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A Novel Approach for Islanding Detection in Distributed Wind Energy Generators within Renewable Energy-Integrated Smart Grid using the 3-Parameter Sine Fit Algorithm

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ABSTRACT- This paper introduces a novel islanding detection method employing the 3 Parameter Sine Fit (3PSF) algorithm, which accurately estimates the angle between voltage and current at Distributed Generators (DGs). The method improves islanding identification in a test system consisting three Wind Energy Generators (WEGs) and an Emergency Diesel Engine Generator (EDEG). To demonstrate the efficacy of suggested novel strategy, the assessment is done under variety of situations such as islanding, load shedding and distribution line loss. Furthermore, a new mathematical model is developed for load shedding and this mathematical model is validated under wide range load shedding variations. This is validated that the 3PSF technique is a potential option for accurate islanding identification. Its superior sensitivity and resilience over ROCOF are highlighted by the results, which are confirmed by MATLAB-Simulink simulations.

Keywords: Rate of Change of Phase Angle Difference (ROCPAD), Distributed Generation (DG), Islanding, Wind Energy Generator (WEG), Rate of Change of Frequency (ROCOF), Emergency Diesel Engine Generator (EDEG), 3 Parameter Sine Fit (3PSF).

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1. INTRODUCTION

In the realm of renewable energy conversion, distributed wind energy generators (DWEG) have emerged as a crucial component of sustainable power generation. These distributed systems, ranging from small-scale turbines to larger installations, contribute significantly to the diversification of energy sources within smart grids. However, as these generators often operate in conjunction with the existing power grid, the possibility of islanding poses a notable concern. Islanding detection mechanisms tailored specifically for DWEG are vital in this context. These detection systems monitor the grid for anomalies, such as sudden changes in frequency or voltage, to swiftly identify islanding scenarios. By promptly isolating the WEG from the grid, when necessary, these mechanisms ensure the safety of maintenance personnel, prevent grid instability, and maintain efficient energy utilization. Islanding detection solutions tailored to DWEG serve as a critical safeguard, enabling their integration into IT enabled grid and smart grids while upholding grid stability and reliability. The substantial penetration of DG through the network is one of the features of modern grids for the expansion of future power system, which creates a number of challenges, [1], [2] to the grid such as:

(1) Relays should not accidentally trip, under load variation or with nonlinear loads present.
(2) Deciding the ideal time settings at which it ought to be disconnected from the main grid in response to any unusual circumstances.
(3) To investigate the generator's potential to assist the network during abnormal operation and to reduce the electrical disturbances caused by the generator disconnection.

Hence, the islanding detection is crucial because it addresses various issues, including human safety, out-of-phase reclosing, and safety hazards. In accordance with IEEE 1547 [3] islanding should be identified in less than two seconds. There are mainly two kinds of techniques for detection of islanding: remote and local. In remote method the channels between the DG and PCC are used for example transfer trip relaying [4], [5]. Supervisory control and data acquisition (SCADA) and microprocessor systems [5], [6] or power line cable communication (PLCC) [7],

[8]. By broadcasting a small signal coming via the DG bus and getting to the breaker location, power line signaling is used in [8] to identify islanding. In [9] the morphological filters and empirical code decomposition (EMD) is used for islanding detection. Remote detection techniques can find islands in the narrow range of non-detection zone (NDZ) but the primary disadvantages of remote approaches, are their possibility of communication link breakdown, need for backup protection as well as they are expensive and difficult to execute.

