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Review

An Extensive Overview of Islanding Detection Strategies of Active Distributed Generations in Sustainable Microgrids

Faisal Mumtaz [1,*], Kashif Imran [1,*], Abdullah Abusorrah [2,3] and Syed Basit Ali Bukhari [4]

[1] USPCAS-E, National University of Sciences and Technology (NUST), Islamabad 44000, Pakistan
[2] Renewable Energy and Power Systems Research Group, Center of Research Excellence in Renewable Energy and Power Systems, King Abdulaziz University, Jeddah 21589, Saudi Arabia
[3] Department of Electrical and Computer Engineering, Faculty of Engineering, K. A. CARE Energy Research and Innovation Center, King Abdulaziz University, Jeddah 21589, Saudi Arabia
[4] Department of Electrical Engineering, The University of Azad Jammu and Kashmir, Muzaffarabad 13100, Pakistan
* Correspondence: fmumtazphd21.ces@student.nust.edu.pk (F.M.); kashifimran@uspcase.nust.edu.pk (K.I.)

Abstract: Active distributed generations (ADGs) are more prevalent near consumer premises. However, the ADG penetration contribute a lot of dynamic changes in power distribution networks which cause different protection and control issues. Islanding is one of the crucial problems related to such ADGs; on the other hand, islanding detection is also a challenging aspect. Therefore, an extensive review of islanding real-time depiction and islanding detection strategies (IDS) is provided in this work. Initially, the focus is on islanding detection concept depiction, islanding detection standardization, benchmark test systems for IDS validation, and software/tools and an analysis of their pros and cons. Then, the detailed classification of IDSs is presented with an emphasis on remote and local methods. Passive, active, and hybrid can be used further to categorize local IDSs. Moreover, the statistical comparative analysis of the IDSs based on the non-detection-zone (NDZ), cost-effectiveness, and false operation are mentioned. The research gap and loopholes in the existing work based on limitations in the existing work are presented. Finally, the paper is concluded with detailed recommendations.

Keywords: active distributed generations; islanding detection; non-detection-zone; smart grids sustainable grids

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1. Introduction

1.1. Background and Motive

The power system is undergoing a significant transition from conventional grids to next-generation grids. The conventional grids comprise three basic divisions: electricity generation at far sites, transmission networks, and distribution networks. Consequently, the incorporation of renewable-energy-source-based ADGs into a distribution network has very much common [1]. The availability of ADGs and their favourable effects on the environment make them the consumer end's first choice in comparison to conventional electricity generation resources [2–5]. Moreover, the ADG units are divided into two categories:

- Grid-forming voltage control units;
- Grid-following current control units.

The ADG units are often operated as grid-following in grid-tied mode, while they are operated as grid-forming in islanded mode [6,7]. This dynamic operational mode of the modern grids posed a lot of challenges in the operation of the existing protection devices. Therefore, managing the transmission of electrical energy and various parallel activities is beyond the capabilities of the usual control and protection strategies [8]. The researchers thoroughly reviewed and evaluated islanding operations to propose the finest way-out for a technical operation of the main utility grid and modern ADG-based microgrids [9,10].

1.2. Problem Statement and Literature Review

Massive blackouts and power system disasters throughout history reflect the reality that utility loss has culminated in severe protection and economic collapses [11]. The stability of power system networks may be threatened by these ADGs with inverter-dominated and non-inverter-dominated facilities, numerous loads, and a complicated control facility [12]. Several protection challenges were reported in the literature review faced by these modern distribution grids due to the penetration of renewable-energy-source-based ADGs [13]. Despite their benefits, ADGs pose some difficulties for power distribution networks.

Unintentional islanding in the ADG-based networks has become a significant issue among all of these challenges [14]. When the dispersed generator keeps feeding the electrical network long after the utility/main grid is cut off [15], the maintenance team is not at risk from planned islanding, but they are at risk from unplanned islanding [16]. Unintentional islanding presents a danger to the shelter of the power system and could spoil utility operations, maintenance personnel, and equipment [17]. Consequently, islanding in power grids is a threatening problem for protection methodology engineers because of the dynamic conditions of ADGs. In addition, due to the halted utility operation caused by unintentional power system islands, ADG unit voltage and frequency levels may become severely impacted [18,19]. Moreover, in an islanding scenario, the ADG units cannot deliver enough fault current to trigger the traditional protective mechanisms [20–22]. Such islanding could harm the system's hardware, jeopardize the dependability of the power supply, and endanger the life of the maintenance personnel. International technical organizations, such as IEC and IEEE, update the codes of the interconnection of ADGs and islanding every 2 to 3 years, emphasizing the significance of islanding detection [23].

Islanding can be categorized as intentional or unintentional islanding. Intentional islanding is a somehow planned situation whereas unintentional islanding occurs during several changes in the system [24]. The major challenge faced by the system due to the addition of ADGs is unintentional islanding, leading to various problems of insufficient grounding of equipment and two-way power flow, causing the loss of safety of workers, affecting the synchronism of the voltage and frequency of synchronous generators and converters (inverters) [25,26], and causing power quality (sag and swell) issues due to the reverse power flow phenomena. Islanding identification is a crucial and challenging job involved with integrated power distribution networks [27–32]. Unintentional islanding detection will become increasingly important and difficult as ADG integration grows. To address these issues, numerous new IDSs have been designed and modeled [33]. The rules for intentional and unintentional islanding detection provide safe operating approaches and lessen the effects of ADG islanding when properly implemented [34]. However, islanding is still an unsolved research issue, as evidenced by the several IDSs that have been presented over the years [35].

To overcome this challenge of unintentional islanding of the microgrid, multiple research schemes have been suggested to address the issue and lessen the problems with islanding detection [36]. This research work provides a thorough analysis of the various IDSs that have been reported in the literature. The two main types of IDSs are remote approaches and local IDSs [37]. The distributed generator side of islanding detection is handled by local methods, but the utility grid side is handled by remote methods, which rely on communication channels to disconnect the ADGs [38]. Therefore, the local techniques are further divided into signal processing, computational intelligence, as well as hybrid, passive, and active strategies [39–41]. The active methods deliberately introduce minor turbulences on the ADG side to judge the turbulences, contrary to the techniques that employed the electrical parameters at the ADGs, and the hybrid strategies combine both passive and active strategies [42]. Apart from the proposed active, hybrid, and remote techniques, passive techniques were the most effective methods compared to all other techniques, but they also presented various issues. Passive methods utilized/determined the system parameters (Voltage, Frequency, Current, and Power) at the point of common coupling (PCC) for unintentional islanding detection [43]. A graphical depiction of analytical data based on existing literature reviews for various kinds of IDSs from 2001–2022 is shown in Figure 1.

