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Passive Islanding Detection in Microgrids Using Positive Sequence Voltage Difference

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This paper presents a new passive islanding detection method for a grid-connected hybrid distributed generation (DG) system. The method utilizes the Absolute Positive Sequence Voltage Difference (APSVD) at the point of common coupling (PCC) to identify islanding events. Detection occurs when the APSVD magnitude surpasses a set threshold for a specified duration. The proposed technique reliably differentiates between islanding (IS) and non-islanding (NIS) conditions across various operating scenarios, including cases with zero power mismatch. This method effectively eliminates the non-detection zone and false tripping caused by various non-islanding (NIS) events. The proposed technique is simple, requiring no classifier for implementation. Additionally, it is independent of utility network characteristics and can be applied to any number and type of distributed generation (DG) units. Compared to existing methods, the proposed approach achieves superior detection times. The results are validated using MATLAB simulations.

Keywords: DG-Distributed generation, APSVD-Absolute positive sequence voltage difference, IS-Islanding, NIS- Non-Islanding.

I. Introduction:

The deployment of distributed generation (DG) in distribution networks has grown significantly in recent years. This rapid expansion enhances system performance and efficiency while reducing power outages. However, several challenges must be addressed before successfully integrating DG units into the main grid. Among these challenges, islanding detection remains a critical issue in interconnected microgrids.[1].

1.1 Motivation:

Islanding happens when a portion of the power grid loses communication with the utility system because of malfunctions or other disruptions, and it is fueled by a local distributed generation system. Situations involving islands can be dangerous. the security of linked equipment, employees, and clients. For islanding estimate, the IEEE 1547 standards provide a maximum detection time of two seconds. As a result, DGs need to have islanding detection systems installed; precise and reliable islanding detection is crucial.

1.2 Literature Analysis:

using active approaches to produce a feedback loop. Conversely, when the power imbalance is small and near zero, passive approaches have a large NDZ [3]. The DGs can function as designed in a safe environment within the NDZ. According to IEEE 1547 regulations, for best performance, the frequency should be between 59.3 and 60.5 hertz, and the voltage should be between 88% and 110% of its rated value. The majority of passive and some active techniques are unable to identify islanding within this practical range. Furthermore, parameter changes and detection mistakes may result from NIS occurrences such short-circuit failures. Numerous passive techniques, including over/under voltage and over/under frequency, have been observed in studies. Numerous passive techniques, including over/under voltage and over/under frequency, have been observed. .Rate of change of frequency (ROCOF) [4], rate of change of power factor angle [5], rate of change of phase angle difference [6], voltage ripple [7], rate of change of active power [8], rate of change of voltage phase [9], rate of change of superimposed negative sequence impedance [10], and reference impedance magnitude are just a few of the detection techniques that researchers have developed. [11] rate of change of positive and negative sequence current [12], frequency oscillation [13], duffing oscillators [14], reactive power change rate [15], Forced Helmholtz oscillator [16], inverse hyperbolic secant function of negative sequence voltage signal change rate [17], and sequence component of superimposed voltage [18]. Feedback and modal components[19] feedback-based [20]. vent index value [21], Numerous techniques for islanding identification based on different transformations, including wavelet, S-transform, and empirical mode decomposition, have been published in a number of publications[22]. The best results were obtained by a small number of researchers who developed and experimentally validated low power mismatch islanding and other non-islanding scenarios [23] ,[24],[25] and [26]. Nonetheless, there are a number of benefits and drawbacks to the aforementioned methods. Several different approaches to island detection have been proposed throughout time. The two primary subcategories of detection techniques are local and remote. The DGs and substations must have wired or wireless communication in order to identify remote islanding. Because local approaches are simpler and less expensive than distant detection techniques, they are preferred for islanding recognition [2] Local detection methods come in three varieties: hybrid, active, and passive. A modest external disturbance is injected into a fraction of the DG or PCC terminals.

1.3 Contribution and Structure of the Article:

An unexpected and prolonged change in PCC voltage, which is used to identify the islanding, may occur as a result of the lack of grid stability during islanding. In order to address the drawbacks of current techniques, this work proposes fresh approaches to islanding detection using the APSVD of the PCC voltage. The PCC voltage signal is continually measured and observed by the sequence analyser. Islanding is detected and IS and NIS situations are differentiated using the difference between the measured and grid-connected PSV. Both DGs are utilized using the suggested method to independently identify islanding.

