., Signal, Bhubaneswar, Odisha, India, Dec. 28–30, 2011.

[9] A. Y. Abdelaziz, A. M. Ibrahim, M. M. Mansour, and H. E. Talaat, “Modern approaches for protection of series compensated transmission lines,” Elect. Power Syst. Res., vol. 75, pp. 85–98, 2005.

[10] T. S. Sidhu and M. Khederzadeh, “Series compensated line protection enhancement by modified pilot relaying schemes,” IEEE Trans. Power Del., vol. 21, no. 3, pp. 1191–1198, Jul. 2006.

[11] F. Gustafsson, Adaptive Filtering and Change Detection. NewYork: W iley, 2000.

[12] S. M. Brahma, “Distance relay with out-of-step blocking function using wavelet transform,” IEEE Trans. Power

Del., vol. 22, no. 3, pp. 1360–1366, Jul. 2007.

[13] Paresh Kumar Nayak, Ashok Kumar Pradhan, and Prabodh Bajpai, “A Fault Detection Technique for the Series Compensated Line During Power Swing”, IEEE Trans. Power Del.,, VOL. 28, NO. 2, APRIL 2013,pp.714 - 722.

[14] S. R. Mohanty, A. K. Pradhan, and A. Routray, “A cumulative sum-based fault detector for power system relaying
application,” IEEE Trans. Power Del., vol. 23, no. 1, pp. 79–86, Jan. 2008