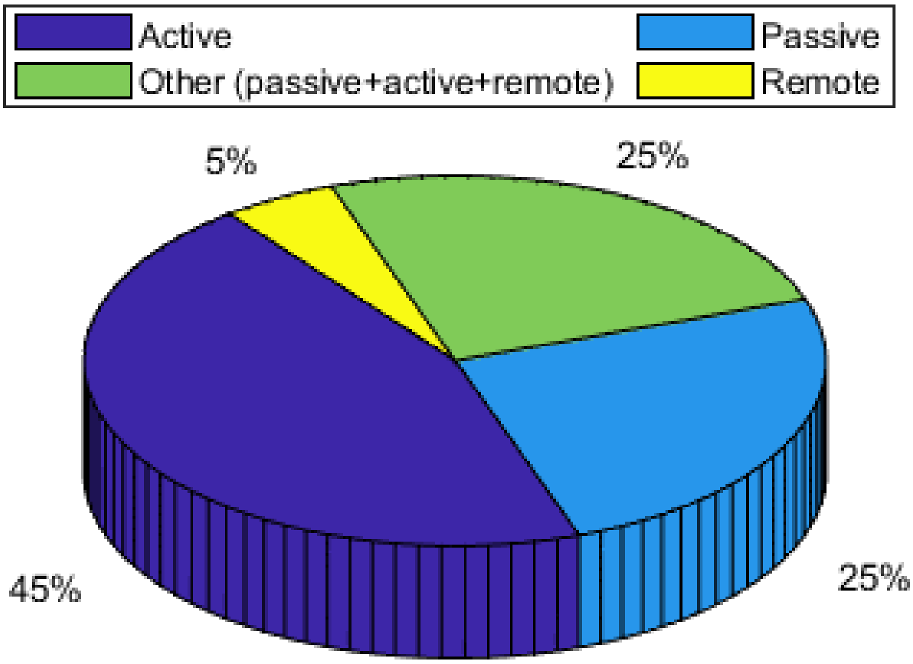


Figure 1. Kinds of IDSs: a graphical depiction of analytical data, 2001–2022 [27–36].

The low cost and low power quality issues of the passive strategies make them simpler and more advantageous to use, but they come with a bigger non-detection zone (NDZ) and are more susceptible to threshold setting. Although the NDZ for active methods is much smaller, they are linked to power quality issues [44]. To overcome the problems of large NDZs and failure of the scheme during negligible/zero power mismatch, modified passive islanding detection techniques had been suggested that practiced/employed signal-processing and various machine-learning-based approaches along with passive techniques. These modified passive schemes helped in reducing the problem of larger NDZs and made the scheme more effective and accurate. Signal-processing and computational-intelligence-based approaches, which are capable of handling complicated nonlinear system issues, have been employed to address the islanding detection challenge [45]. Few islanding detection methodologies make use of sophisticated mathematical, intelligent, and signal-processing methods as effective identification tools available in the literature [46–48].

1.3. Limitations of the Existing Research

The previous researchers comprehensively addressed islanding challenges but there are still a lot of limitations.

- They had high implementation costs due to the exorbitant devices such as PMUs [10,16,22,49]
- Few of the schemes could not be more accurate for small-scale systems as compared to other islanding detection techniques [12,16,18].
- They also produced a high computational burden on the system, and power quality issues [11,31].
- Some schemes do not address the noisy measurement issue, while real power network measurements had a noisy data set [16,22,38].

1.4. Significant Value Additions

In this study, an extensive review of the islanding detection and IDSs of ADGs has been reported. The value additions of the presented work are as follows:

- Islanding detection is depicted with a real-time scenario for the better understanding of the readers.
- A detailed and extensive review is presented of the existing international standards regarding the islanding detection issue.
- International test beds are discussed thoroughly that are utilized for NDZ analysis.
- A detailed classification is presented of the IDSs according to state-of-the-art research work.
- The detailed and comprehensive statistical comparative analysis is presented for the better understanding of the readers/researchers.
- The research gap in the field of the IDS problem is highlighted.
- The feature recommendations were also presented for the readers' understanding.

The rest of the review paper is structured into subsequent sections as depicted in Figure 2: Section 2 presents the definition, standardization, standard test systems, and software and tools. Section 3 explains the detailed categorization of islanding detection strategies based on existing work. Section 4 presents the statistical comparison of existing research in the field of IDSs. The research gap is mentioned in Section 5. Finally, the paper is concluded with recommendations in Section 6.

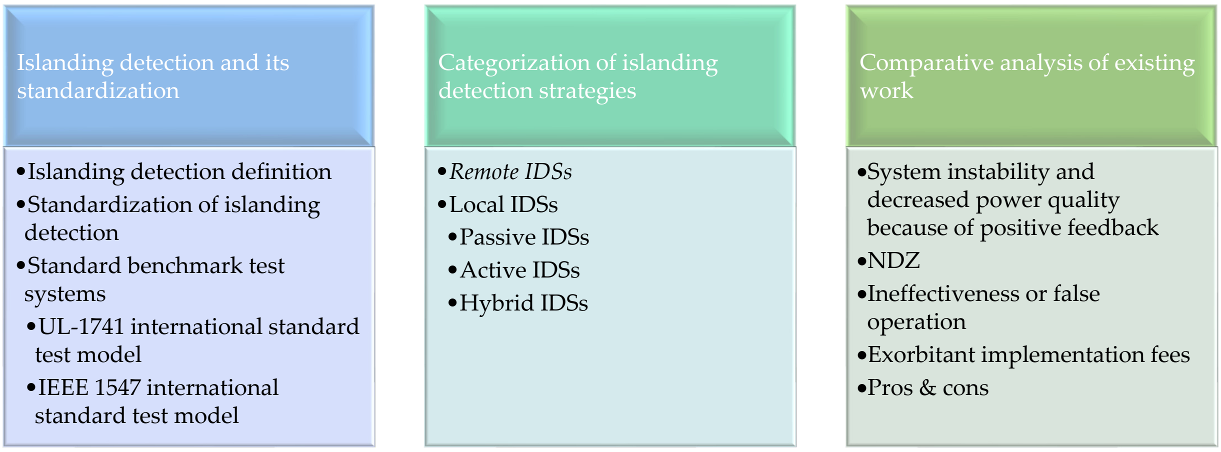


Figure 2. The layout illustration of the established review paper.