This article's noteworthy contributions will include the following:

- Utilizing the specified threshold value, accurately distinguish between NIS and IS circumstances.
- Compatible with all international standards and applicable to any converter-based integrated DGs.
- In comparison to earlier studies, the simulations that were yielded the best results.
- The need for adaptive thresholds is avoided by selecting a single threshold level that functions in every operating scenario.
- Identifies islanding in situations with changing loads.

Simulation findings for various islanding and NIS scenarios demonstrate the viability of the suggested approach. The structure of the remaining article is as follows: **Section II** provides a description of the hybrid DG test structure. The proposed algorithm and methodology are detailed in **Section III**. **Section IV** presents the results and discusses the implications of the proposed approach. Lastly, **Section V** provides the concluding remarks.

II. Test system under consideration:

The test setup consists of a two photovoltaic (PV) system supply input power. As illustrated in Fig. 1, the system PV system with a voltage source converter (VSC) connected to the grid. The PV system is linked in series with the VSC through a DC-DC link capacitor. In the PV system, the DC link voltage is regulated by the maximum power point tracking (MPPT) output. To maintain a unity power factor during DC-to-AC conversion at the required voltage and frequency for grid transmission. The PV system have power capacities of 250 kW each [27].

III. Proposed Islanding detection method:

3.1 A symmetrical component in time domain: The concept of symmetric components was first introduced to analyze unbalanced polyphase networks.[28]This technique allows the decomposition of an unbalanced three-phase system (V_{abc}) into three distinct components: **positive-sequence** V_{abc}^{1}, **negative-sequence** V_{abc}^{2}, **and zero-sequence** V_{abc}^{0}, This decomposition helps in understanding and analyzing the steady-state behavior of unbalanced systems.

$$V_{abc} = V_{abc}^{1}+V_{abc}^{2}+V_{abc}^{0} \quad \textbf{(1)}$$

From a common three phase voltage matrix V_{abc}.The symmetric components for phase "α" can be derived as $V_S = TV_{abc}$, Where $V_S = [V_\alpha^1, V_\alpha^2, V_\alpha^0]T$ T is the transformation matrix.

$$\begin{bmatrix} V_\alpha^1 \angle\theta_\alpha^1 \\ V_\alpha^2 \angle\theta_\alpha^2 \\ V_\alpha^0 \angle\theta_\alpha^0 \end{bmatrix} = \begin{bmatrix} 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \\ 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} V_a \angle\theta_a \\ V_b \angle\theta_c \\ V_c \angle\theta_c \end{bmatrix} \quad (2)$$

Where $\alpha = e^{j120°}$

$$V_b^1 = \alpha^2 V_a^1 : V_c^1 = \alpha V_a^1 \quad (3)$$
$$V_b^2 = \alpha V_a^2 : V_c^2 = \alpha^2 V_a^2 \quad (4)$$
$$V_a^0 = V_b^0 = V_c^0 \quad (5)$$

Since this is a frequency-domain method, Lyon [29]improved it by computing the symmetrical components in the time domain using a time-shifting operator. We used the same transformation detailed for the phase "*a*" to find the instantaneous positive, negative and zero sequence components.

$$\begin{bmatrix} V_\alpha^1 \\ V_\alpha^2 \\ V_\alpha^0 \end{bmatrix} = \begin{bmatrix} 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \\ 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} V_a(t) \\ V_b(t) \\ V_c(t) \end{bmatrix}$$

Where $Va(t)$, $Vb(t)$and $Vc(t)$ denote the instantaneous voltages in three phases.

