GRIDWORKS

Unintentional Islanding Working Group (UIWG): Final Report

December 8, 2023

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Executive Summary

If an electric distribution circuit or segment disconnects from a larger electric grid, any connected distributed energy resource (DER) must quickly de-energize or separate from the electric grid so that an unintentional "island" does not form (i.e., a portion of the area's electric system remains energized). Unintentional islanding (UI) is defined as unplanned, unapproved energization of some portion of a power system by one or more DERs (following disconnection from any larger electric grid). UI can result in transient voltages and frequencies, damage to utility or customer equipment, or subsequent uncleared or delayed clearing faults. UI can technically occur on either the transmission or distribution system. However, no UI of distribution-level DERs within the service territories of California's three investor-owned utilities (IOUs) has occurred. It is difficult, if not impossible, to determine whether this is the result of mitigations in place or whether no UI events would have occurred even in the absence of these mitigations.

Inverter-based DERs can normally detect a voltage sag during fault conditions and trip offline, thus avoiding creating an island. However, particular types of faults (e.g., high impedance faults) or switching errors may prevent the voltage reduction required for a timely trip of the inverter within the emergency power supply (EPS). Thus, inverters are required to have additional anti-islanding protection beyond the simple detection of voltage sag. Even with these additional anti-islanding mitigations in place, concerns regarding the performance of inverter-based DERs' anti-islanding capabilities when a machine-based generator is present on the distribution system remain.

California's IOUs currently take different approaches with respect to how they assess and manage the potential risks of UI formation, with Pacific Gas and Electric (PG&E) differing most significantly in its approach. PG&E requires additional screening of distribution-level DERs. If the DER does not pass the screens, the developer can either elect to conduct a Risk of Islanding (ROI) study with one of PG&E's pre-approved third parties or move directly to installing mitigations. The ROI study is conducted at the developer's expense. If the DER fails the ROI study, additional mitigations may need to be installed. The additional mitigations include direct transfer trip (DTT) and/or the addition of a Supervisory Control and Data Acquisition (SCADA) utility-operated recloser at the DER's point of interconnection. DTT isolates the DER from the distribution and transmission system whenever an upstream breaker trips offline and is typically applied for transmission-level faults. The SCADA-operated recloser can be opened by the utility distribution operator during a UI event. Mitigations like DTT can introduce additional project costs for the developer of over $1 million and thus serve as a deterrent to further DER development. This is only a concern when a machine-based generator is present on the distribution circuit and is not an issue when only certified-inverter-based generation is present.

Neither Southern California Edison (SCE) nor San Diego Gas and Electric (SDG&E) currently require this additional screening or the installation of DTT. Based upon the results of a recent Electric Program Investment Charge (EPIC) UI study sponsored by SCE, the utility may install utility-owned SCADA equipped reclosers in the future under some conditions.[1]

In 2021, the California Public Utilities Commission (CPUC) issued Decision (D.) 21-06-002 to streamline the interconnection application process for DERs. Amongst other edicts, the Decision establishes the Unintentional Islanding Working Group (UIWG) to review, discuss, evaluate, and recommend *distribution system-level* solutions to island formation arising from increased DER penetration.

The UIWG found that other emerging UI mitigations could eventually prove viable alternatives to wired DTT. Some of these are ready for deployment or pilots and others still need additional work in laboratory settings. These include:

- Synchrophasors, also known as phasor measurement units
- Bulk system timing reference (BUSTR)
- Cellular Wireless DTT (rather than spread spectrum wireless)
- Power Line Carrier (PLC) Method
- Spread spectrum broadcast GOOSE protocol

In the near term, the UIWG supports PG&E's efforts to pilot cellular wireless DTT and spread spectrum broadcast (GOOSE) as potential alternatives to the current wired DTT UI mitigation.

[1] DER Dynamics Integration Demonstration EPIC Phase III Final Project Report

Due to limitations in the broadcast radius, PG&E questions synchrophasors are truly a cost-effective alternative to DTT.

PLC is currently being deployed by a handful of utilities in the Northeast and Midwest. One of its main advantages is that it can cover all the DERs on a given circuit rather than needing to be relayed point to point. However, it currently faces propagation challenges. The signal cannot pass through transformers or underground distribution. Additionally, as higher frequencies are leveraged to achieve higher bandwidth, cross coupling with distribution lines not meant to communicate these signals unfortunately becomes possible. For these reasons, the UIWG is not recommending that PG&E prioritize further exploration of utilizing PLC as a UI mitigation at this time.