2. Islanding Detection and Its Standardization

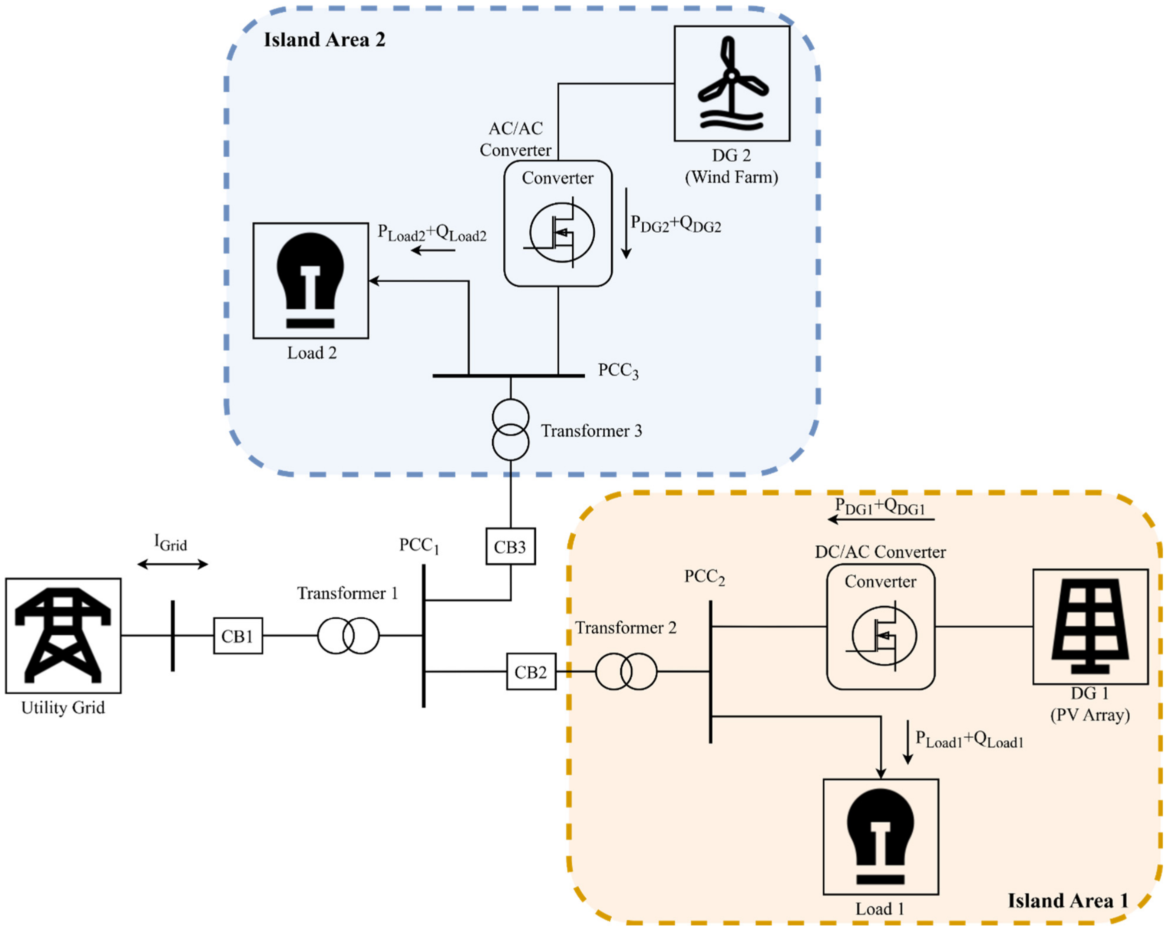
This section focuses on the definition and the standardization of the islanding detection concept. Secondly, two well-known international standards test systems named UL-1741 and IEEE 1547 required for the performance analysis of IDSs are elaborated here with their equivalent circuits. In addition, this section enlightens us on the software and tools used in the designing of islanding detection strategies with their detailed advantages and disadvantages.

2.1. Islanding Detection by Definition

The alternative of distributed electricity generation is being actively studied throughout the world, particularly in nations where the centralized power generation infrastructure is quite outdated and produces significant environmental damage [49]. According to Karlsson, "ADGs refers to a source of electrical power generation that is directly connected to the distribution grid or is located on the customer's side". One of the key issues with ADGs is the potential for isolating regions known as islands, that could continue to function regularly even if the electrical grid is cut off [50]. On the other hand, losses in the growth of power network islanding pose a challenging concern. For applications without detection and response, combining various techniques for islanding detection based on other work processes is preferable [51]. Initially, the islanding conditions are defined in two basic ways to better ease the reader's understanding:

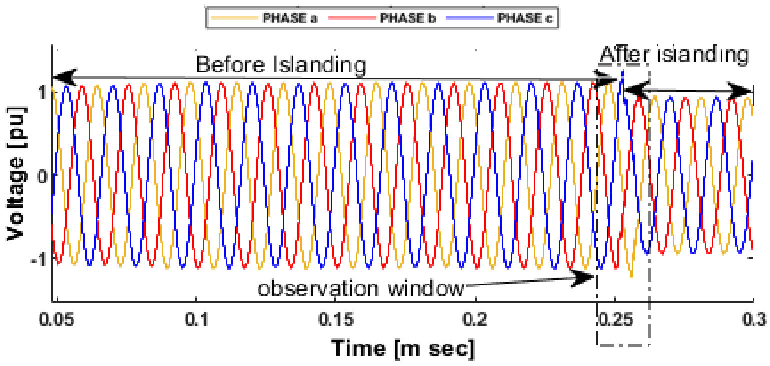
- "Islanding is a situation when an ADG shelves electrical power even when there is no sustained approach to the main electrical grid".
- "Islanding is a situation when the grid lost power from the main grid but there is uninterrupted power received by the loads from the distributed generation (DG) units".

Unintentional islanding of DGs can lead to equipment damage, grid protection system interference, power quality issues, and even safety risks for people. Islanding could be hazardous for utility maintenance workforces who might not be aware that a circuit is powered at a standstill since it might stop devices from automatically reconnecting [52]. Figure 3a depicts the islanding condition of ADGs in microgrids; different island areas depicted as Island Area 1 and Island Area 2 are connected to the main grid through the point of common coupling (PCC). The real-time voltage behavior of a simulation in a loop scenario during the islanding event at the PCC is depicted in Figure 3b. It is shown that the islanding event occurred at 0.25 m secs; it is challenging to detect such a minute change in voltage.



(a)

Figure 3. *Cont.*



(**b**)

Figure 3. (**a**) Islanding condition of ADGs in microgrids. (**b**) Voltage behavior depiction during islanding event at the PCC.

Without proper frequency control, the equilibrium between load and generation in the islanded circuit may also be disturbed, leading to abnormal voltages and frequencies [53]. ADGs are required to distinguish between islanding events and proximately disengage from the circuit as a result; this procedure is known as anti-islanding.

2.2. Standardization of Islanding Detection Methods

The following standardization is very crucial in any islanding detection scheme design. Therefore, in this review, a few islanding detection standards are addressed. In most international standards, the fundamental concept of islanding detection for the connected ADG grid is comparable. For the most common parameters that are under consideration in islanding detection, all consider the same factors, such as the quality factor, detection time, voltage/frequency thresholds, and network frequency [54]. The number of the aforementioned criteria, however, may vary. Unfortunately, an expensive inverter-based implementation results from the failure to adapt to various standards [55]. As a result, inverter and ADG equipment costs are greater than anticipated [56]. The primary criteria for several of the standards are presented in Table 1.

Table 1. Standardization of IDSs.