Active and passive local methods are the two different categories. A disruption is purposefully supplied to the framework in order to deliberately identify the islanding circumstances in the active procedures. As a result, the active procedures are applied for particular DG *i.e.* inverter-based DG. A condenser or capacitor is introduced by [10], [11] to purposefully cause equality power mismatches in order to identify an islanding condition. The active frequency drift [12], the current harmonic injection by [13], Sandia frequency shift by [14], the positive feedback method by [15] and the voltage drifting approach by [16], are a few of the active procedure for generators based on inverter. The current injection technique for islanding applied in [17] facing the problems of selective few components of high frequency injected current. Similar islanding finding techniques in case of synchronous-based generators are provided in [18-20]. Two control loops for reactive and active power with positive feedback are provided in [18] to render the unstable system in an islanding scenario. Then, in [20] updated loops for both active and passive power control suggested which boost the synchronous generator's ability to ride through obstacles and detect islanding situations. The [19] also adds integral controllers to the governor and a synchronous generator excitation mechanism to create the system slightly unstable when it is islanding. The [21] describes a technique for regulating the two probabilistic phasing neural network controllers. The drawback of active islanding tactics is the decline in the quality of the electricity. Monitoring the system's electrical quantities forms the basis of passive approaches. The benefit of passive techniques is that their adoption has no effect on the DG system's regular operation. Passive islanding detection techniques may be used for synchronous (DGs) and inverter-based. The prevalent passive detecting devices are over/under voltage or frequency relays presented in [22]. The ROCOF which has a vast NDZ, is among the popular islanding detection methods. Another one is vector surge relays presented in [23] and other passive technologies that have lately been presented in [24] employ the wavelet transform to identify islanding and reduce NDZ, another one is signal processing techniques [25] using near loop frequency regulation and a high-frequency detection of impedance mechanism, [26] introduced a passive technique for DGs based on inverter. In [27], a voltage index was used to determine the islanding circumstance for big power disparities. As slight imbalances might result in significant power mismatches, the line current was examined for minor power imbalances to disconnect certain loads. In [28] the modified EMD is used to disintegrate PCC voltage into a several oscillatory elements for detection of islanding. Learning technique have been established in [29] to identify the traits that distinguish islanding from grid linked circumstances. Islanding and grid-linked disruptions are classified using a deep learning-based approach after initially analyzing various features using signal processing techniques. In [30] the proportion of the product of negative sequence voltages and current of both sides *i.e.* DG and grid is used to detect the islanding and in [31] the strategy based on adaptive boosting and modal current is suggested. The EMD tool is used to convert the modal current into a Nano frequency component of currents which are then correlated with the help of Hilbert's transform for detecting the islanding. In [32] the new algorithm is proposed for islanding detection using some logical operator but does not show the effect of loss of line, and the effect of islanding on other DG. The [33] present ROCPAD, the method detect the islanding more accurately than the other one. The extensive analysis of islanding for the power mismatch from 0% to 80% is carried out in [33].

In the IT revolution, where data centers, cloud services, and various critical systems heavily rely on uninterrupted power, any disruption or outage in the grid could have significant repercussions. Islanding detection helps prevent islands of power generation that could form during grid disturbances, ensuring the stability of the overall grid. Hence, this research suggests a novel approach i.e. 3PSF algorithm to estimate the angle in passive islanding detection technique ROCPAD and compare with ROCOF. These are used for the detection under power mismatch, loss of lines and faults. An empirical novel mathematical model of ROCOF and ROCPAD is developed for the load shedding and their performances have been also investigated under the wide range of load shedding i.e. from 10% to 80% of the existing load. The detection of islanding is also seen at PCC for 0% power mismatch and the effect of this islanding on the adjacent DG in the test system is also observed.

The proposed techniques are validated through MATLAB/SIMULINK. The performance of proposed 3PSF is found superior.

The suggested islanding technique has following features:

- The method proposed in this paper; instantaneously detect the islanding without any delay which will be a great revolution for the IT industry.
- The method also effectively detects the islanding in 0% power mismatch situation.
- This work is also able to detect the distribution line loss.
- The proposed method also detects the islanding not only on the target DG but on other adjacent DG and at PCC as well.
- The sensitivity of proposed technique is validated through the load shedding from 10% to 80% of existing load.

2. PROPOSED METHODOLOGY

In the proposed methodology the 3PSF is used, it is a fitting technique dependent on parameter approximation, the sine-wave's amplitude, frequency, phase, and DC component are determined by fitting the sample sequence using the least squares approach. Hence to calculate the phase angle.

Let us consider the signal in *eqn. (1)*

$$y = E\sin(wt + \varphi) + c \qquad (1)$$

Where,
y is the signal of voltage
E is the amplitude of the signal
w is the angular frequency
ϕ is the phase angle

The *eq. (1)* can be expanded to *eq. (2)*

$$y = E\sin wt\cos\phi + E\cos wt\sin\phi \quad (2)$$

$$\& \; y = E_1 \sin wt + E_2 \cos wt$$

Where,

$$E_1 = E\cos\emptyset \quad (3)$$

$$E_2 = E\sin\emptyset \quad (4)$$

From *eqn. (3) & eqn. (4)*, the *eqn. (5)* can be derived

$$E = \sqrt{E_1^2 + E_2^2} \quad (5)$$

The phase angle $\emptyset$ can be calculated from eqn. (6)

$$\emptyset = \begin{cases} \arctan\frac{-E_1}{E_2}; E_2 \geq 0 \\ \arctan\frac{-E_1}{E_2} + \pi; E_2 \geq 0 \end{cases} \quad (6)$$

Since the sequence time is $t_1, t_2 \ldots t_n$ and the respective data are $y_1, y_2 \ldots y_n$. The sample data is represented in the fitting procedure as shown in *eqn. (7)*.

$$f(abc) = \sum[y_i - (E_2 \cos wt + E_1 \sin wt + c)]^2 \quad (7)$$

To reduce the inaccuracy as much as possible, the following condition shown in *eqn. (8)* must be satisfied.