In addition to the technologies recommended for piloting, the UIWG believes an additional UI mitigation warrants further testing. The BUSTR method should be explored and eventually be evaluated in the longer term for piloting. Sandia National Laboratories is currently assembling a coalition and pursuing funding opportunities to conduct demonstration projects and pilots at-scale. Sandia will report back on its progress and findings to the three California IOUs and other utilities over the coming years. The merits of potential business models for BUSTR also need to be discussed.

Type III generators, like doubly-fed induction generator (DFIG) wind turbines, were not evaluated in previous studies by Sandia National Laboratories upon which UI mitigations are based (SAND 2018-8431 and SAND 2012-1365). Funding and other resources to study these generators are needed and could likely be provided by the Department of energy (DOE) to Sandia. In the meantime, PG&E should work with developers to explore other interim solutions.

Several Working Groups are underway as part of the effort to revisit the Institute of Electrical and Electronics Engineers (IEEE) 1547 and 2030 series of standards. These represent ideal forums for continued discussion of alternatives to wired DTT. In addition to the IEEE Working Groups, the UIWG recommends that the CPUC support continued discussion amongst stakeholders on the topic of UI mitigations. This could occur informally via a quarterly call for 60-90 minutes during which stakeholders can share information and ask questions. Participants of the UIWG could be invited and other stakeholders could request to join if interested, including other IEEE members. The purpose of this call would be to support informal information sharing; it does not need to be a formal meeting with expectations that utilities prepare and have materials approved in advance.

Key Terms

- **Active anti-islanding:** A type of anti-islanding detection that creates a small disturbance at the point of DER connection. The DER actively creates a small disturbance attempting to destabilize the system and drive it to a trip threshold. The response is analyzed to determine if the disturbance was able to affect a specific electrical parameter. If yes, it is assumed an island has occurred and the DER must cease power production/conversion. This mitigation performs its intended function by an active control action.

- **Anti-islanding:** Mitigation systems designed to prevent unintentional islanding. These mitigation systems can be embedded in the utility infrastructure or in customer interconnection equipment.
- **Direct Transfer Trip (DTT)**: A communications-based method for tripping a DER. Whenever an upstream breaker trips offline (e.g., feeder breaker at the substation), the DTT then isolates the DER from the distribution and transmission system. The communications medium may take one of several forms, such as telephone line, fiber optic cable or radio transmission.
- **Distributed Energy Resource (DER):** A source of active power that is connected at the distribution level of an electric power system.
- **Doubly-fed Induction Generators (DFIG):** A generator that can adjust the active and reactive power fed to the grid from the stator independently of the generator's rotational speed via two three-phase windings, one stationary and one rotating, both separately connected to equipment outside the generator. These are often referred to as "Type III" generators. Prior studies conducted by Sandia National Laboratories (SAND 2018-8431 and SAND 2012-1365), upon which UI mitigations are based, did not address Type III generators.
- **Electromechanical Generator** (also referred to as a rotating machine generator): A machine that converts mechanical power to electrical power, using electromagnetic windings on a rotating shaft driven by a mechanical prime mover. Both synchronous and induction electric machines can be applied as a DER, depending on the design.
- **Generic Object Oriented Substation Event** (**GOOSE) protocol**: A communication model defined by the IEC 61850 standard, which uses fast and reliable mechanisms to group any format of data (e.g., status, value) into a data set and transmit it across communication networks.
- **Grid Following:** A current source device whose voltage and frequency is determined by the electric power system to which it is connected.
- **Grid Forming:** A voltage source device that can control its own voltage and frequency. A grid forming device can operate as a standalone system (e.g., intentional island).
- **Institute of Electrical and Electronics Engineers (IEEE) 1547-2018:** Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces. Focuses on the technical specifications for and testing of DER interconnections. Provides the minimum functional technical requirements that are generally needed for a sound interconnection.
- **Intentional Islanding:** A planned electrical island. Intentional islanding can be a benefit in many applications, such as microgrids.
- **Inverter:** A machine, device, or system that changes direct-current power to alternating-current power.
- **Islanding:** A condition where a portion of a larger electric power system is electrically separated from the rest of the electric power system but remains energized solely by the local electric power system or a single DER. An example is when a portion of the distribution grid remains energized during a fault occurrence on the distribution system, after the protection equipment has disconnected that portion of the distribution grid from the rest of the grid.
- **Passive anti-islanding:** A type of anti-islanding detection that monitors electrical parameters, such as over-/undervoltage and over-/underfrequency, at the point of DER connection. Upon detecting an abnormal condition, the DER must cease power

production/conversion. This mitigation performs its intended function continuously without a control action.