Standards / Parameters	IEEE1547.1	IEEE929 (2000)	BS EN 62116	BS EN 50160
Network frequency	60 Hz	60 Hz	50 Hz	50 Hz
Q_f	1	2.5	1	1
Islanding detection time	<2 s	<2 s	<2 s	<2 s
Voltage threshold	0.8 to 1.1 Pu	0.8 to 1.1 Pu	0.85 to 1.15 Pu	0.9 to 1.1 Pu
Frequency threshold	50.3 to 60.5 Hz	50.3 to 60.5 Hz	48.5 to 51.5 Hz	49 to 51 Hz

2.3. Standard Benchmark Test Systems

It is very crucial to validate the performance of IDSs for several islanding events, whether a scheme works well during harsh system conditions or may fail, such as how the NDZ of the passive schemes is very high when the load and generation are balanced, similarly to the fault going along to islanding in numerous ADG-dependent networks or the co-operation among several ADG systems that are provided with anti-islanding protection. Therefore, the performance analysis in such conditions has been performed on the standard benchmark test beds. A situation known as islanding occurs when a portion of the utility that controls both load and generation gets cut off from the rest of the system and keeps running. Islanding detection is part of the security standards for distributed generation (DG) imposed by IEEE Std. 929 and IEEE Std. 1547.

When an event of islanding appears, there are still some difficulties in the event of islanding detection that require more research, in order to design sustainable IDSs. Many renowned international organizations, such as IEEE and IEC, have produced particular codes for the operation, interconnection, and control of ADG systems with the main grid [57]. The networks that make up the integrated power system must adhere to certain criteria to be operational, evaluated, safe, and maintained. IEEE 1547 and UL-1741 are the two more prominent islanding test beds that are mostly used to assess the efficacy of any designed IDSs [58–60].

2.3.1. UL-1741 International Standard Test Model

The first test bed discussed in this review paper is a well-renowned UL-1741 International Standard Test Model. Figure 4 depicts the UL-1741 International Standard Test Model for islanding detection strategies validation [61]. It consists of a main grid model with the ADG unit interconnected with a PCC with a circuit breaker (CB). These specifications of inverters, charge controllers, converters, and interconnection system equipment (ISE) are used in grid-connected and islanded power systems [62]. The active load power is changed to place the inverter at 25%, 50%, 100%, and 125% of the inverter's rated output based on the UL 1741 Std. Adjustments are made to the reactive power in 1%-degrees within 95% and 105% of the balanced condition (unity power factor loading). To provide power, the inverters, shared loads, converters, and ISE are designed to be used in parallel with an electric power system [63].

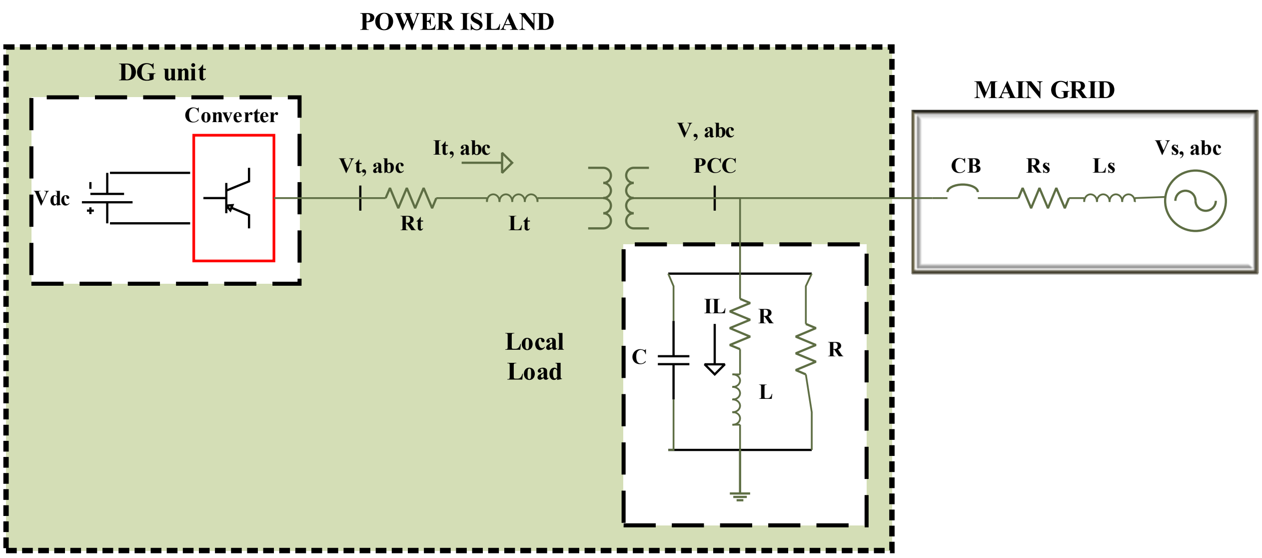


Figure 4. UL-1741 International Standard Test Model for islanding detection strategy validation.

2.3.2. IEEE 1547 International Standard Test Model

The second test bed discussed in this review paper is the IEEE 1547 test bed. Figure 5 shows the single-line diagram of the IEEE 1547 International Standard Test Model. The standards testbed covering the interconnection of ADGs was no doubt IEEE Std 1547, which was created by the Standards Coordinating Committee 21 on Photovoltaics, Fuel Cells, Storage Energy, and Dispersed Generation. According to the specifications of IEEE 1547, the DG is built to run with a power factor that is almost unity. The reactive power reference value (Qref) is typically set to zero, imitating a DG operating with a unity power factor. Two sets of controllers make up the DG interface: one is for controlling current, and the other is for controlling power. In response to a frequently voiced need for revisions to the subclauses about voltage control, the voltage response to Area EPS atypical circumstances, and frequency response to Area EPS atypical circumstances in IEEE Std 1547-2003, IEEE Std 1547 was updated in 2014 IEEE Std 1547a-2014 [64,65].

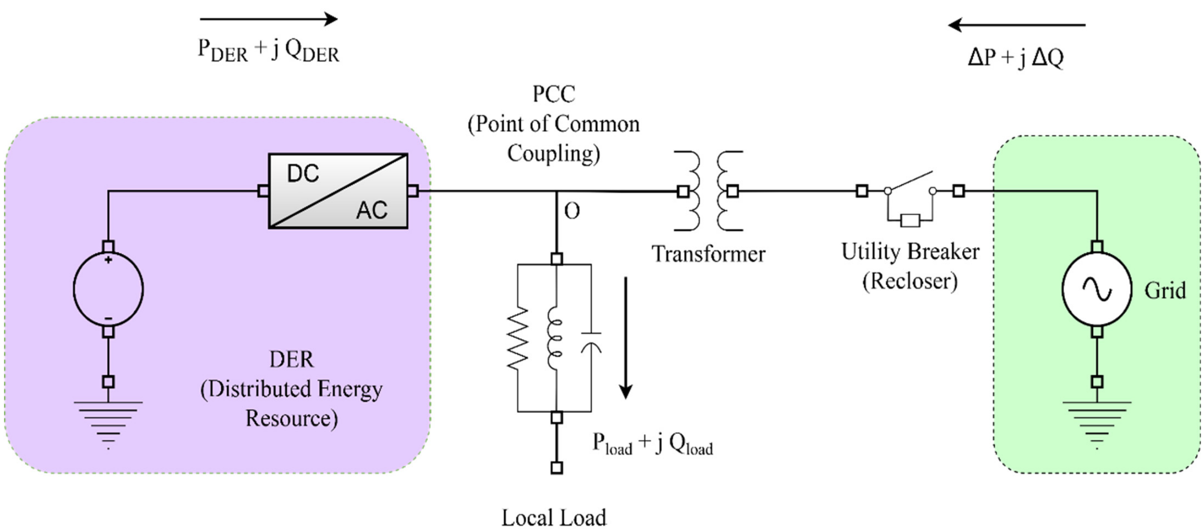


Figure 5. IEEE 1547 International Standard Test Model.