$$\frac{\partial f}{\partial E_1} = 0; \frac{\partial f}{\partial E_2} = 0; \frac{\partial f}{\partial c} = 0 \quad (8)$$

The eqn.9 can be written as

$$\sum y_i - \sum E_2 \cos wt - \sum E_1 \sin wt - \sum c \quad (9)$$

$$\& \sum E_2 \cos wt + \sum E_1 \sin wt + \sum c = \sum y_i \quad (10)$$

Let $a_i = \cos wt$
$b_i = \sin wt$

Then the following mathematics shown in *eqn. (11)* to *eqn. (14)* is done to calculate E_1 and E_2 and by using the values of E_1 and E_2 the value of $\emptyset$ is calculated.

$$E_2 \sum a_i^2 + E_1 \sum a_i b_i + c\sum a_i = \sum y_i\, a_i \quad (11)$$

$$E_2 \sum a_i b_i + E_1 \sum b_i^2 + c\sum b_i = \sum y_i\, b_i \quad (12)$$

$$E_2 \sum a_i + E_1 \sum b_i + c\sum 1 = \sum y_i \quad (13)$$

The above *eqn. (11), (12) and (13)* can be represented in a matrix form

$$A.B = X \quad (14)$$

Here, $A = \begin{bmatrix} \sum_{i=1}^n a_i^2 & \sum_{i=1}^n a_i b_i & \sum_{i=1}^n a_i \\ \sum_{i=1}^n a_i b_i & \sum_{i=1}^n b_i^2 & \sum_{i=1}^n b_i \\ \sum_{i=1}^n a_i & \sum_{i=1}^n b_i & \sum_{i=1}^n 1 \end{bmatrix}$, B= $\begin{bmatrix} E_2 \\ E_1 \\ c \end{bmatrix}$,

X= $\begin{bmatrix} \sum_{i=1}^n y_i . a_i \\ \sum_{i=1}^n y_i . b_i \\ \sum_{i=1}^n y_i \end{bmatrix}$

Similarly, the same procedure is followed for the current waveform and the angle of the current is found.

Then from *eqn. (15)* the ROCPAD is calculated.

$$\text{ROCPAD} = \frac{d(\emptyset_v - \emptyset_i)}{dt} \quad (15)$$

Now, further the important step is to calculate frequency for ROCOF detection. Hence the sine signal shown in *eqn. (16)* can be written as

$$y_i = E\sin(\theta_i + \emptyset) + c \quad (16)$$

Where, i=1, 2……., n.

$$\& \; \theta_i = \frac{2\pi i}{N}$$

Then, *eqn. (17)* can be derived

$$y_i = E\sin\left(\frac{2\pi i}{N} + \emptyset\right) + c \quad (17)$$

By studying the consecutive sequence and with the help of lissajous, frequency can be determined and then form *eqn. (18)* the ROCOF can be calculated.

$$\text{ROCOF} = \frac{df}{dt} \quad (18)$$

The ROCOF is determined and compared to the predetermined threshold limit. Islanding is recognized if its value surpasses the pre-determined threshold limit. *Fig.1* displays the flowchart of ROCOF method.

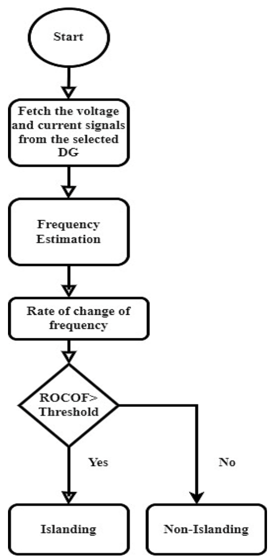

Figure 1: Flowchart of ROCOF relay

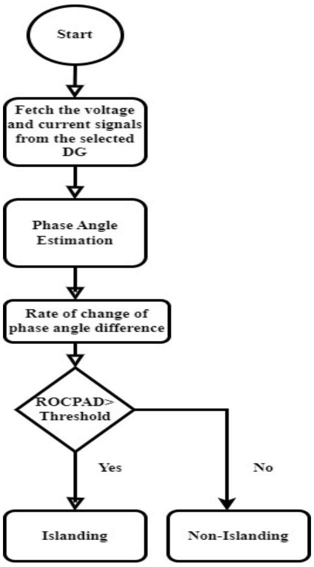

Figure 2: Flowchart for 3PSF to estimate ROCPAD

In the 3PSF for ROCPAD technique, the measured current and voltage at the target DG is cascaded to phase approximation by the 3PSF algorithm shown in *figure 2*, where angle is determined and after that the ROCPAD is estimated and if it is greater than threshold the islanding occurs.

