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Technical Report TA User Project

IsDHDG

Islanding Detection in Integrated Hybrid DG System

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Table of contents

Abbreviations

CB	Circuit Breaker
DER	Distributed Energy Resource
DG	Distributed Generation
IsDHDG	Islanding Detection in Integrated Hybrid DG system
MG	Microgrid
PCC	Point of Common Coupling
PSSC	Positive Sequence Superimposed Current
ROCPAD	Rate of Change of Phase Angle Difference
ROCOF	Rate of Change of Frequency
SCADA	Supervisory Control and Data Acquisition
SVM	Support Vector Machine
TA	Trans-national Access
TIV	Transient Index value
VVS	Voltage Vector Shift

Executive Summary

This document is the technical report on the ERIGrid TA project ***IsDHDG***. The report describes the objectives, experiments and comprises the obtained results and conclusions.

The motivation of the research stands on the observation of dynamic behaviour and transients of a distribution subsystem with multiple distributed energy resources to pre-planned and/or accidental switching events. The switching events may lead to islanding of the subsystem and formation of an autonomous microgrid. In this work, the islanding condition is detected by investigating the transient events and defining two new criterions i.e. transient index value (TIV) at the distributed generation terminal and positive sequence superimposed impedance angle (PSSC) at the point of common coupling.

The objective of the research is to implement and validate a new islanding algorithm in a developed microgrid system integrated with hybrid DGs, nonlinear loads, storage devices and capacitors, to overcome the drawback of conventional islanding detection techniques (large non detection zone and detection time) by utilizing the voltage and current information from both local and remote ends.

The proposed IsDHDG islanding algorithm is effective and accurate in discriminating the islanding and non-islanding events, reducing the non-detection zone, and assuring the reliability of the operation. Because of faster detection capacity (less than one cycle) and simple computational procedure, more reliable and secured way to detect islanding phenomenon is possible in digital platforms.

1 General Information of the User Project

USER PROJECT PROPOSAL	
User Project title	Islanding Detection in Integrated Hybrid DG System
User Project acronym	IsDHDG
Host infrastructure	Smart Grids Technologies Laboratory (SGTL) – TECNALIA, Spain
Name of the ACCESS PROVIDER representative	Emilio Rodríguez
Access period	14/06/2019 - 07/07/2019
N° of Access Days	15
Name of the User Group Leader	Ms. Ruchita Nale (NIT Raipur, India)
User group members	Ms. Ruchita Nale (NIT Raipur, India) Prof. Nand Kishor (MNNIT Allahabad, India)

2 Research Motivation

Recently, the penetration of distributed energy resources has increased significantly due to consumer demand for higher reliable electricity, reduced transmission and distribution line losses and environmental issues [1]. However, the incorporation of distributed generation (DG) creates technical problems as nature of distribution network changes from passive to active. These problems include frequency stabilization, voltage stabilization, intermittency of the renewable resources, and power quality issues. The formation of the microgrid (MG), which is cause by the disconnection from the main grid without stopping the energy generation from the DG sources, can also be considered as a drawback of DG [2]. The disconnection of the main source is called islanding, which can be either intentional or unintentional. The purpose of intentional islanding is to construct a power “island” during system disturbances, which are commonly introduced because of the faults. However, the active part of the distribution system should sense the disconnection from the main grid and shut down the distributed generators in countries where island mode operation is not allowed. Undetected island MG is generally called “unintentional islanding”.

Unintentional islanding gives rise to major issues which includes: 1) maintenance of voltage and frequency within standard acceptable limits, 2) hazard to line worker security by DG units feeding the loads, and 3) out of phase reclosure of DG unit as a result of instantaneous reclosing.

Hence in IEEE 1547–2003 standard, it is recommended to isolate all the DG units from the main grid as soon as islanding condition occurs and disconnection is persisting till the normal grid supply is restored so as to give protection to the generators and loads connected to the system. Therefore, uncovering effective solutions to resolve this problem is necessary. Research work on unintentional islanding detection is rapidly growing to ensure that the system is operated under the standard requirements. Researchers have proposed various remote and local end information-based techniques for detection of islanding. However, most of the techniques gives undesired tripping signal during certain critical scenarios.

Issues with detection of islanding condition

a) Low active and reactive power mismatch during islanding creates mal-operation of relays.
b) Capacitor switching events.
c) Difficult to distinguish between islanding and fault events.