2.4. Software and Tools

The mathematical modeling and experimental validation of any IDS is a challenging task. The IDS stated in the literature reviews were modeled in the software in a loop environment, while the hardware in a loop environment was engaged for experimental validation of some IDSs. Different authors utilized different tools and software for the designing and validation of islanding detection schemes. MATLAB/Simulink is more prominently used in most of the research work during software in-loop analysis while other different software has also been suggested in previous work. However, during hardware validation of the proposed IDSs, the experimental setup is designed using dSPACE using control desk software and RT labs [66–73]. The advantages and disadvantages of the software and tools are shown in Table 2. Some of the software and tools utilized for the designing and mathematical modeling of IDSs as follows:

- MATLAB/Simulink software;
- ETAP software;
- DigSilent Power Factory ® software;
- Software phase-lock loop (SPLL) technology;
- HOMER simulation software;
- dSPACE using control desk software;
- PSCADEMTDC software;
- LabVIEW software;
- Hardware in the loop (HIL) by RT lab.

Table 2. Advantages and disadvantages of software and tools.

Software and Tools	Advantages	Disadvantages
MATLAB/Simulink software [40,66]	• Easy plotting of data and complex analysis. • MATLAB Coder converts user code to C++, Java, Python, Net, etc. • Supports parallel processing and GPU support.	• MATLAB's interpreted language is slow. • Only useful for scientific research; for product development, other languages are preferred. • Cost of license.
ETAP software	• Facilitates the design of electrical systems. • Ease of use. • Offers a wide variety of electrical studies.	• The interface is confusing for beginners. • Offers overwhelming configuration. • High system requirements.

Table 2. *Cont.*

Software and Tools	Advantages	Disadvantages
DigSilent Power Factory ® software [16,45]	• A leading power system analysis software application for analyzing generation, transmission, distribution, and industrial systems. • Provides sophisticated and advanced applications. • Easy to use, combines reliable and flexible system-modeling capabilities with state-of-the-art algorithms.	• Expensive license. • Lack of example materials for reference compared to Simulink.
HOMER simulation software [74,75]	• Simulates a list of real technologies. • Detailed results for analysis and evaluation. • Determines possible combinations of a list of different technologies and their size while providing rapid system combinations.	• High-quality and detailed input data are needed. • Experienced criteria are needed to converge to good solutions.
PSCADEMTDC software [35]	• Enables schematic construction of circuits, runs simulations, and analyzes and manages data in a completely integrated, graphical environment. Useful in the analysis of steady-state systems. • Powerful and flexible graphical user for EMTDC electromagnetic transient simulation engine.	• Supports only time plots, not able to plot harmonic magnitude or phase versus frequency. • Precise information on the power system is needed to accurately run the simulation.
LabVIEW software [28]	• Drag-and-drop user interface library for building models. - Modular design and hierarchical design. - Professional and multiple high-level development tools • Flexibility and scalability while reducing the cost.	• Expensive. • Cannot extend the development environment. • Outdated GUI elements.
Hardware in the loop (HIL) by RT lab [10]	• Offers an excellent alternative to traditional testing methods. • The physical plant is replaced by a precisely equivalent computer model, running in real-time on a simulator. • Can accurately reproduce the plant and its dynamics.	• HIL requires expensive equipment to run simulations. • HIL simulations do not support all complex algorithms and advanced models.

3. Categorization of Islanding Detection Strategies

The incorporation of ADGs is expanding daily as a result of the rapid breakthroughs in technology, science, and economics, as well as the need to protect the environment and the atmosphere [76]. Major advantages of integrating these ADGs into the distribution grid include boosting energy reliability and efficiency, lowering line deterioration, and enhancing power quality [77–79]. They serve to increase the system's dependability and efficiency in addition to being secure, affordable, clean, environmentally friendly, and cost-effective [80]. Traditional IDSs can be segregated into two groups: remote IDS and local IDS. In contrast to local IDSs, which monitor system parameters across the network, remote IDSs consider communications between the ADGs and the grid. The local IDSs are once more divided into active, passive, and hybrid IDSs. The detailed and generalized categorization of the IDSs is depicted in Figure 6.

3.1. Remote IDSs

Remote IDS are those schemes in which the islanding detection depends on the utility side instead of the ADG side. The remote methods rely on grid and network connectivity, which includes inverter-based ADGs and synchronous-based ADGs [81]. Strategies for detecting remote islanding rely on the communication between ADGs and utilities. Even though these methods might be more dependable than local ones, the improved signal-processing algorithms and communication set-up used for islanding detection is applied to the remote approaches. Remote IDSs are therefore not appropriate for small-scale systems, although they are frequently employed in large-scale projects. They are expensive to deploy and hence not practically viable. The remote IDSs have zero NDZ and are ADG-type-independent of the remote approach [39,78].