3. TEST SYSTEM DESCRIPTION

Figure 3 shows the test system that is being examined. The base power is 10 MVA. The system under investigation is a radial distribution system connected to the main grid PCC by four DG units—three WEG and one EDEG. The DG units are separated by 20 kilometers, with the micro grid operating at a voltage of 25 kV. The specifications for the loads, generator, transformers, distribution lines and DGs [33] are shown in *table 1*.

Table 1. **Specification of transformers, Generators, DGs, Loads and Distribution Lines (DL)**

Equipment	Description
Generator	MVA =1000, V_{base}= 120KV, rated kV= 120, f= 50Hz
Distributed Generators DG1, DG2, DG3, and DG4	1.5 MW wind turbines. 5MW, 400V Emergency Diesel Generator
Transformers TR-1	MVA=50, f= 50 Hz, rated kV = 120/25, V_{base}= 25 kV, R_1=0.00375pu, X_1=0.1 pu, R_m=500 pu, X_m=500pu
TR-2, TR-3, TR-4 and TR-5	MVA=10, f= 50 Hz, rated kV = 575/25, V_{base}= 25 kV, R_1=0.00375pu, X_1=0.1 pu, R_m=500 pu, X_m=500pu
Distribution lines DL-1, DL-2, DL-3 and DL-4	Pi-section 20km each, rated KV =25, MVA= 20, V_{base}= 25 KV, R_0= 0.1153 ohms/km, R_1= 0.413 ohms/km L_0= 1.05e-3 H/km, L_1= 3.32e-3 H/km C_0= 11.33e-009 F/km, C_1= 5.01e-009F/km
Loading L1 L2, L3, L4, L5	15MW, 5Mvar 8MW,3Mvar

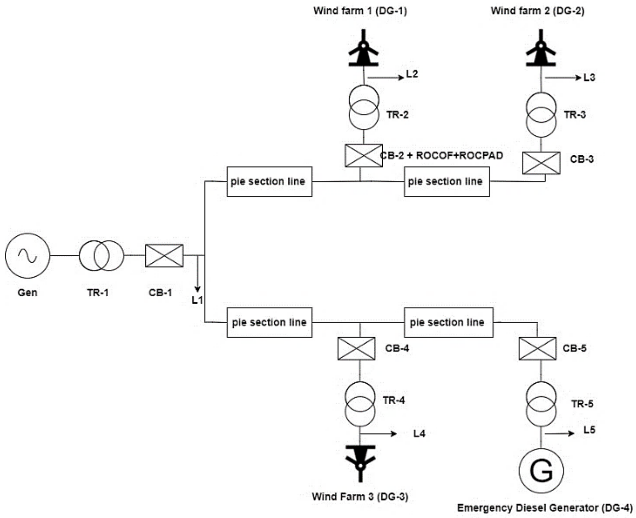

Figure 3: Diagram of Test System

4. RESULTS & DISCUSSION

There are many islanding detection methods known now days, the most common is ROCOF relay but the non–avoidable drawback of the ROCOF relay is that it does not detect islanding with power mismatches less than 15% and hence it is not reliable relay for small power mismatches condition. In the mentioned results both the condition of high-power mismatch as well as low power mismatch in case of ROCOF is depicted in *figure 4* and *figure 5* respectively.

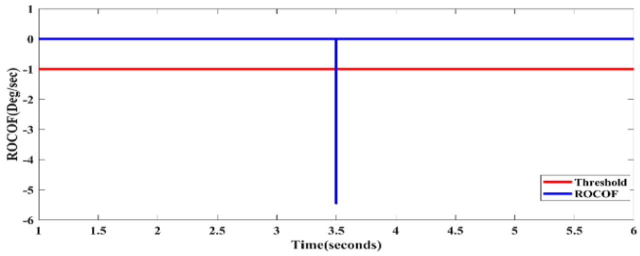

Figure 4: The dynamic performance of ROCOF under high power mismatch

From the outcomes depicted in *figure 4* and *figure 5*, it is driven that the ROCOF technique shows detection for the high-power mismatch condition not for the low power imbalance. It is discovered that the suggested 3PSF for ROCPAD performs well under these circumstances *i.e.* the detection of islanding instantaneously without any delay for the high and low (zero) power mismatch condition which are illustrated in *figure 6* and *figure 7*.