- **Recloser:** A fault interrupting device that has the characteristic of a circuit breaker. It can also provide time delay reclosing capabilities.
- **Sandia Frequency Shift (SFS):** An active unintentional islanding detection method that utilizes positive feedback in positive-sequence frequency or phase to destabilize an unintentional island.
- **Sandia Voltage Shift (SVS):** An active anti-islanding method that utilizes positive feedback on voltage magnitude to destabilize an unintentional island.
- **Supervisory Control and Data Acquisition (SCADA):** A networked computer-based system for gathering and analyzing real-time data to monitor and control equipment that deals with critical and time-sensitive materials or events.
- **Synchronous Generator** (also referred to as a machine generator): An electrical machine that converts mechanical power into alternating current (AC) electrical power at a specific voltage and frequency. The rotor of a synchronous generator spins at a constant speed in synchronism with the AC output of the generator. Synchronous generators are voltage source devices that can support the development of and the sustainment of an island.
- **Uncertified DER**: A DER that does not meet all of the specific requirements before interconnection to a utility system. Examples are conformance with applicable industry standards and inverters being listed by the California Energy Commission or other recognized organization. An uncertified DER is not "certified" to UL 1741 SB but can have devices installed to meet certification requirements such as relays, generator controls, and DTT. One example is a synchronous machine that does not have an active islanding certification nor voltage and frequency tripping, but can have relays installed to meet the requirements.
- **Underwriters Laboratories (UL) 1741 SB:** A test standard that provides type and interoperability tests for conformance to IEEE 1547-2018. All inverters that are interconnected in California must be certified to UL 1741 SB.
- **Unintentional Islanding (UI)**: Islanding for which the electric power system was not designed or planned.

Background/Context

Unintentional Islanding

If an electric distribution circuit or segment disconnects from a larger electric grid, any connected distributed energy resource (DER) must quickly de-energize or separate from the electric grid so that an unintentional "island" does not form (i.e., a portion of the area's electric system remains energized). Unintentional islanding (UI) is defined as unplanned, unapproved energization of some portion of a power system by one or more DERs (following disconnection from any larger electric grid). Unintentional islanding can result in transient voltages and frequencies, damage to utility or customer equipment, subsequent uncleared or delayed clearing faults, and prospective safety risks to workers and the public if contact occurs with an energized line. UI can technically occur on either the transmission or distribution system. However, no unintentional islanding of distribution-level DERs within the service territories of California's three investor-owned utilities (IOUs) has occurred. However, it is difficult, if not impossible, to determine whether the absence of a distribution-level UI event involving a DER is the result of mitigations in place or whether none would have occurred even in the absence of these mitigations. This is only a concern when a machine-based generator is present on the circuit and is not an issue when only certified-inverter-based generation is present.

DERs can normally detect a voltage sag during fault conditions and trip offline, thus avoiding creating an island. Typical inverter-based DERs use active anti-islanding techniques in these instances. The umbrella term "inverter-based DERs" includes technologies like rooftop solar photovoltaics, Type 4 wind turbines, fuel cells, and battery energy storage systems. However, particular types of faults (e.g., high impedance faults) may prevent the voltage reduction required for a timely trip of the inverter within the DER. Thus, inverters are required to have additional anti-islanding protection beyond the simple detection of voltage sag. All inverters interconnected to utility systems in California must be certified to Underwriters Laboratories (UL) 1741 SB.

However, even with UL 1741 SB certification, two concerns regarding the performance of inverter-based DERs' anti-islanding capabilities remain. Two research reports by Sandia National Laboratories (SAND 2018-8431 and SAND 2012-1365) show through lab studies and simulations, inverter-based anti-islanding protection can fail under certain conditions. When DERs with different "types" or methods of anti-islanding protection interact with each other, their anti-islanding effectiveness can sometimes be compromised. With some notable exceptions, inclusion of "synchronous generators" also makes islanding detection more challenging for inverters. This category of synchronous generators does not include doubly fed induction generators (DFIG), which are classified as "asynchronous."[2]

In addition to the results of Sandia's research, some stakeholders have expressed other concerns regarding proper functioning of DERs' anti-islanding capabilities include. Note that while these are theoretically possible, it is unlikely they would occur. These concerns include:

- A high power factor which can result in the affected DER not needing to supply reactive power;
- Component failure within the inverter can cause anti-islanding protection to fail;
- Certain transmission line and substation-level external faults may prevent the traditional voltage and frequency schemes from operating effectively (i.e., detect close balance between generation and load).