Using the discrete form, we can determine the instantaneous positive, negative and zero sequence components for phase "*a*"as,

$$V_a^1(k) = \frac{1}{3}[V_a(k) + V_b(k + \theta_1) + V_c(k + \theta_2)] \quad (7)$$

$$V_a^2(k) = \frac{1}{3}[V_a(k) + V_b(k + \theta_2) + V_c(k + \theta_1)] \quad (8)$$

$$V_a^0(k) = \frac{1}{3}[V_a(k) + V_b(k) + V_c(k)] \quad (9)$$

Where 120 degrees of phase shift corresponds to the sample quantities θ_1 and 240 degrees of phase shift corresponds to θ_2. The instantaneous value of the positive sequence voltage component of a symmetrical three-phase network is equal to that of a phase, while the instantaneous value of the negative sequence voltage component and the zero sequence voltage component are both zero.

3.2 Proposed Islanding detection with APSVD:

When a PV inverter operates in steady state, there is a little variation in the output power due to high switching frequencies and DC link voltage ripple. Because the impedance of the grid, these variations are often absorbed and have little impact on the voltage of the PCC. However, because the grid stability effect is lost after islanding, these oscillations become considerable. Following islanding, the PCC level single-phase voltage as V_{1s}.

$$V_{1s} = V_g \sqrt{\frac{P_{inv}}{P_{load}}} \quad (10)$$

Vg denotes the grid's RMS phase voltage, P_{inv} is the three phase inverter mismatch output power, and P_{load} denotes the load's power consumption. Because$V_g$and P_{load} are regarded constants, any difference in the power of $P_{inv}$is instantly reflected is V_{1s}. To further improve the performance of the proposed technique, APSVD is calculated as follows:

$$\text{APSV D} = |\,(V_{pcc}^1)\text{ instantaneous} - (V_{pcc}^1)\text{ nominal}\,| \quad (11)$$

The APSVD is calculated from the absolute output of the difference measured and nominal positive sequence voltages at the PCC as APSVD are given in

$$\text{APSVD} = \frac{1}{T}\int_{t-T}^{T} |\text{APSVD}(t)|\,dt \quad (12)$$

In this expression, T is the duration of the signal and t is the instantaneous time (s).

3.3 Islanding detection Signal: Assume that an islanding detection method can more rapidly find island solutions and precisely pinpoint the NIS scenario and unique islanding characteristics. Consequently, the PSC is a crucial element of the suggested research methodology. Sequence analysers are utilized to measure the three-phase voltages at the PCC. The output was then produced by feeding the recorded signals into a sequence approach that was based on the PSC. The APSVDM between the output and the gathered signals is the outcome of a sequence analyzers' processing.