The motivation of the research stands on the observation of dynamic behaviour and transients of a distribution subsystem with multiple distributed energy resources to pre-planned and/or accidental switching events. The switching events may lead to islanding of the subsystem and formation of an autonomous microgrid. After disconnection from the main grid, micro-grid experiences transients. The severity of the transients is highly dependent on (i) the pre islanding operating conditions, (ii) the type of the event that initiates islanding, and (iii) the type of the DG units within the microgrid. In this work, the islanding condition is detected by investigating the transient events and defining two new criterions i.e. transient index value (TIV) at DG terminal and positive sequence superimposed impedance angle (PSSC) at the point of common coupling (PCC).

2.1 Objectives

The objective of the research is to implement the already proposed islanding algorithm in a developed microgrid system integrated with hybrid DGs, nonlinear loads, storage devices and capacitors:

- To overcome the drawback of conventional islanding detection technique having large non detection zone and detection time by utilizing the voltage and current information from both local and remote ends, so as to improve the reliability of the detection technique.
- To validate the already proposed islanding algorithm by us on large DG system having hybrid resources (inverter & turbine).
- Develop multi resolution signal decomposition methods for detailed investigation for following conditions:
  - with nonlinear dynamic changes in the operation of generation resources at the time of islanding event;
  - effect of different control schemes in generation resources at the time of islanding event;
  - influence of interaction between the resources (including energy storage dynamics) on islanding detection.
  - Simultaneous occurrence of dynamic events (e.g. islanding associated with fault occurrence).

2.2 Scope

The proposed research (*IsDHDG*) can contribute in many ways to make the stressed grid, a healthy and smart grid. Presently, the available approaches for islanding detection are mainly of two types: local end information-based approaches and remote end information-based approaches. The different critical conditions that may influence islanding detection methods are (1) power mismatch situation, (2) capacitor switching, (3) heavy load switching and (4) load quality factor (5) low resistance fault. The available techniques and the conventional approaches are although very reliable but they will not sustain for all the critical conditions. A single logic-based approach will not suitable for all the critical conditions. In the proposal, it is proposed to develop signal processing-based technique for islanding detection mainly when event is associated with fault conditions (simultaneous occurrence) and switching transients. The detection methodology has been tested for different critical conditions such as low active and reactive power mismatch and switching events. The complete study is carried out in MATLAB software with measured test signals obtained from real time simulator OPAL-RT.

3 State-of-the-Art/State-of-Technology

Conventional distribution systems are passive networks where power is supplied to the distribution level from the transmission systems. The concept of DG is introduced to exploit the advantage of renewable power generation and extended to distribution level. Islanding is a condition where main source is disconnected from the microgrid. The islanding can be intentional or non-intentional. Islanding can be intentional (pre planned) or unintentional (accidental) based on their occurrence. Creating an island intentionally for load shedding and maintenance purpose is referred to as intentional islanding whereas unintentional islanding occurs due to inception of fault or failure of equipment. Unintentional islanding gives rise to major issues which includes: 1) maintenance of voltage and frequency within standard acceptable limits, 2) hazard to line worker security by DG units feeding the loads, and 3) out of phase reclosure of DG unit as a result of instantaneous reclosing. Hence, detection of occurrence of island is very essential in power system.

Several techniques for detection of islanding phenomenon have been reported in recent years [4]-[20].

Remote islanding detection methods are communication-based methods which employs supervisory control and data acquisition (SCADA) [4] or power line signaling scheme [5], [6] for detecting islanding condition. These schemes are reliable but their implementation cost is high. Active islanding detection methods proposed in [7]-[8] are based on injecting disturbances periodically to the host network and then studying the system responses at the local end. Henceforth, the major drawback of this technique is the deterioration of power quality by interjection of disturbances in the network [9].

Passive islanding detection methods causes no disturbances to the system and are based on continuous monitoring of the local end parameters such as voltage, current and frequency to determine, whether the DG is islanded from the grid. When islanding occurs, one or more of the above quantities may vary and by setting a proper threshold value the islanding and non-islanding conditions can be classified [10]-[17]. A few commonly used passive islanding detection techniques includes rate of change of frequency (ROCOF) [10] voltage vector shift relay (VVS) [11], rate of change of phase angle difference (ROCPAD) [12], average rate of change of reactive power and load shift approach [13], rate of change of inverse hyperbolic secant function of negative sequence voltage signal [14] and sequence component of superimposed voltage [15]. The major disadvantage with most of the passive methods is that, they fail to detect islanding condition if the power imbalance in the system is low. The conventionally used ROCOF relay [10] fails to detect islanding when active power mismatch in the system is low. This is due to the fact that with reduced active power mismatch, deviation in frequency remains minimum. Hence, misconduct the detection task through preset threshold. Similarly, rate of change of voltage relays have higher non-detection zone when reactive power mismatch in system is low [16]. Therefore, there is a need to develop a simple and efficient approach which can detect event not only under normal operating condition but also perform reliably at the time of lower side of active and reactive power mismatch, utilizing minimum number of voltage cycles.