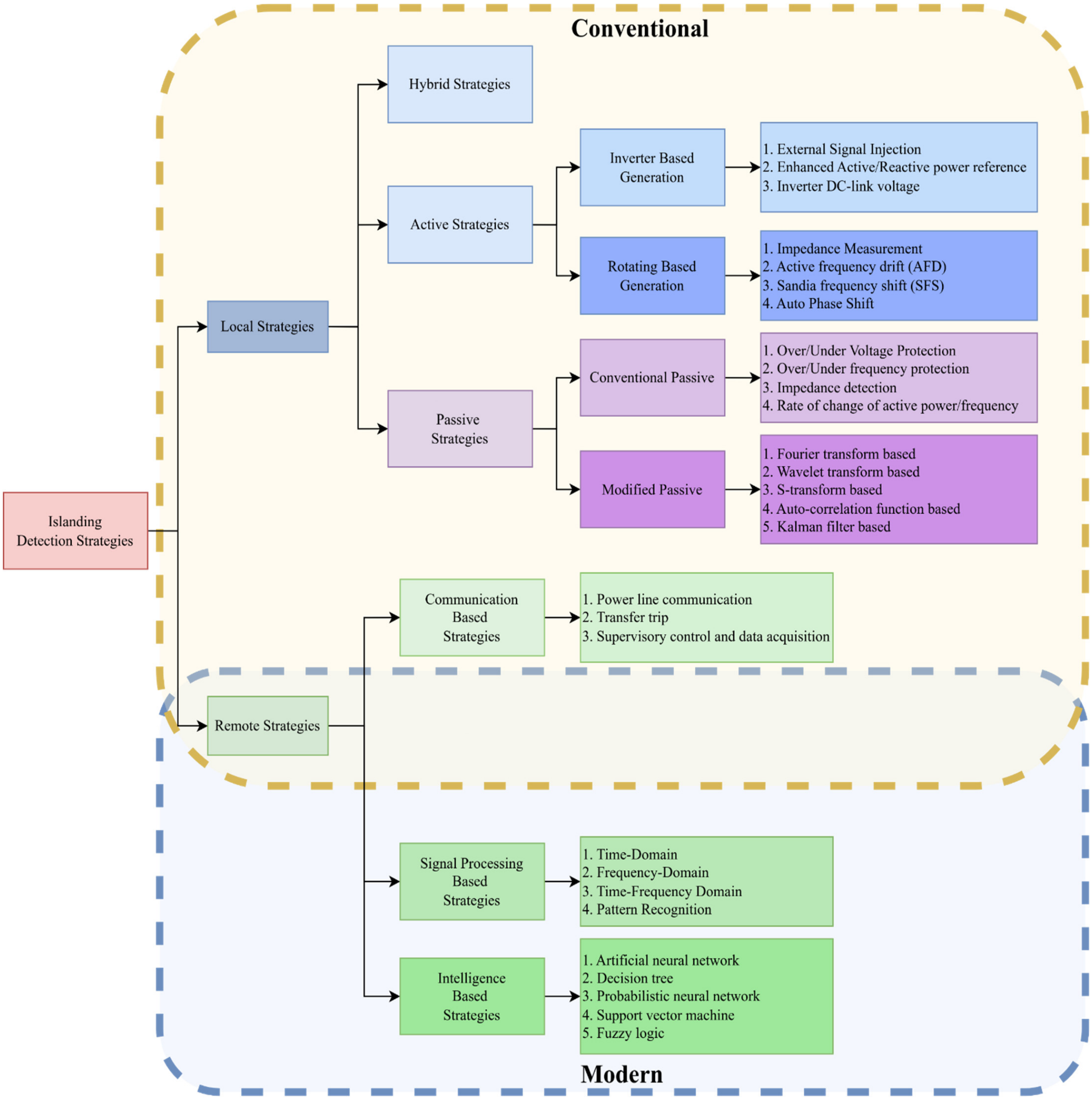


Figure 6. Detailed categorization of the islanding detection strategies.

3.2. Local IDSs

When the detection depends on the ADG side, islanding detection approaches call in the local detection methods. In comparison to local IDSs, remote IDSs have a low NDZ and high dependability [30,82]. Local IDSs are further categorized as the following:

3.2.1. Passive IDSs

The generalized workflow of passive IDSs is depicted in Figure 7. Initially, passive approaches measure system parameters including voltage, frequency, harmonic distortion, and other fluctuations. Then, these parameters are compared with predefined threshold settings; if they are more than the pre-defined threshold, the system is considered islanding.

In some advanced IDSs, the islanding detection indices were generated from the measured system parameters and these indices were compared with the threshold to identify the islanding conditions [8]. When the islanding occurred in the power network, these parameters vary remarkably from their normal values. However, the level of the pre-specified threshold setting has been used for determining whether a condition is islanding or non-islanded in both a direct parameter or index comparison. However, a lot of things are considered while setting the threshold value to exactly distinguish islanding from other system disturbances [83,84].

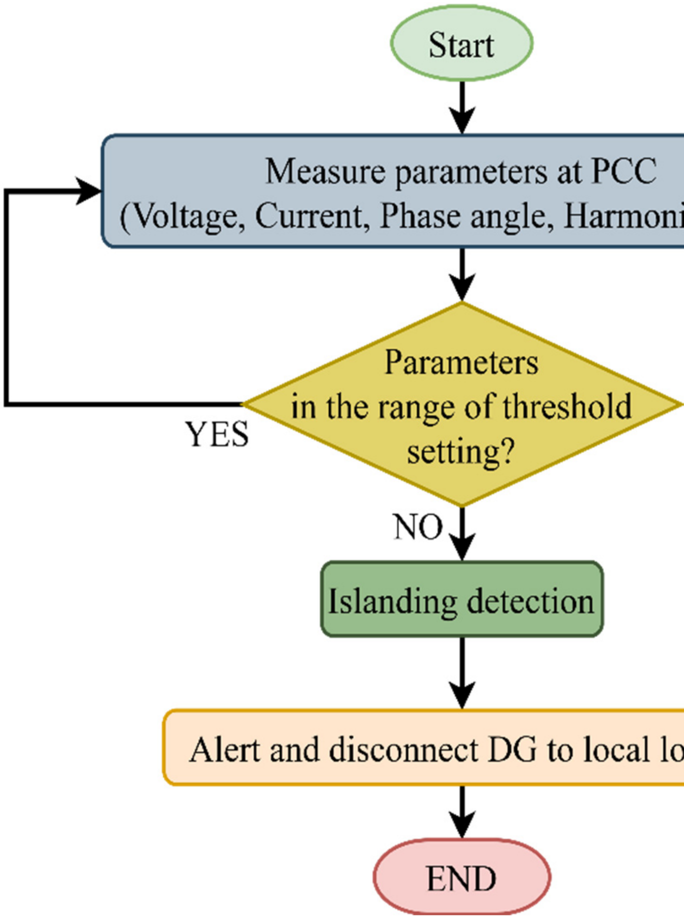


Figure 7. Generalized workflow of passive strategies.

Although passive IDSs are sharp and do not interrupt the system, they have a noteworthy NDZ where passive IDSs are incapable of detecting the islanding state. To find islanding scenarios, passive approaches rely on local measurements that are readily available. In actuality, a grid's abrupt islanding modifies some electrical properties including frequency and voltage [15,85,86]. Relays for over/under voltage and frequency are consequently the most used passive methods. Other methods depend on measurements of harmonic distortion, voltage phase, and rate of change of frequency.

- Over/under voltage;
- Rate of change of frequency;
- Over/under frequency;
- Voltage phase jump detection, etc.

3.2.2. Active IDSs

The generalized workflow of Active IDSs is depicted in Figure 8. When compared to passive IDSs, islanding can also be detected using active methods even when the generation and load are perfectly matched. By producing disturbances, active approaches directly influence how the power system operates [87]. Active approaches introduce minor disturbances that immediately affect how the power system operates. When the dispersed generator is islanded, these modest disturbances have a large impact on system characteristics, whereas they have less impact when it is connected to the grid. Phase shift techniques, impedance measuring techniques, and reactive power export techniques are some examples of active techniques [73,81].