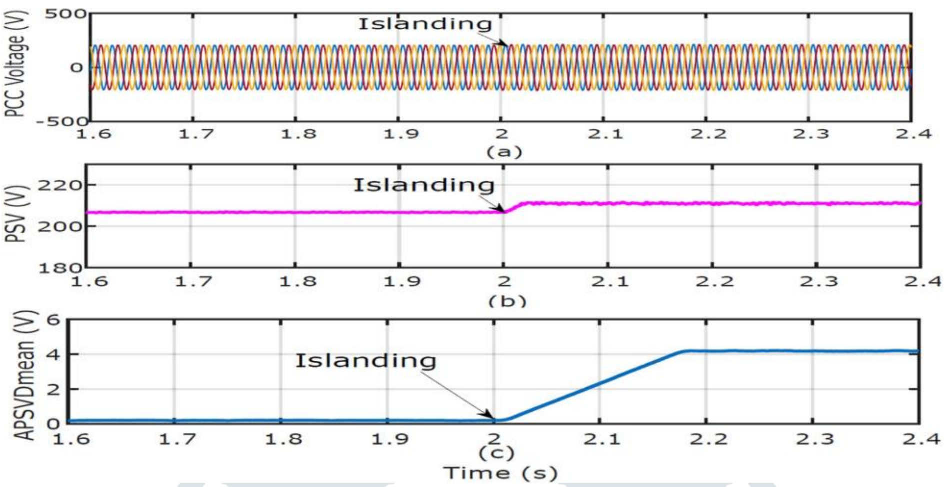

Fig.1 (a) 3 phase Voltage at PCC (b) PSV (c) APSVD

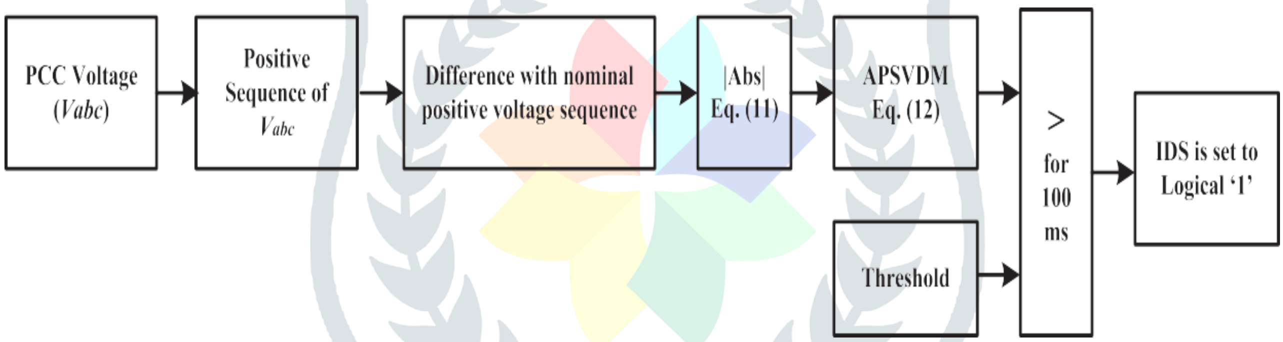

Fig 2. Proposed method of absolute positive sequence voltage difference means.

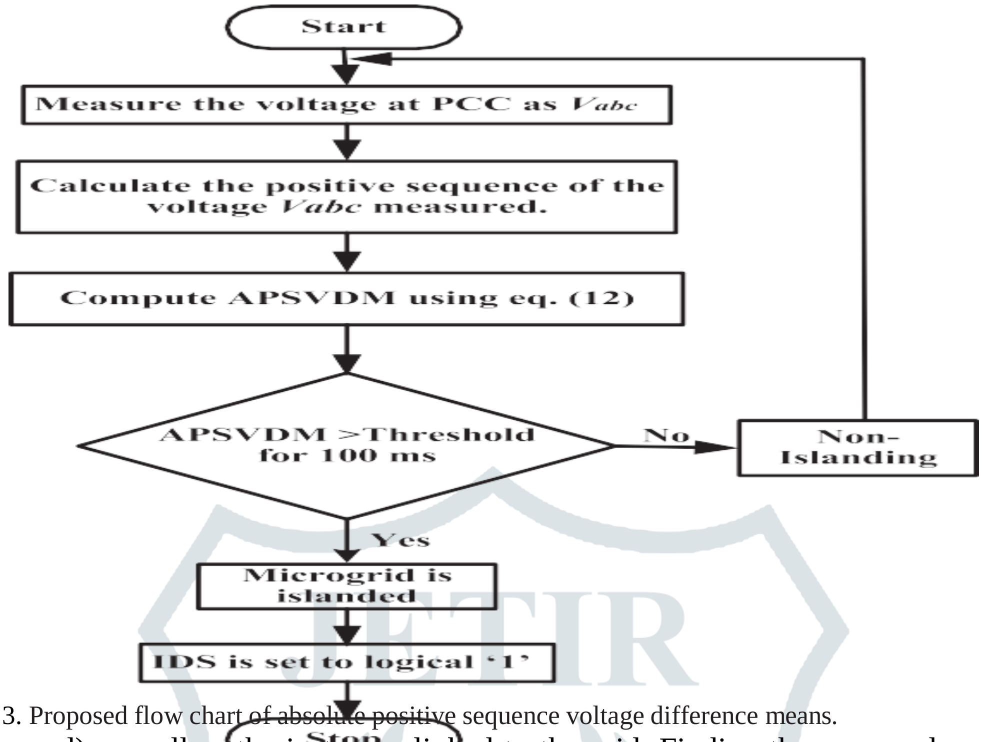

Fig 3. Proposed flow chart of absolute positive sequence voltage difference means.