In [16]-[20], several new techniques have been proposed employing machine learning based techniques, intelligent techniques and signal processing techniques to improve the performance of passive methods. Wavelet singular entropy-based technique [17], fuzzy rule-based classifier employing decision tree-based technique [18], machine learning algorithm incorporating support vector machines (SVM) [19] and artificial neural network based technique [20] have been proposed lately. However, higher sensitivity towards noisy signal, requirement of large number of training data sets, complex training procedure and unsatisfactory results in case of unknown data sets are the several limitations of the above schemes. Hence, in this project, a new technique based on the transient response of the voltage waveform is proposed to detect the islanding event. The proposed approach is capable of being immune to other disturbances in the system, thus providing effective and reliable islanding detection.

4 Executed Tests and Experiments

4.1 Test Plan

Testing of IsDHDG requires microgrid set up with two distributed energy resources and the voltage and current measurement at DG and PCC end.

In the offline set up for validation of proposed algorithm, two converters are used to emulate the behaviour of DGs connected. The testing of IsDHDG can be carried out in two steps.

First the real time voltage and current signals from the microgrid set up are retrieved using Opal-RT with a sampling frequency of 1 kHz. This signals are recorded and stored in MATLAB in *.mat* format.

In the next stage, this saved sampled data is utilized for validation of algorithm run in MATLAB. Subsequently the islanding detection indices (transient index value and positive sequence super-imposed current phase angle)are computed and the algorithm is verified for islanding and no-islanding conditions.

The complete microgrid set up including various components is depicted in Figure 1.