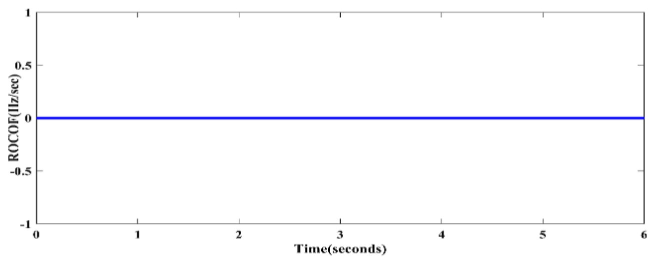

Figure 5: The dynamic performance of ROCOF under low power mismatch

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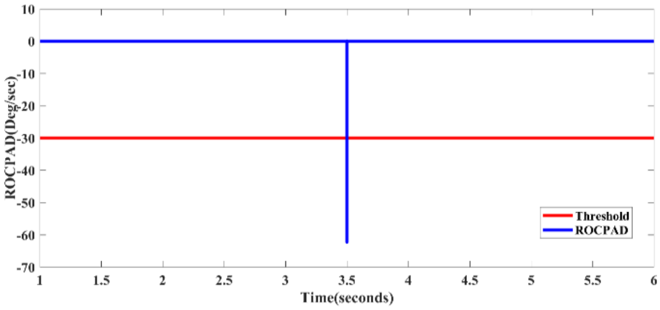

Figure 6: The dynamic performance of 3PSF for ROCPAD under high power mismatch

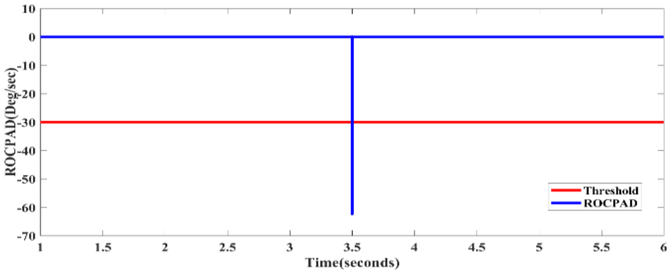

Figure 7: The dynamic performance of 3PSF for ROCPAD under low power (zero) mismatch

In the given test system shown in the *figure 3*, the ROCOF and 3PSF for ROCPAD relay are connected to the wind farm 1 through circuit breaker 2, and if the islanding is done on PCC through circuit breaker 1 at 3.5 seconds the ROCOF fails to detect but 3PSF for ROCPAD relay detecting the islanding which are illustrated in *figure 8* and *figure 9* respectively.

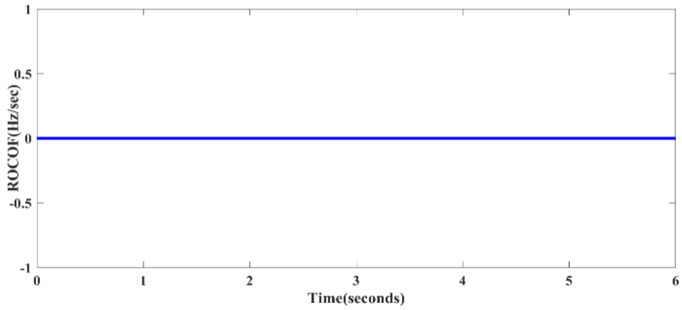

Figure 8: The failure of detection of islanding by ROCOF at PCC through opening the CB1 at 3.5 seconds

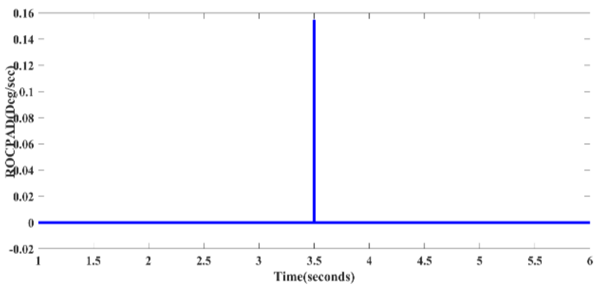

Figure 9: The detection of islanding by 3PSF for ROCPAD at PCC through opening the CB1 at 3.5 seconds

Now, the islanding is done at adjacent DG-2 by switching the CB 3 at 3.5 seconds, the effect of this islanding (CB-3 opening) is observed at DG-1 in the proposed radial test system. The results depicted in *figure 10* and *figure 11* indicating that the ROCOF fails to detect but the 3PSF for ROCPAD detecting the islanding clearly.