(which was measured) as well as the instances linked to the grid. Finding the mean value offers a reliable standard by which to measure other values, such the threshold. If the mean value of the APSVDM is greater than the threshold by more than 100 ms, the timer sets the IDS to logic 1, which initiates islanding detection. If the calculated APSVD average is below the threshold, the IDS stays at logic 0. fig 3. shows the proposed flow chart for IDS. If the calculated APSVD average is below the threshold, the IDS stays at logic 0. Fig. 2 shows a block diagram depiction of the suggested process. After a great deal of NIS case modelling, the intentional 100 ms latency time was achieved. The suggested method is impervious to temporary misidentification brought on the NIS conditions because of the added time. Fig. 3 shows a flowchart that illustrates the steps of the recommended approach. The DG source can provide all of the required energy if there is no power imbalance between it and the load demand. This is the worst-case scenario being investigated here as passive techniques are unable to identify islanding. Fig. displays the waveforms generated by the recommended approach when the power distribution is equal. The effectiveness of the algorithm is tested in several IS and NIS scenarios.

IV. RESULT & DISCUSSION:

Several IS and NIS situations are used to assess the algorithm's efficacy. Table 4.1lists the number of tests carried out in each scenario type. 4.1 Islanding condition: A condition known as "islanding" will occur if the utility grid cuts off communication between the DGs and distribution system. hen actual and reactive power mismatches are small and the load has a certain quality factor, it might be particularly difficult to detect voltage changes under islanding detection guidelines. At time t = 2s, the primary circuit breaker is flipped, connecting the DG to the utility grid and validating the test system's stated scenarios.

4.1.1 Impact of quality factor: By varying the quality factor of the load, the suggested approach is examined under perfectly mismatched power conditions. A quality factor falls between 1 and 2.5, according to the islanding detection recommendations. A more reactive load, denoted by a larger Qf, reduces oscillations in the voltage and current waveform after islanding. To ensure accurate identification even under the most severe circumstances, a quality factor of 2.5 has been given to the load. The response of the APSVDM and IDS to a situation in which the powers of all quality metrics are appropriately balanced is shown in Fig. 4. Regardless of power imbalance, the suggested approach ensures accurate island identification. This indicates that the proposed algorithm has no NDZ.

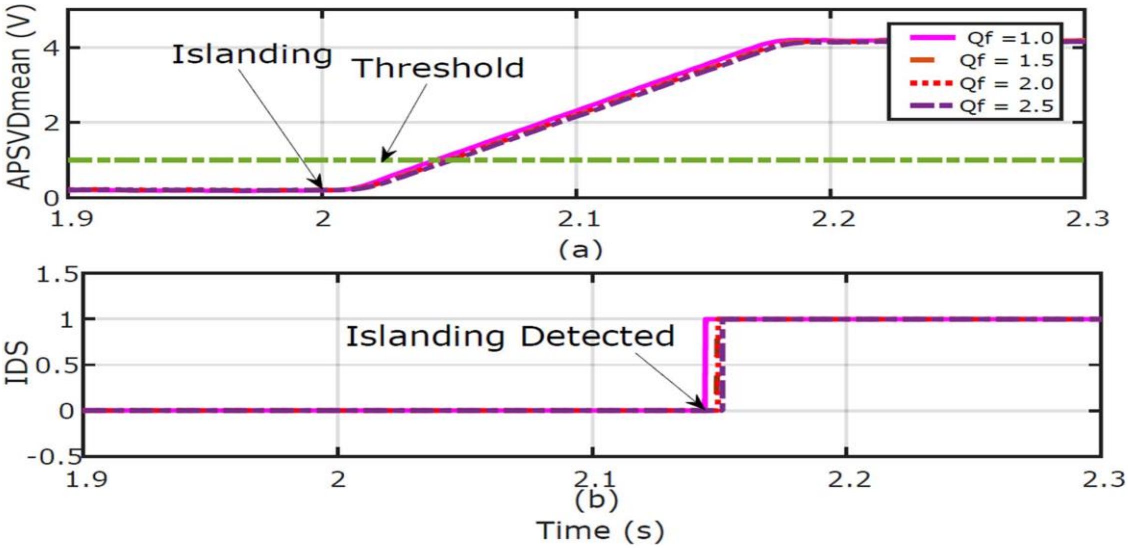

Fig. 4. (a) APSVDM for varying quality factor. (b) IDS.