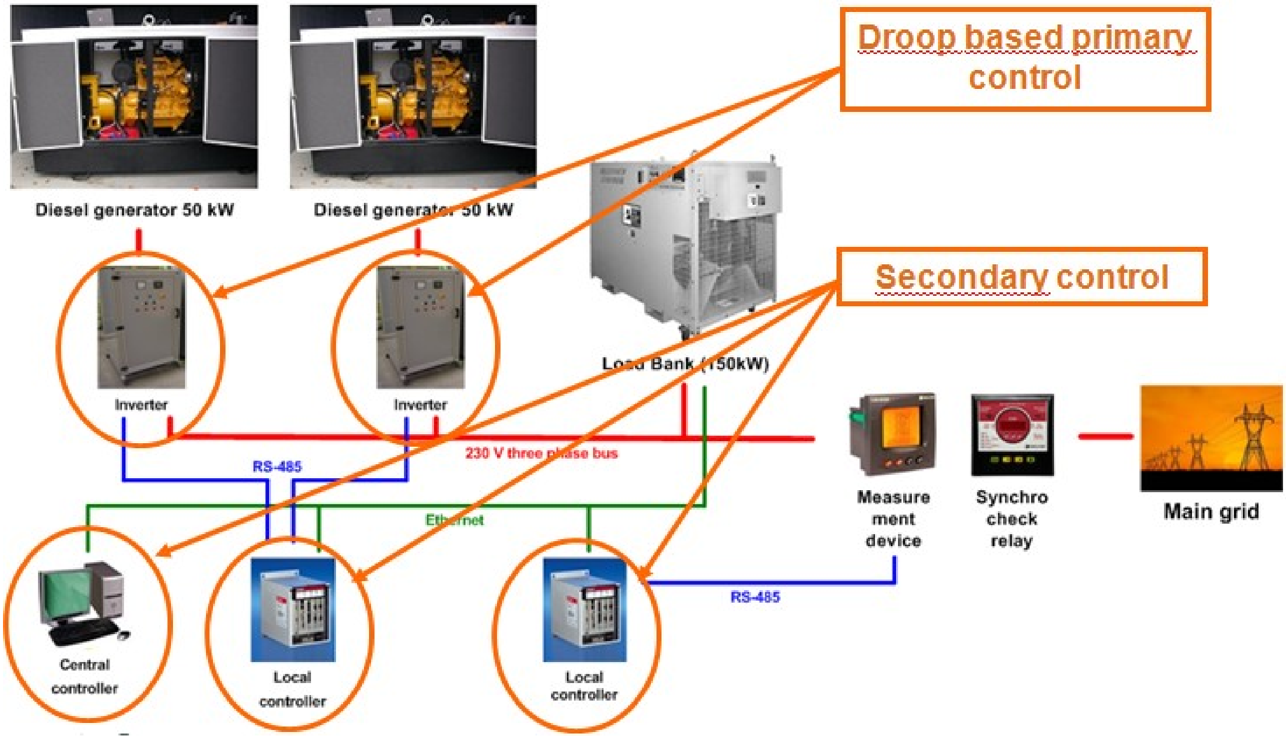


Figure 1. Microgrid set-up

The grid is operating at 400 V, 50 Hz. The converters are connected to grid through line impedance and isolation transformer at PCC. Both the converters are operating in current control mode in grid connected mode whereas after islanding, it will operate in voltage control mode. A synchro check relay continuously monitors the voltage, phase displacement and frequency of two supplies. It ensures the right conditions before the connection of the distributed generation source to the point of common coupling (PCC) in order to avoid any damage to the connected equipment. The communication link RS 485 is provided which enables fast communication among multiple components. A microgrid management system controls the operation of the infrastructure to run according to certain strategy, physically connects/disconnects the elements, and changes the microgrid topology, by means of a switching cabinet. Two independent control system are used to control the operation of both power converters.

1. Local control
    - Local control implemented in the inverters (Fr-P & V-Q droop).
    - The frequency signal allows instantaneous sharing of load among the generators in the microgrid.
    - Key control for grid connected to island transition and island operation.

2. Secondary control. Functions of the secondary control:
    1. Connected operation: Maintains the power exchange with the main grid to predefined values
    2. Islanded operation: Recovers the reference frequency (50 Hz)

4.2 Standards, Procedures, and Methodology

The standards, procedure and methodology which has been followed is tabulated in Table 1.

Standards	Procedures	Methodology
• The voltage and current signals are streamed according to IEEE C37.118.2-2011 compliance with a specific host ID (TCP/IP), port and device ID code.	• The overall procedure is discussed in previous section.	• Load switching operation • Capacitor switching • Low power imbalance condition between grid and DGs.

Table 1. Standards, procedure and methodology

Methodology:

To distinguish islanding and non-islanding scenario two criterions are utilized:

1. Peak of transient index value (TIV), which is computed from measured three phase voltages.
2. Positive sequence superimposed current angle (PSSC) determined from three phase currents injected at PCC.

TIV identifies the events which causes severe transients in the microgrid leading to islanding and PSSC angle is used to confirm the presence of islanding. Islanding is detected when magnitude of TIV exceeds the threshold and PSSC angle is positive.

Different islanding and non-islanding scenarios are performed to observe its effect on IsDHDG:

1. Capacitor switching event (non-islanding scenario).
2. Islanding event with low power mismatch.

4.3 Test Set-up(s)

The proposed approach is validated utilizing the real time signals obtained from experimental set up. The laboratory experimental set up for detection of islanding condition is illustrated in Figure 2 and the single line diagram of the test set up is depicted in Figure 3.

The components in microgrid and the prototype component rating is mentioned below:

- Grid configurator
- Number of converters: 2
- Rated power of each converter: 40 kW
- DC Bus voltage: 700 V
- AC collector voltage: 400 V
- Total active load: 50 kW
- Reactive load: 70 kVAr