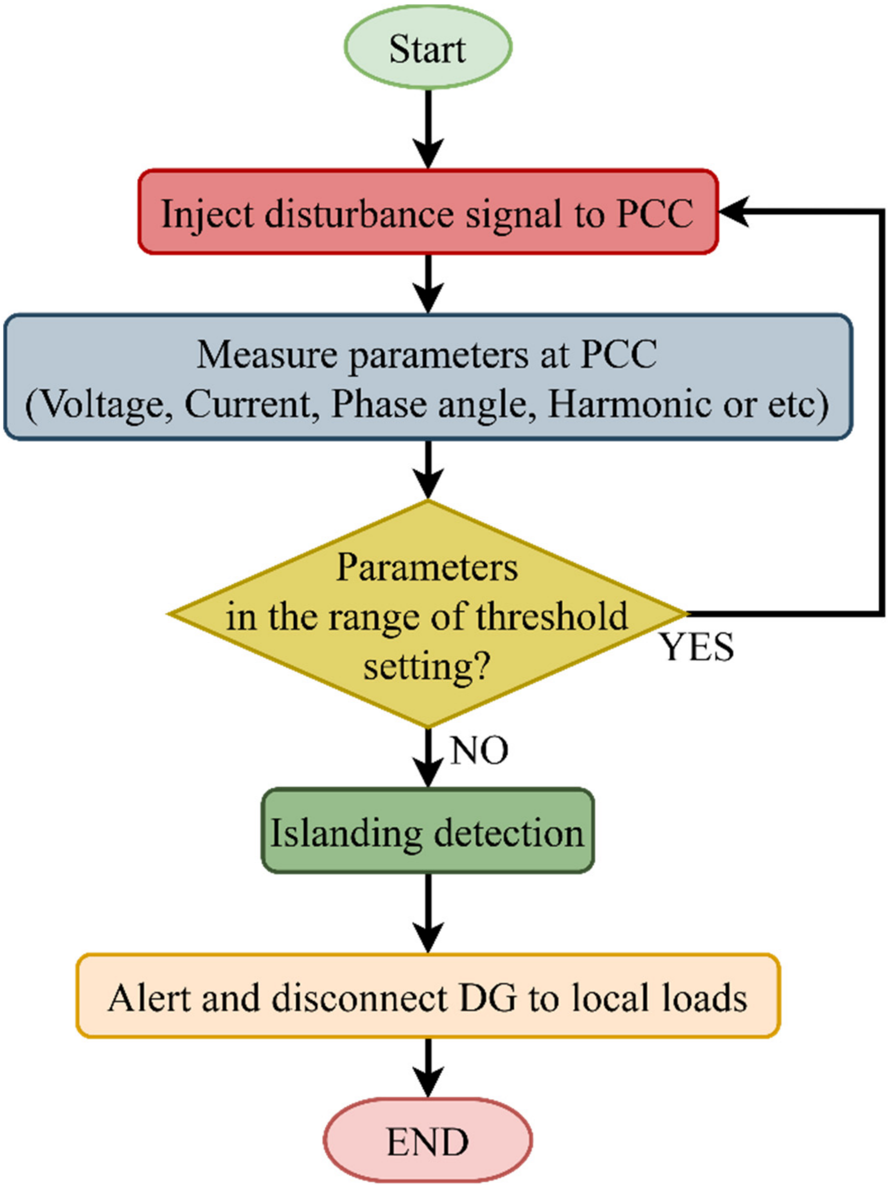


Figure 8. Generalized workflow of active strategies.

The rationale behind active IDSs is that this minor disturbance will cause a substantial variation in system characteristics when the ADG is unconnected from the grid but will have little effect when the ADG is connected [88]. Some of the most-stated IDSs in previous literature are based on the following:

- Negative-sequence current injection;
- Impedance measurement at a specific frequency;
- Impedance measurement;
- Slip mode frequency shift, etc.

3.2.3. Hybrid IDSs

Both active and passive IDSs are used in hybrid systems. Only when the islanding is suspected by the passive IDS is the active IDS used. Active and passive IDSs are collectively used to create hybrid IDSs [89,90]. To overwhelm the disadvantages of both passive and active IDSs and achieve greater effectiveness, hybrid methods use two levels of detection operations. The passive IDS is employed as the primary defence during the detecting operation, and the aggressive detection method is used when the passive method suspects islanding [27,91]. The generalized workflow of hybrid strategies is depicted in Figure 9.

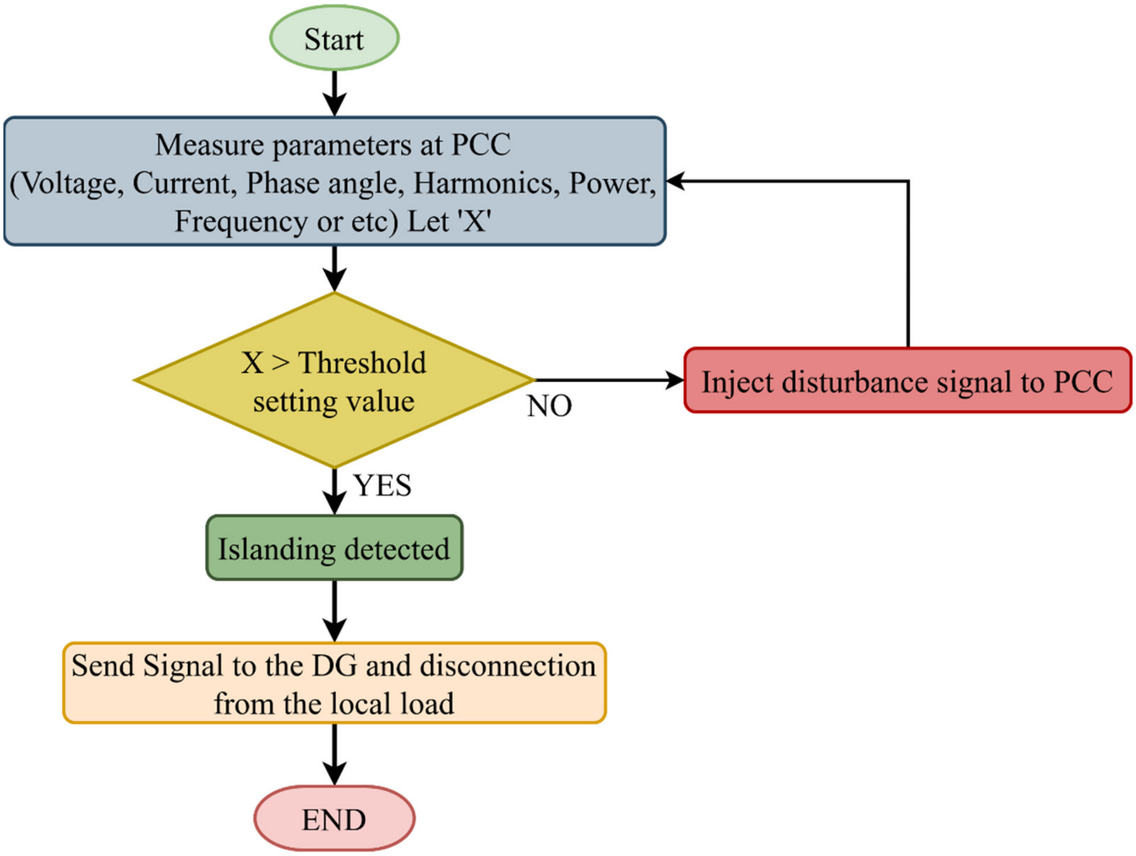


Figure 9. Generalized workflow of hybrid strategies.