4.1.2 Real power mismatch:

This analysis of the islanding phenomenon takes into account all potential values of the actual power imbalance between the distribution and utility grids. When dispersed generators and the central power grid are unable to provide enough energy to fulfil the needs of the distribution system's loads, a power mismatch arises. The DG capacity is greater than the load capacity if the real power imbalance is positive, and vice versa. Variations in actual power between 2% and 20% are examined to see if they improve or diminish possibilities. Assume that the power imbalance variance is more than 20%. Voltage levels would diverge from the NDZ region in such a situation, resulting in the greatest imbalance, which we estimated to be about 20%. Fig. 5. shows the reactions of APSVDM and IDS based on different actual power imbalances. Therefore, regardless of the actual power imbalance, the method under discussion may accurately detect an islanding occurrence.

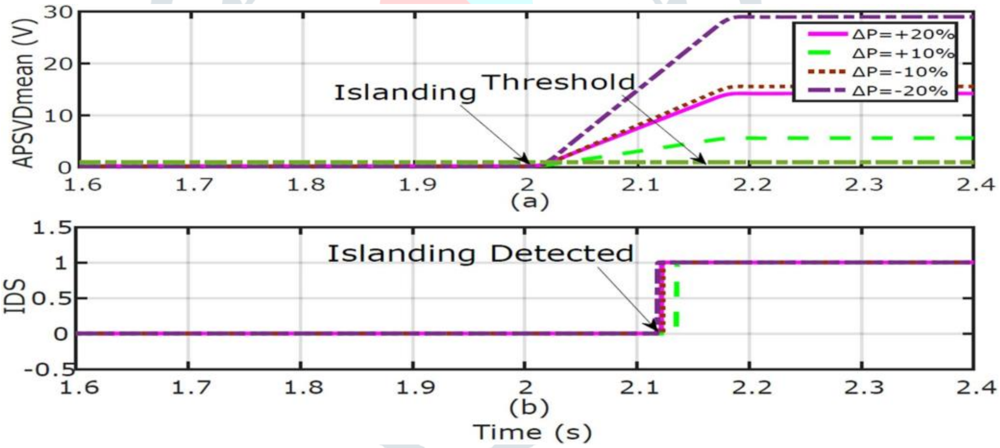

Fig 5. (a) APSVDM for real power mismatches (b) IDS.

4.1.3 In analyzing the islanding phenomenon, various amounts of reactive power imbalance between the DG and the grid are considered. For several different amounts of reactive power imbalance, islanding happens at time 2sec. Fig. 6 shows the sensitivity of APSVDM and IDS to reactive power imbalances. It is shown that the suggested method can detect an islanding event even when the reactive power imbalance is extreme. Positive and negative reactive power variations (0.2% to 2.0%) are analysed. The frequency will drift away from the NDZ if the reactive power imbalance exceeds +2% or falls below −2%, respectively