Figure 2. Microgrid set up in SGTL laboratory

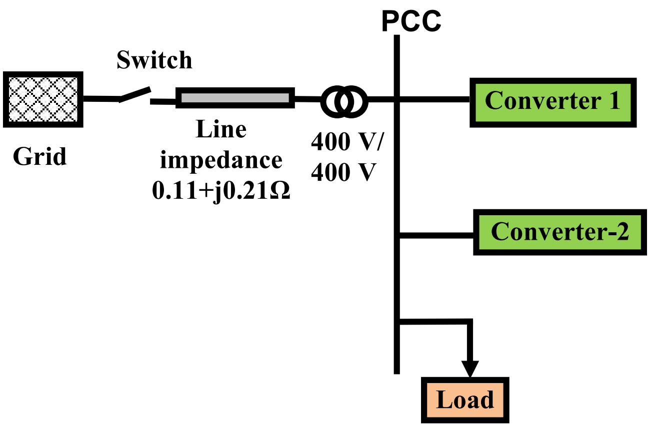


Figure 3. Single line diagram of the test set-up

4.4 Data Management and Processing

The data is managed to store in workspace of MATLAB as discussed in section 4.1.1. Then from workspace, it is saved in the computer as ".mat" file. The data quality is good and does not has the measurement errors therefore the data pre-processing is not required. The algorithm can directly consume the signal to process it to produce the results. The algorithm is written in such a way that whatever the type of event created, algorithm will identify islanding event based on the deviation in TIV and PSSC angle. The stored data in workspace can also be analysed later for the other monitoring information or application.

5 Results and Conclusions

5.1. Results

The main goal is the offline validation of IsDHDG for fast and accurate detection of islanding condition utilizing real-time signals obtained from OPAL-RT as depicted in Figure 4. For that, we have created different test cases and few of the test cases are described below.

Case 1: *Non-islanding event (capacitor switching)*

In order to improve the power factor in the distribution system, capacitor banks are regularly switched ON and OFF which causes fluctuations in voltage signals. In such a case, discrimination of the switching event against islanding event is very crucial. To create this scenario, following steps have been followed:

i. First, the power delivered by each converter (converter-1 and converter-2) is set to 8 kW.
ii. Initial active and reactive load connected to system is 20 kW and 25 kVAr respectively.
iii. The power through the tie line connected in between grid and PCC is 4 kW.
iv. Next, the capacitor of 20 kVAr is switched ON and the signals at DG and PCC end are stored.