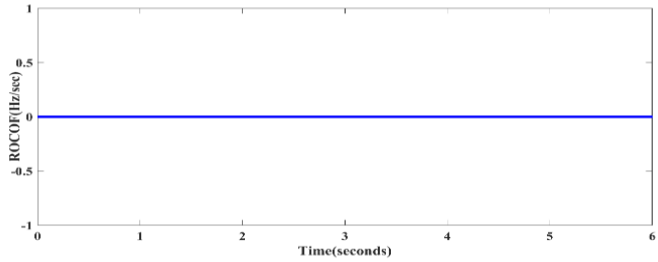

Figure 10: The failure of detection of islanding by ROCOF at adjacent DG (DG-3)

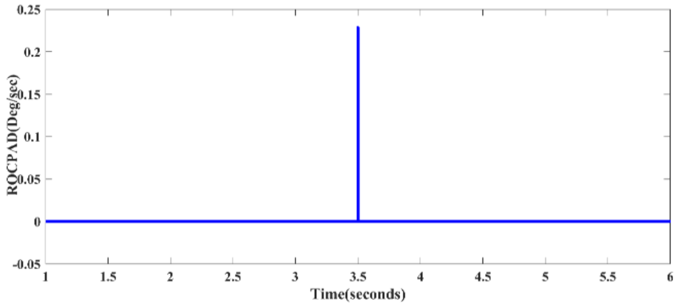

Figure 11: The detection of islanding by 3PSF for ROCPAD at adjacent DG (DG-3)

Both the techniques are now checked for the loss of distribution line. Here the results displayed in *figure 12* and *figure 13* presents that the ROCOF fails to detect but 3PSF for ROCPAD detect this loss of line.

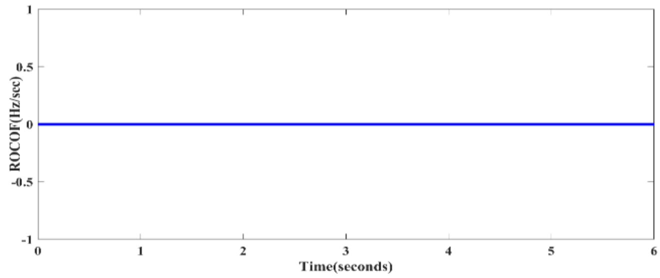

Figure 12: The failure of detection of distribution line loss by ROCOF

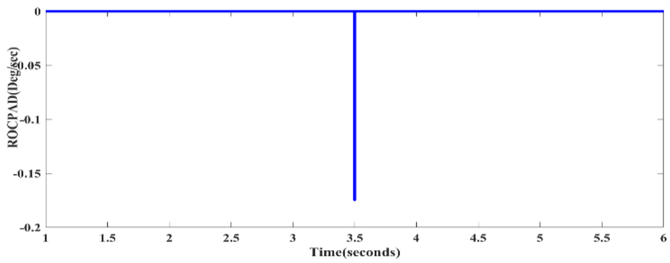

Figure 13: The detection of Distribution line loss by 3PSF for ROCPAD

Further the active load shedding is done from 10% to 80 % and the observation is illustrated in *figure 14* and *figure 15* for the ROCOF and 3PSF for ROCPAD respectively.

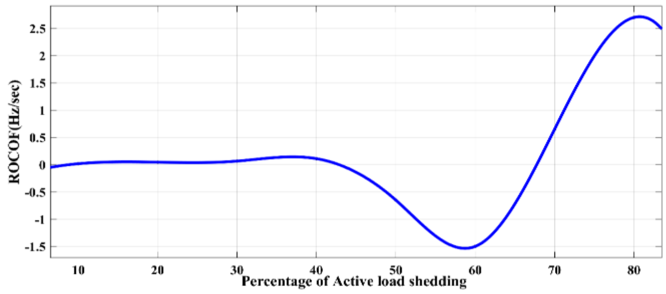

Figure 14: Performance of ROCOF in Active load shedding

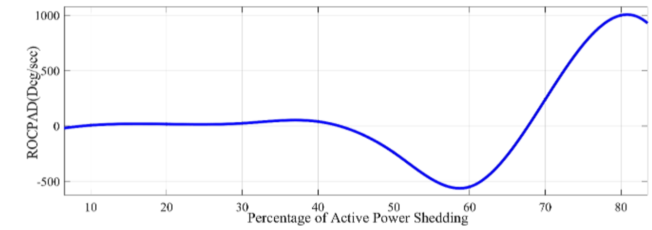

Figure 15: Performance of 3PSF for ROCPAD in Active load shedding

A novel empirical mathematical model for the load shedding is developed to observe its effect on ROCOF and 3PSF based ROCPAD. The equation is as follows:

$$F(x) = \frac{(x_{i+1}-x)^3}{6h} M_i + \frac{(x-x_i)^3}{6h} M_{i+1} + \frac{(x_{i+1}-x)}{h}(y_i - \frac{h^2}{6} M_i) + \frac{(x-x_i)}{h}(y_{i+1} - \frac{h^2}{6} M_{i+1}) \quad (19)$$

The following assumptions are taken for f(x) as mentioned here under:

- Outside the interval (x_o,x_n) f(x) exits as the linear polynomial.
- In each of the subintervals, the polynomial f(x) is a cubic one.
- For each point, f'(x) and f''(x) are continuous.