4. Comparative Analysis of Existing Work

Before drawing any comparisons, it is necessary to understand the approaches' boundaries and how they should be applied. The following restrictions may apply to all the approaches mentioned:

- System instability and decreased power quality because of positive feedback;
- NDZ;
- Ineffectiveness or false operation;
- Exorbitant implementation.

Each IDS has apparent benefits and drawbacks, as seen from a thorough review examination. Although active IDSs and low NDZ have faster detection rates, their influence on power quality can reduce the effectiveness of power systems [27,77]. The islanding detection methods, their benefits and drawbacks, and some instances are listed in the Table 3.

Table 3. Comparative analysis of existing work.

Islanding Detection IDSs	Remote IDSs	Local IDSs		
		Passive IDSs	Active IDSs	Hybrid IDSs
Examples	1. Transfer trip method 2. Power line signaling method	1. Rate of change of output power method [29,32]. 2. Rate of change of frequency over power method [12,82]. 3. Harmonic distortion method [11,14]. 4. Voltage unbalance method [44,90]. 5. Change of impedance method [19,36]. 6. Rate of change of frequency method [29].	1. Phase (or frequency) shift methods (such as SMS, AFD, AFDPF, and ALPS) [17,89]. 2. Reactive power export error detection method [19]. 3. Impedance measurement method [15,91].	1. Technique depends on voltage and reactive power shift [88]. 2. Technique depends on positive feedback and voltage imbalance.
Pros	Highly reliable	1. A minimal identification period [2,10]. 2. Accurate in the islanded network when there is a substantial imbalance between generation and demand [39]. 3. Do not perturb the system [20].	Can identify islanding even when generation and demand in an island system are perfectly matched (small NDZ) [27,66].	1. When islanding is anticipated, disruption is merely injected. 2. Have very low NDZ.
Cons	Execution expenses are high, particularly for small networks [74,75,90–94]	1. Particular attention must be given while establishing thresholds [9,70]. 2. When the load and generation in the islanding system closely match, islanding is difficult to identify [34]. 3. Unwanted tripping may occur if the environment is overly hostile [16].	1. Cause the system to be perturbed [42]. 2. Perturbation frequently impairs the quality of the electricity and, if severe enough, may impair system stability even while linked to the grid [67]. 3. Because more time is required to observe the system's reaction to a perturbation, detection times are lengthy [77].	As both passive and active methods are used, the islanding detection time is increased.

There have been numerous IDSs put out, which can be generally divided into remote and local IDSs; every method has a benefit and a drawback. With a variety of system configurations, remote IDSs function well and have high dependability, faster detection speeds, and superior performance [9]. However, the main downsides related to remote IDSs are the implementation costs, operational efficacy, and failure due to communication link failure. Passive IDSs that employ conventional safety measures can identify the islanding condition. As a result, if the ADG and load power become balanced, they have a high NDZ; therefore, such IDSs fail in islanding detection. The modified passive IDM increases detection speed and reduces NDZ by employing frequency- and time-domain-based signal-processing techniques. These techniques are also more precise and efficient due to the usage of technology such as pattern recognition, artificial intelligence, and signal processing [7–9]. Considering better performance, a comparatively low NDZ, and increased trustworthiness by combining the advantages of both active and passive IDMs, hybrid IDSs may be the best method of detecting islanding [11]. The improved passive IDMs are consequently preferred due to their high reliability, precision, low cost, simplicity, and real-time industrial applications, as can be inferred from the foregoing talks. Additionally, compared to distant systems, these techniques are computationally light, making them a flexible method of islanding detection [20,26,92].

Grid-connected DGs must adopt the passive approach as a minimum standard because it is both affordable and practicable. Passive IDSs are also simple to utilize and do not degrade the quality of the power. The huge NDZ and challenges in threshold setting are disadvantages of passive IDSs [93]. Additionally, the passive IDSs are not always guaranteed, particularly in the load-source balance scenario. Since active IDSs are designed to lower the NDZ, most active methods have far less NDZ than passive methods, in some cases zero except when there are high Q-factor loads. However, the idea behind active IDSs is to destabilize the system to move the system's operating point toward the UFP/OFP and UVP/OVP trip limits [64]. As a result, active IDSs can reduce the stability of the system and the quality of the electricity. When more inverters are connected to the same DG, this problem will become more serious. On the other hand, a huge NDZ and, in some situations, a potential failure in detection are disadvantages of passive IDSs. To prevent malfunction, great care should be taken to set the proper detection threshold value for passive IDSs [38,41]. The kind of ADG and system parameters will have a big impact on the technique choice for islanding detection [57,63]. In recent years, hybrid IDSs have been proposed, and it appears that the hybrid IDSs are the best option for detecting islanding when changes in system parameters are significant and when launching an active IDS when those changes are not significant enough for a passive IDS to make an absolute unequal treatment [25,94].

5. Research Gap

This publication fills the research gap of ongoing research with a detailed review of many IDSs, classification, and a brief description of each approach.

- First, a summary of common techniques, including remote and local IDSs, was provided.
- The passive, active, and hybrid local IDSs are further divided into three categories. There follows a succinct explanation of signal processing and intelligent-based IDSs.
- Based on the benefits, drawbacks, and different capacity parameters, a thorough comparison of several approaches was offered.
- It is discovered that the NDZ of the passive IDSs is higher than that of the Active and Hybrid approaches.
- Although the NDZ is a less active technique, it lowers the quality of the power.
- In contrast to passive IDS, hybrid IDSs have a lower NDZ and combine the traits of both active and passive IDSs.
- Although the remote IDSs lack NDZ, they are extremely sophisticated when compared to the local approaches.
- Combining signal processing and intelligent schemes is the basic need of the modern world.
- Hardware in the loop validation of a lot of the schemes has not been provided; therefore, new researchers also focused on the specified area.

6. Conclusions and Recommendations

Near customer premises, ADGs are increasing rapidly, and their penetration has caused numerous dynamic changes in power distribution networks, which lead to a variety of protection and control problems. One of the main problems with these ADGs is islanding; however, it can be difficult to detect the islanding events. Hence, this paper provided a thorough review of real-time illustrations of islanding conditions and islanding detection strategies. Islanding detection conceptualization depiction and different international standardization have been a part of this review. The detailed focus is on software/tools with an analysis of their advantage and disadvantages; two benchmark test systems IEEE-1547 & UL 1741 was reviewed that were utilized for IDS validation. The thorough classification of IDSs is then provided, focusing mostly on local and remote techniques. In addition, the local IDSs' further categorization, named as passive, active, and hybrid categories, can be depicted with their general workflow. We also addressed the statistical comparison of the efficiency of the IDSs based on NDZ, cost-effectiveness, and ineffectiveness or false operation.

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