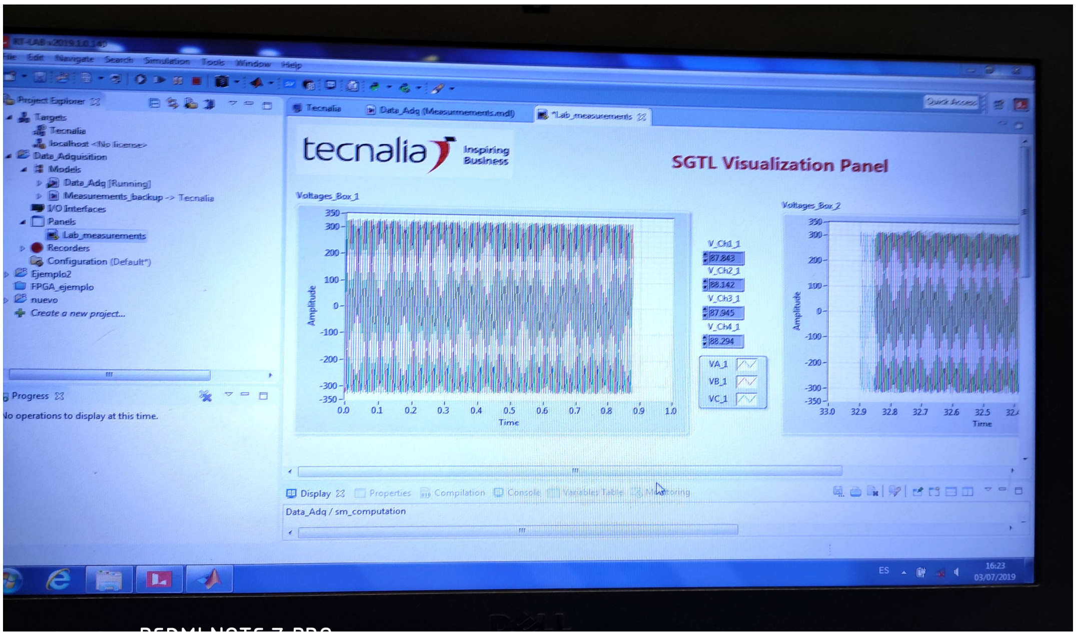


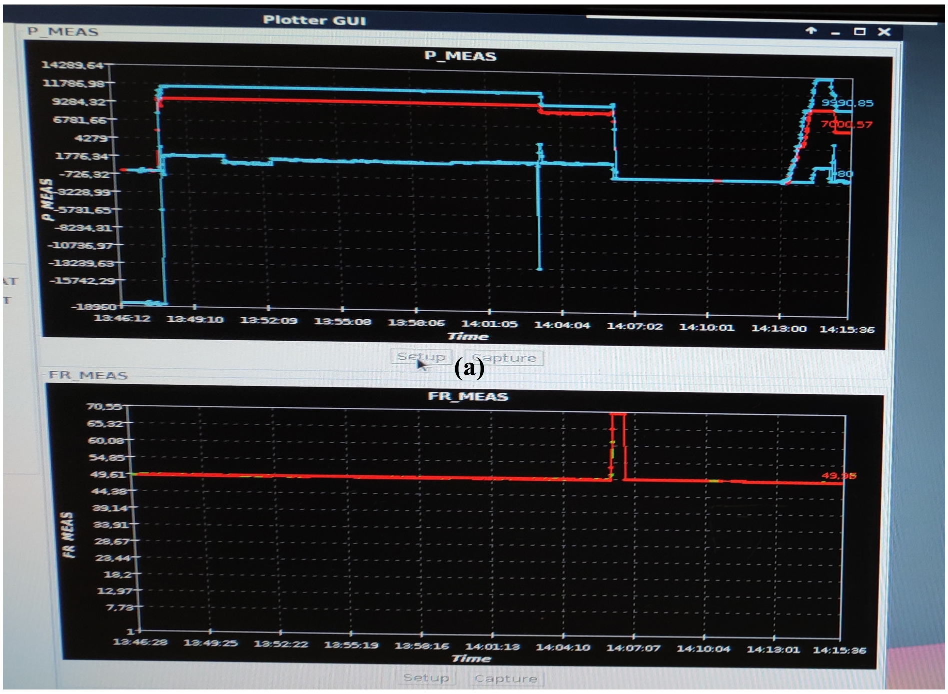
Figure 4. Real time monitoring of voltage and current signals at DG and PCC end using real time simulator

Case 2: ***Islanding event with low power mismatch***

In this scenario, an islanding event is created with approximately 12% active power mismatch.

First, the power delivered by each converter is set to 8 kW; tie line power flow is fixed at 2 kW; total load connected to the system is 18 kW.

Next, the switch connected in between grid and PCC is opened to create an islanding condition. Hence, under this condition the converters mode of operation is switched to voltage control mode and the overall load is supplied by both the converters. The power delivered and frequency are monitored and the real time plots are depicted in Figure 5 during islanding condition.



(a)

(b)

Figure 5. Real time monitoring of (a) Active power supplied by converter-1, converter-2 and grid (b) frequency at PCC

Further, the measured signals at both DG and PCC end are plotted by utilizing the real time saved data in *.mat* files. The voltage signals plotted offline during islanding condition are shown in Figure 6. The islanding detection index i.e. TIV and PSSC is depicted in Figure 7. From Figure 7(a) it is noted that, the magnitude of TIV is much higher during islanding condition than during capacitor switching event (non-islanding scenario). Also, the variation in PSSC angle (Figure 7(b)) is positive during islanding and negative during non-islanding scenario. Hence, discriminating both the events accurately and reliably.