Here, f'' (x_i) = M_i and h = x_{i+1} - x_i

M_i can be calculated from the following equation

$$M_{i-1} + 4M_i + M_{i+1} = \frac{6}{h^2}(y_{i-1} - 2y_i + y_{i+1}) \quad (20)$$

Where i=1 to (n-1) and y_i = f(x_i)

As we know that M_o=0 and M_n=0 since the graph is linear for $x<x_o$ & $x>x_n$.

The results of the active load shedding for ROCOF and 3PSF based ROCPAD are displayed in *figure 14* and *figure 15* respectively. This is observed clearly that there is no appreciable change in the graph till 40% change of existing load thereafter the appreciable change is observed. So, it is understood that load shedding should not be above 40 % of existing load otherwise relay will detect islanding.

5. CONCLUSION

The suggested 3PSF approach detects islanding instantaneously with 0% power mismatch situation. It also detects islanding in case of loss of lines and load shedding. A novel empirical mathematical model for variation of loads shedding is observed on both the techniques *i.e.* ROCOF and 3PSF based ROCPAD and it is seen that the detection is identified above 40% load shedding. The 3PSF based ROCPAD relay has the ability to recognize the islanding at PCC as well as in the adjacent DG.

REFERENCES

[1] Wright, P. S., Davis, P. N., Johnstone, K., Rietveld, G., & Roscoe, A. J. (2018). Field measurement of frequency and ROCOF in the presence of phase steps. *IEEE Transactions on Instrumentation and Measurement*, *68*(6), 1688-1695.

[2] Vieira, J. C., Freitas, W., Xu, W., & Morelato, A. (2006). Efficient coordination of ROCOF and frequency relays for distributed generation protection by using the application region. *IEEE transactions on power delivery*, *21*(4), 1878-1884.

[3] Basso, T.; DeBlasio, R. IEEE 1547 Series of Standards: Interconnection Issues. IEEE Trans. Power Electron. 2004, 19, 1159–1162.

[4] Etxegarai, A., Eguía, P., & Zamora, I. (2011, April). Analysis of remote islanding detection methods for distributed resources. In *Int. conf. Renew. Energies power quality* (Vol. 1, No. 9).

[5] Bratton, R. E. (1984). Transfer-trip relaying over a digitally multiplexed fiber optic link. *IEEE transactions on power apparatus and systems*, (2), 403-406.

[6] Redfern, M. A., Barrett, J., & Usta, O. (1995). A new microprocessor-based islanding protection algorithm for dispersed storage and generation units. *IEEE Transactions on Power Delivery*, *10*(3), 1249-1254.

[7] Ropp, M. E., Aaker, K., Haigh, J., & Sabbah, N. (2000, September). Using power line carrier communications to prevent islanding [of PV power systems]. In *Conference Record of the Twenty-Eighth IEEE Photovoltaic Specialists Conference-2000 (Cat. No. 00CH37036)* (pp. 1675-1678). IEEE.

[8] Xu, W., Zhang, G., Li, C., Wang, W., Wang, G., & Kliber, J. (2007). A power line signaling based technique for anti-islanding protection of distributed generators—Part I: Scheme and analysis. *IEEE Transactions on Power Delivery*, *22*(3), 1758-1766.

[9] Prakash, S., Purwar, S., & Mohanty, S. R. (2020). Adaptive detection of islanding and power quality disturbances in a grid-integrated photovoltaic system. Arabian Journal for Science and Engineering, 45(8), 6297-631.

[10] Bejmert, D., & Sidhu, T. S. (2014). Investigation into islanding detection with capacitor insertion-based method. *IEEE Transactions on Power Delivery*, *29*(6), 2485-2492.

[11] Rostami, A., Abdi, H., Moradi, M., Olamaei, J., & Naderi, E. (2017). Islanding detection based on ROCOV and ROCORP parameters in the presence of synchronous DG applying the capacitor connection strategy. *Electric Power Components and Systems*, *45*(3), 315-330.

[12] Wen, B., Boroyevich, D., Burgos, R., Shen, Z., & Mattavelli, P. (2015). Impedance-based analysis of active frequency drift islanding detection for grid-tied inverter system. *IEEE Transactions on industry applications*, *52*(1), 332-341.

[13] Voglitsis, D., Papanikolaou, N., & Kyritsis, A. C. (2016). Incorporation of harmonic injection in an interleaved flyback inverter for the implementation of an active anti-islanding technique. *IEEE Transactions on Power Electronics*, *32*(11), 8526-8543.