Project Objectives

The California Public Utilities Commission (CPUC) issued Decision (D.) 21-06-002 in 2021 to streamline the interconnection application process for DERs. Amongst other edicts, the Decision establishes the Unintentional Islanding Working Group (UIWG) to review, discuss, evaluate, and recommend distribution system level solutions to island formation arising from increased DER penetration. This Decision is partially based on the Rule 21 Working Group 4 Report's Proposal

[2] SAND2012-13657 and SAND2018- 8431

18d.[3] To bring structure to the UIWG's discussions, Appendix B of CPUC D.21-06-002 directs the UIWG to discuss and develop responses to a list of questions. The Working Group's findings and recommendations are to be documented in this final report.

Working Group Overview

At the direction of the CPUC via D.21-06-002 Gridworks, a non-profit facilitation organization, assembled a Working Group comprised of utility representatives, DER project developers, researchers, and other industry experts. The Working Group met monthly, usually on the third Wednesday of the month for approximately one year. The meetings were structured according to the Work Plan which was developed by Gridworks with input from Working Group members. The meetings primarily focused on addressing the questions laid out in Appendix B of D.21-06-002. These meetings produced the content contained in this report. The Working Group meetings covered the following topics:

- Meeting #1: UIWG Kick-off Meeting and Work Plan Development
- Meeting #2: Building a Shared Foundation of Knowledge
- Meeting #3: Problem Statement Development
- Meeting #4: Anti-Islanding Evaluation Processes and Standards
- Meeting #5: Existing Unintentional Islanding Mitigations
- Meeting #6: New/Additional Unintentional Islanding Mitigations
- Meeting #7: Evaluating Potential Mitigations
- Meeting #8: Conclusions and Recommendations
- Meeting #9: Placeholder Meeting to Revisit Unresolved Topics
- Meeting #10: Draft Report
- Meeting #11: Final Report

Problem Statement

Potential Implications of an Unintentional Island

UI is concerning because it could result in a variety of negative consequences, including:

- Causing transient voltages and frequencies to utility and customer equipment, potentially damaging that equipment.
  - Potential customer equipment that could be damaged includes: interconnection equipment like reclosers and transformers and/or load equipment like motors, adjustable-speed drives, appliances, and electronics. The number of customers along a circuit can typically range from several hundred to several thousand.
  - Potential utility equipment that could be damaged includes the following:

[3] https://gridworks.org/wp-content/uploads/2020/08/R21-WG4-Final-Report.pdf

        - Distribution transformer (if the high side is ungrounded) due to overvoltage for an unbalanced fault at an estimated cost of $3,000,000
        - Substation Distribution Breaker at an estimated cost of $250,000 without a relay package and an additional $125,000 for damage to a relay package
        - Insulator and lightning arrester damage: ~$1,800
        - Customer service transformers: ~$34,000
        - Underground cables: ~$450/ft
    - Utility customers would collectively be responsible for covering any claims associated with damage to customer and/or utility equipment. The amount of damage would depend upon the extent of the voltage or frequency deviation.
- Reducing fault current capability in the islanded section which could lead to possible subsequent uncleared or delayed clearing faults, leading to potential property damage, introducing public safety risks, and potential for wildfires. Additionally, UIs separate the normal grounding source from the island which could result in additional overvoltage conditions.
- Automatic reclosing which could result in an out-of-phase condition that would cause high current and mechanical stress to rotating-machine-based equipment if closed into the out-of-sync system.

The likelihood that any given DER would form an unintentional island is difficult to quantify because it is driven by a number of factors, including:

- DER (generation and storage) to load ratio;
- DER mix;
- System and weather conditions; and
- Time of year (i.e., birds nesting on lines in the spring can cause faults on the system).

Recent Developments in UI Mitigations for California

California's investor-owned utilities (IOUs) currently take different approaches with respect to how they assess and manage the potential risks of UI formation, with PG&E differing most significantly in its approach. This is partially because PG&E's grid is more susceptible to the possibility of UI created by distribution-level DERs for the following reasons:

- Greater penetration of machine-based DERs and concentration of these machine-based DERs in a limited number of locations (primarily at biomass facilities in the Southern part of PG&E's service territory);
- Substation design protection schemes and sectionalizing methods;
- Utility system configuration; and
- Limited use of high-speed transmission protection.