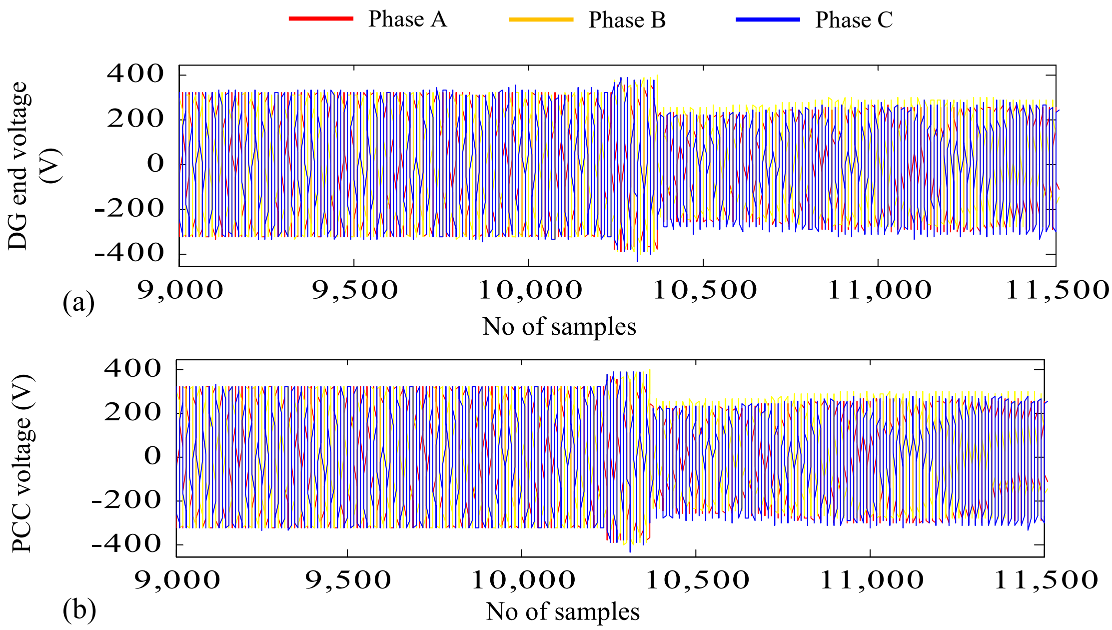


Figure 6. (a) DG end voltage signal (b) PCC end voltage signal during islanding condition

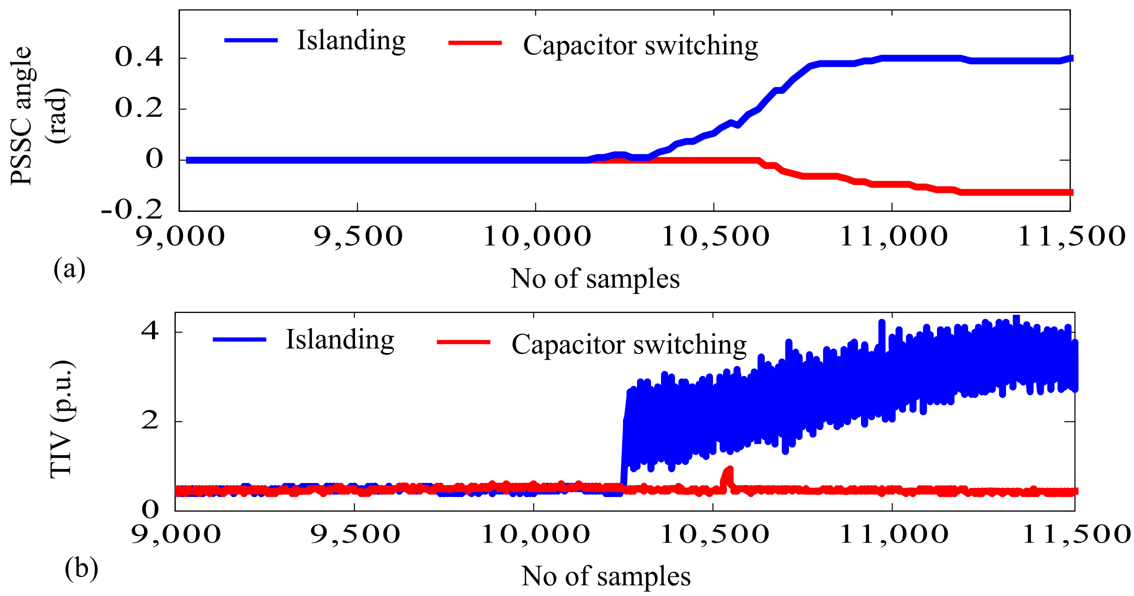


Figure 7. Response of the islanding detection technique during islanding/non-islanding scenario: (a) Transient index value (TIV) (b) Positive sequence superimposed impedance angle (PSSC)

5.2. Conclusions

- IsDHDG is effective and accurate in discriminating the islanding and non islanding events.
- With the proposed approach, the non-detection zone had reduced and hence the reliability of the operation was assured.
- Because of faster detection capacity (less than one cycle) and simple computational procedure, more reliable and secured way to detect islanding phenomenon is possible in the digital platform using the proposed integrated technique.

6 Open Issues and Suggestions for Improvements

Open issue is the time taken to execute the algorithm. Not enough fastness in the algorithm may restrict it to get implemented in real-time power system.

The suggestions for improvements are:

- Appropriate selection of the parameters so as to achieve fast monitoring with maintaining the accuracy.
- Time to execute for algorithm can be minimized by reducing the window size and by looking into many other factor involved in the coding.
- Multiple load switching operation can be observed successfully for getting accurate and quick results.

7 Dissemination Planning

Writing research paper in collaboration with the TA user group manager and other group members after making improvements.

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9 Annex

9.1 List of Figures

9.2 List of Tables