[14] Azim, R., Li, F., Xue, Y., Starke, M., & Wang, H. (2017). An islanding detection methodology combining decision trees and Sandia frequency shift for inverter-based distributed generations. *IET Generation, Transmission & Distribution*, *11*(16), 4104-4113.

[15] Sun, Q., Guerrero, J. M., Jing, T., Vasquez, J. C., & Yang, R. (2015). An islanding detection method by using frequency positive feedback based on FLL for single-phase microgrid. *IEEE Transactions on Smart Grid*, *8*(4), 1821-1830.

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[16] Emadi, A., Afrakhte, H., & Sadeh, J. (2016). Fast active islanding detection method based on second harmonic drifting for inverter-based distributed generation. *IET Generation, Transmission & Distribution*, *10*(14), 3470-3480.
[17] Liu, M., Zhao, W., Wang, Q., Huang, S., & Shi, K. (2019). Compatibility issues with irregular current injection islanding detection methods and a solution. *Energies*, *12*(8), 1467.
[18] Du, P., Nelson, J. K., & Ye, Z. (2005). Active anti-islanding schemes for synchronous-machine-based distributed generators. *IEE Proceedings-Generation, Transmission and Distribution*, *152*(5), 597-606.
[19] Roscoe, A. J., Burt, G. M., & Bright, C. G. (2014). Avoiding the non-detection zone of passive loss-of-mains (islanding) relays for synchronous generation by using low bandwidth control loops and controlled reactive power mismatches. *IEEE Transactions on smart grid*, *5*(2), 602-611.
[20] Zamani, R., Hamedani-Golshan, M. E., Haes Alhelou, H., Siano, P., & R. Pota, H. (2018). Islanding detection of synchronous distributed generator based on the active and reactive power control loops. *Energies*, *11*(10), 2819.
[21] Tan, K. H., & Lan, C. W. (2019). DG system using PFNN controllers for improving islanding detection and power control. *Energies*, *12*(3), 506.
[22] Vieira, J. C., Freitas, W., Xu, W., & Morelato, A. (2008). An investigation on the nondetection zones of synchronous distributed generation anti-islanding protection. *IEEE transactions on power delivery*, *23*(2), 593-600.
[23] Pigazo, A., Liserre, M., Mastromauro, R. A., Moreno, V. M., & Dell'Aquila, A. (2008). Wavelet-based islanding detection in grid-connected PV systems. *IEEE Transactions on Industrial Electronics*, *56*(11), 4445-4455.
[24] Ning, J., & Wang, C. (2012, July). Feature extraction for islanding detection using Wavelet Transform-based Multi-Resolution Analysis. In *2012 IEEE Power and Energy Society General Meeting* (pp. 1-6). IEEE.
[25] Zamani, R., & Golshan, M. E. H. (2018, April). Islanding detection of synchronous machine-based distributed generators using signal trajectory pattern recognition. In *2018 6th International Istanbul Smart Grids and Cities Congress and Fair (ICSG)* (pp. 91-95). IEEE.
[26] Liu, X., Zheng, X., He, Y., Zeng, G., & Zhou, Y. (2019). Passive islanding detection method for grid-connected inverters based on closed-loop frequency control. *Journal of Electrical Engineering & Technology*, *14*, 2323-2332.
[27] Abd-Elkader, A. G., Saleh, S. M., & Eiteba, M. M. (2018). A passive islanding detection strategy for multi-distributed generations. *International Journal of Electrical Power & Energy Systems*, *99*, 146-155.
[28] Bezawada, P., Yeddula, P. O., & Kota, V. R. (2021). A novel time-domain passive islanding detection technique for grid-connected hybrid distributed generation system. Arabian Journal for Science and Engineering, 46, 9867-9877.
[29] Kong, X., Xu, X., Yan, Z., Chen, S., Yang, H., & Han, D. (2018). Deep learning hybrid method for islanding detection in distributed generation. *Applied Energy*, *210*, 776-785.
[30] Kumar, M., & Kumar, J. (2023). A Solution to Islanding Event Detection Using Superimposed Negative Sequence Components-Based Scheme. Arabian Journal for Science and Engineering, 1-15.
[31] Bhatt, N., & Kumar, A. (2020). A passive islanding detection algorithm based on modal current and adaptive boosting. Arabian Journal for Science and Engineering, 45, 6791-6801.
[32] Abyaz, A., Panahi, H., Zamani, R., Haes Alhelou, H., Siano, P., Shafie-Khah, M., & Parente, M. (2019). An effective passive islanding detection algorithm for distributed generations. *Energies*, *12*(16), 3160.
[33] Samui, A.; Samantaray, S.R. Assessment of ROCPAD Relay for Islanding Detection in Distributed Generation. IEEE Trans. Smart Grid 2011, 2, 391–398