PG&E has very recently implemented a new procedure for DER interconnection applicants. This procedure begins with a new screening process that looks at machine and inverter ratios including the type of active anti-islanding to determine if mitigations are required. If the DER fails to pass this screening process, the developer can move directly to installing mitigations or pursue a Risk of Islanding (ROI) study at their own expense. These ROI studies involve modeling the affected system with the DER (including manufacturer-specific controls) in either Power Systems Computer Aided Design (PSCAD) or Matrix Laboratory (MATLAB) and running simulations to determine if an island is possible.[2] If the DER fails the ROI study, additional mitigations may need to be installed. Preparing for an ROI study requires the project developer to expend time and resources. Depending upon the number of devices being studied, ROI studies can require 6-8 weeks to prepare for and complete and cost approximately $20,000-30,000.

Based on the recommendations laid out in the Rule 21: Working Group 4 Report, PG&E adopted additional per-feeder ROI screens that consider the following:

- Aggregate generation relative to minimum load;
- Aggregate machine generation or aggregate uncertified distributed generation to total generation ratio;
- Fixed power factor modes; and
- Inverter control algorithm methodologies.

As of the publication of this report, PG&E has not yet completed this new ROI Screening process with any DERs. Historically, PG&E saw three distribution-level DERs over three years fail its prior Anti-Islanding screening process and need to install DTT.

Neither SCE nor SDG&E feel the need to perform such enhanced anti-islanding screening.

The Remaining Problem: DTT

For DERs that fail PG&E's new ROI Screens, PG&E remains concerned about the potential for UI of distribution-level DERs to occur when certain machine-based DERs without UI protection desensitize or disable inverter-based DERs' anti-islanding nearby. This is not currently a concern for SCE or SDG&E. PG&E has never experienced an instance of unintentional islanding of a distribution-level DER. It is impossible to know whether this is the result of PG&E's extensive screening process and mitigations or if it would not have occurred even in the absence of those procedures.

Mitigations for the problem of UI created by distribution-level DERs when their anti-islanding systems fail are currently available. In fact, Rule 21: Working Group 4 Report recommended:

1. Requiring protective equipment for machine-based generators over 40kW requesting interconnection to the distribution system like protective relays and passive elements.
2. If supplemental review for a proposed inverter-based generator determines that the proposed generator fails the anti-islanding screen due to existing machine generation, the utility would need to install the required recloser at its own expense.

In addition to the mitigations listed above, PG&E may require a DER to install DTT and/or a SCADA-equipped recloser if it fails the new ROI study. The specified DTT is typically installed due to a transmission-initiated UI event. DTT isolates the generation from the substation and transmission system. Grid operators can manually use a SCADA-equipped recloser (if specified as a mitigation) to manually disconnect the machine generator or line section if they detect a sustained island during a UI event. DTT is typically only installed after a risk of islanding study is performed to assess the need for further mitigations. Unfortunately, DTT can prove costly to install and DER project developers have cited it as an obstacle to their efforts. For the three historical projects that failed PG&E's prior ROI study and were required to install DTT, developers incurred the following costs:

- Project 1 (2MW): $1.5 million
- Project 2 (3.6 MW): $1.3 million
- Project 3: (2.8 MW): $885,000

Additional Cost of Ownership (COO) and Income Tax Component of Contribution (ITCC) charges are not included in these numbers. These factors can roughly double the costs to the developer. Recent inflation would likely also drive up these costs for future DER projects.

Neither SCE nor SDG&E currently require the installation of DTT.

Focus of the UIWG

While PG&E historically only saw three distribution-level DERs install DTT over three years, the substantial costs of mitigations justify further discussion around alternatives to DTT and cost allocation. With this in mind, the UIWG endeavored to enumerate, evaluate, and prioritize mitigations to the problem of unintentional islanding of distribution-level machine-based DERs.

Key Findings

The following summarizes the key findings and conclusions of the UIWG. Answers to each of the questions posed in Appendix B of D.21-06-002 are included in a separate section below.