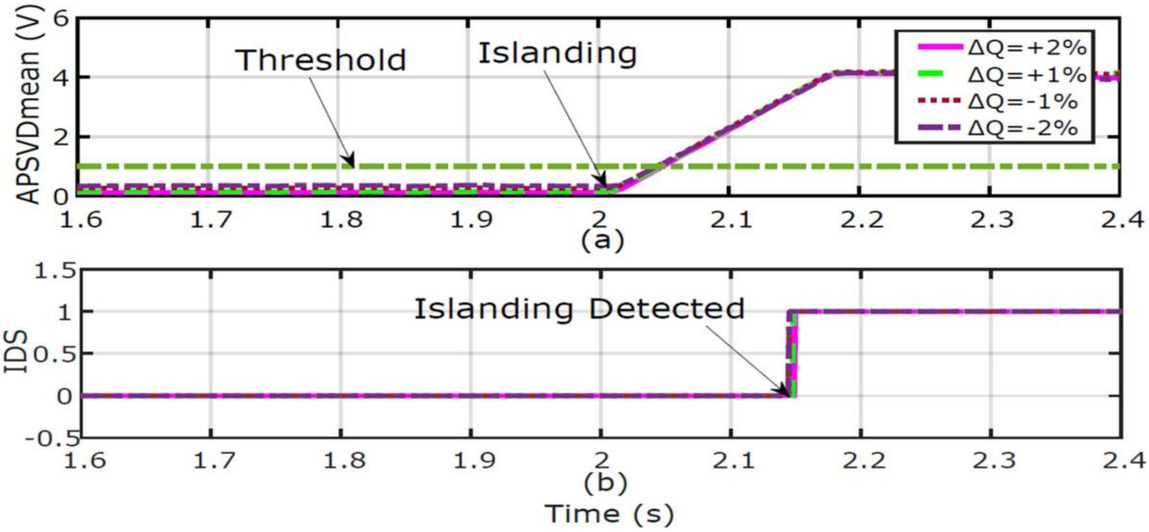

Fig 6 (a)PSVDM for reactive power mismatches (b) IDS.

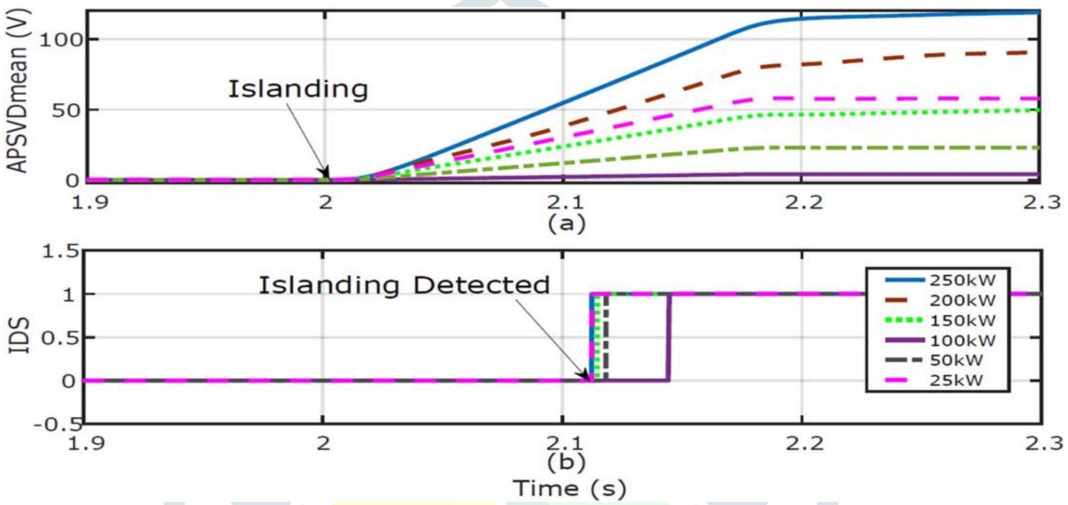

Fig.7 (a) APSVDM for different DG powers. (b) IDS

Table 1 Different tested scenario:

Event	Variation	No. of test
Islanding		
Active power mismatch	-20% to +20%	20
Reactive power mismatch	-2% to +2%	20
Quality factor	1 to 2.5	8

4.1.4 This part compares the islanding detection timings of the suggested technique for various Q_f to literature detection times. Table 2. shows the suggested islanding.

Reference	Q-factor	Detection time (ms)	Ref.	Q-factor	Detection time (ms)
[2]	1	>340	[30]	2.5	>200
[7]	1	>300	[31]	2.5	>350
[11]	2.5	<350	proposed	1	140
[14]	1.57	<600		1.5	145
[16]	0.96	<454		2	148
[1]	2.5	>325		2.5	152

Table 2. Comparison table for proposed islanding with literature

Table 2 shows the suggested islanding approach is faster than earlier studies.

V.CONCLUSION:

This article describes a passive approach to islanding detection utilizing the APSVDM. The result shows how effective the proposed technique is in identifying important IS and NIS events for load quality factors, zero-power mismatch and capacitor switching. It has been demonstrated that the proposed method detects inadvertent islanding significantly faster than previous islanding detection techniques. Selecting a single threshold eliminates the requirement for adaptive thresholds in various operational scenarios detection approach is faster than earlier studies. Additionally, any DG having an inverter interface may use the process. For all loads Qf < 2.5, islanding with 0% NDZ is identified, and it conforms with all international standards.

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