The Problem

- The potential problem of unintentional islanding of distribution-level DERs in California is the sole concern of PG&E. It is not currently a concern for SCE and SDG&E. However, many other utilities across the country require the installation of UI mitigations under certain conditions.
- To-date, PG&E has not experienced any instances of unintentional islanding of a distribution-level DER. It is difficult to discern whether this is the result of studies and mitigations PG&E requires or an indication that unintentional islanding of distribution-level DERs is not yet an issue.
- Some stakeholders expressed concerns that higher penetration of DERs in the future may exacerbate the problem of UI remain. DTT may also prove challenging to implement efficiently at-scale as the penetration of DERs increases over time.

Cost-effectiveness of UI Mitigations

- The potential costs associated with damage to utility and customer equipment of an unintentional island created by a distribution-level machine-based DER could outweigh the cost of current UI mitigations. However, some stakeholders contend that the risk of UI occurrences caused by DERs at the distribution level is negligible. Either way, the likelihood that any or all these damages would materialize is difficult to determine, complicating an evaluation of whether the costs of mitigations are justifiable.

- PG&E recently updated its anti-islanding screens to reflect findings from the Rule 21 Working Group 4 Report.[4] No ROI study has since been completed by PG&E, although one study was underway at the writing of this report. The following are therefore difficult to assess:
    - The developer and utility time and costs incurred in preparing for these studies;
    - The likelihood that any developer would fail the test and either pursue mitigations or abandon the project entirely; and
    - The developer and utility costs associated with any resulting mitigations.

Emerging Alternatives

- Other emerging UI mitigations could eventually prove viable alternatives to wired DTT. Some of these are ready for deployment or pilots and others still need additional work in laboratory settings. These include:
    - Synchrophasors, also known as phasor measurement units;
    - BUSTR (bulk system timing reference);
    - Cellular Wireless DTT (rather than spread spectrum wireless);
    - Power Line Carrier (PLC) Method; and
    - Spread spectrum broadcast GOOSE protocol.

  Additional details for these alternatives to wired DTT are included in the table below.

- At some point in the future, grid operators may want or need DERs to intentionally create islands in the form of microgrids. Certain UI mitigations would be incompatible with this grid forming future, and certain active anti-islanding methods could potentially introduce power quality issues. As other alternatives to wired-DTT are considered for wide-scale deployment, interaction of these solutions in a grid forming future should be considered.
- Several Task Forces are underway as part of the effort to revisit the IEEE 1547 and 2030 series of standards. These represent ideal forums for continued discussion of alternatives to wired DTT.

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[4] PG&E's specific Risk of Islanding study is included as one of the evaluation screens (Perform ROI Study). Please see the flow chart from Decision 21-06-002 (Appendix D, page D3).

Summary Table: Alternatives to Wired DTT

The following table summarizes the known alternatives to wired DTT. Further information on which of these alternatives the UIWG recommends is included in the Recommendations section below.

Wired DTT Alternative	Description	Advantages	Drawbacks	Status
Synchrophasors	Broadcast-based approach with reference signals that cover a large footprint	• Only need one transmitter to serve multiple DERs, each with their own receiver, which reduces costs • As DER interconnection requests increase, reduces burden of study • Could aid in operational visibility (if there is an event/transient, can determine what DERs are doing at that moment)	Broadcast radius is inversely related to signal (i.e., higher data rates reduce broadcast footprint)	• Ready for pilot • PG&E already uses synchrophasors on the transmission side
BUSTR (bulk system timing reference)	Similar to synchrophasors, but with more data via analog system rather than digital	Can be used for more than just DER, increasing cost-effectiveness	Slow data rate due to analog system	• Needs addtn'l study • Sandia will update utilities on progress in the next two years
Power Line Carrier Method (PLC)	Transmitter at substation puts signal on power lines and each DER has a receiver; when breaker opens, lose signal which	• Can cover all of the DERs or island-forming switches downstream from the PLC transmitter. • Can be lower-cost than DTT because a separate communications channel is not needed.	• Propagation is challenging (lots of things "eat" and deflect signal) • Variability in the power line impedance makes signal conductivity unreliable.[5]	The Distributed Generation Permissive (DGP) System developed by GridEdge Networks is already in use by several utilities in the Northeast and Midwest including National Grid and ComEd

[5] https://www.epri.com/research/products/000000003002008557

	receiver can quickly detect	• Very limited non-detection zone.	• Transmitter reliability is crucial.	
Cellular Wireless DTT (rather than spread spectrum wireless)	Wireless DTT that uses a cellular network as its communication medium	• Line-of-sight not a concern • More affordable than wired DTT	• Often involves a third-party carrier—data privacy issues, ongoing subscription costs • Reliability is lower than with wired DTT	• PG&E looking for pilot location
Spread spectrum broadcast GOOSE protocol	Similar to spread spectrum wireless with the exception that GOOSE can send a trip signal to multiple locations simultaneously	• One subscribing device can transmit to five separate sites, reducing costs • Communications requirements are less stringent than synchrophasors • Operates at high speed	Line of sight challenges	• PG&E looking for pilot location

Recommendations

Alternatives to Wired DTT

In the near term, the UIWG supports PG&E's efforts to pilot cellular wireless DTT and spread spectrum broadcast (GOOSE) as potential alternatives to the current wired DTT UI mitigation. Due to limitations in the broadcast radius, PG&E questions whether synchrophasors are truly a cost-effective alternative to DTT.

PLC is currently being deployed by a handful of utilities in the Northeast and Midwest. One of its main advantages is that it can cover all of the DERs on a given circuit rather than point to point. However, it currently faces propagation challenges. The signal cannot pass through transformers or underground distribution. Additionally, as higher frequencies are leveraged to achieve higher bandwidth, cross coupling with distribution lines not meant to communicate these signals unfortunately becomes possible. For these reasons, the UIWG is not recommending that PG&E prioritize further exploration of utilizing PLC as a UI mitigation on its system at this time.

Along with the technologies recommended for piloting, the UIWG believes an additional UI mitigation warrants further testing. The BUSTR method should be explored and eventually be evaluated in the longer term for piloting. Sandia National Laboratories is currently assembling a coalition and pursuing funding opportunities to conduct demonstration projects and pilots at-scale. Sandia will report back on its progress and findings to the utilities over the coming years. The merits of potential business models for BUSTR also need to be discussed. This topic is particularly complex because BUSTR provides broader benefits like more adaptative control of the distribution system, beyond just UI mitigation. For a utility owned and operated system, a subscription model could be leveraged. A federal ownership model could also be considered in which the federal government owns and operates the system and socializes the costs through taxes.

In the longer term, utilities like PG&E should look to leverage planned grid enhancements and associated communications infrastructure improvements as opportunities to reduce the need for DTT. However, it may be several decades before these upgrades are completed.

Revisions to IEEE 1547 and IEEE 2030 Standards

Several Working Groups are underway as part of the effort to revisit the IEEE standards; the UIWG recommends this venue for further discussion of alternatives to wired DTT.

Future revisions to IEEE standards should also endeavor to avoid introducing obstacles to future wireless communications-based UI mitigations. Electric utilities need to begin planning for a future of grid forming rather than grid following technologies.

Socialize Learnings from Future ROI Studies

The UIWG recommends that PG&E consider sharing the learnings gained from future ROI studies with other project developers, the CPUC, and other utilities. This should be done in a way that addresses any confidentiality concerns on the part of the relevant project developer. For example, the utility could provide the feeder/substation location (if possible) and offer the results as a simple yes/no passed. The study results could be hyperlinked to the PG&E RAM map.

Technologies Not Evaluated in Prior Laboratory or Field Studies

Type III generators, like DFIG wind turbines, were not evaluated in previous studies by Sandia National Laboratories upon which UI mitigations are based (SAND 2018-8431 and SAND 2012-1365). Funding and other resources to study these generators are needed and could likely be provided by the Department of energy (DOE) to Sandia. In the meantime, PG&E should work with developers to explore other interim solutions. Such interim solutions that could be explored include:

- Leveraging the active anti-islanding LOMD (loss of mains detection) of a solar photovoltaic or battery inverter as a trip signal for the wind turbine generator (WTG). This approach would need to be proven in the ROI study process. Successful implementation of this approach is dependent upon the following:
  - Ability to get the trip signal from those inverters;
  - An interlock scheme such that the WTG could not operate while the inverter-based generation was offline;
  - A fail-safe signaling scheme;
  - The possibility that the DFIG WTG would desensitize the PV/Battery LOMD; and
  - Utility buy-in on the method.
- One UIWG participant proposed allowing developers to carry insurance that indemnifies the utility and covers any harm that might arise from an unintentional islanding event. In this case, the utility's risk could be mitigated, and islanding risk could be eliminated as a driver for DTT. This alternative requires vetting by the PG&E legal team. At the time of the finalization of this report, a response has not been provided.

The Potential Future Problem

UI should continue to be monitored and evaluated as DER adoption grows. Greater penetration of distributed generation on a circuit could lead to delayed tripping of generators during a UI event and an island persisting longer than two seconds. This is because greater balance between generation and load makes the island harder to detect and thus shut down. The grid is also becoming more bi-directional; the old paradigm of unidirectional signals will need to evolve. Further exploration into mitigations beyond inverter-based anti-islanding may be warranted.

Ultimately, California will need to move away from active anti-islanding in DERs that use positive feedback. This is because DER penetration levels may eventually become high enough that destabilizing anti-islanding methods will degrade the transient response of the grid. It is unclear when this threshold will be reached, but we know it exists. This means that the most effective tool available for preventing unintentional islands in inverter-based DERs will become unusable above some DER penetration level. An alternative solution needs to be put in place before that threshold is reached.

Ongoing Dialogue

In addition to the IEEE Task Forces, the UIWG recommends that the CPUC support continued discussion amongst stakeholders on the topic of UI mitigations. This could occur informally via a quarterly call for 60-90 minutes during which stakeholders can share information and ask questions. This venue could support discussion of emerging research, pilots, industry conferences, and developments from standards development organizations (SDOs). Participants of the UIWG could be invited and other stakeholders could request to join if interested, including other IEEE members. The purpose of this call would be to support informal information sharing; it does not need to be a formal meeting with expectations that utilities prepare and have materials approved in advance.

Additions to the California Energy Commission's Solar Equipment List

To support implementation of its new screening process, PG&E needs to determine the aggregate percentage of inverters with Type 1 or Type 2A anti-islanding detection method on a feeder, distribution transformers, or line. PG&E currently has over 1,000 inverters listed internally and believes this captures approximately 90% of the market. However, as new equipment continuously emerges onto the market, PG&E is experiencing difficulty capturing the entire market. While PG&E does reach out to manufacturers, information is sometimes delayed and/or provided in non-uniform formats. This can lead to delays for the project developer because they cannot supply all of the information needed to PG&E.

PG&E proposed, and the UIWG agreed, to streamline this process by including anti-islanding information on the California Energy Commission's (CEC) equipment list. This will ideally reduce the time and effort spent seeking information by providing utilities and manufacturers with a central and consistently formatted repository. If the information for a particular manufacturer and model is not available, PG&E will still process the application.

D.21-06-002 Questions and Answers

To bring structure to the UIWG's discussions, Appendix B of D.21-06-002 directs the UIWG to discuss and develop responses to a list of questions. Those questions are enumerated here along with the Working Group's proposed answers.

1. What types of technical evaluations/studies need to be conducted to determine the system conditions that would drive the need for additional mitigation?

   Answer: PG&E's new Risk of Islanding (ROI) screens outlined in Appendix D of CPUC Decision 21-06-002. If the proposed project fails all of the screens, PG&E will need to conduct a manual determination of the necessary mitigation(s) based on system configuration. At present, neither SDG&E nor SCE require such studies. However, SDG&E continues to look into the risk of UI and agrees with PG&E that if there is a quantifiable risk of an UI then a ROI study will need to be performed to mitigate that risk. The bounds of the study are still being investigated by SDG&E.

2. What information would be necessary from DERs (such as anti-islanding algorithms) in order to perform technical evaluation?

   Answer: Distribution-level DERs may potentially go through two distinct technical evaluations. The first is performed by PG&E and follows the steps outlined in the Appendix. If the DER fails that screening process, the developer can either choose to directly install mitigations or pursue an ROI study with a PG&E-approved third-party at the developer's expense. To the extent the DER also fails the ROI study, mitigations may be needed.

   PG&E currently requires the following information to conduct its new screening process:

   - Single line diagrams
   - Electrical specifications
   - Type of DER
   - Protection equipment and settings
   - Voltage control operating model
   - Anti-islanding detection method

   SDG&E concurs with PG&E's list and notes that the type and characteristics of communication gateways and protocols should also be required.

   If it is determined ROI study is needed to avoid mitigation and a developer chooses to pursue an ROI study, then following additional information will be required:

   - Electrical model of the substation and distribution circuit under study - provided by PG&E
   - PSCAD model of project DERSs, and plant level controllers, if applicable - provided by developers
   - Protection settings for all generators - provided by developers
   - PSCAD models shall be provided with a PSCAD checklist that documents the IEEE 1547-2018 compliant settings of the DER as well as their corresponding sections in the PSCAD model reference manual - provided by developers

3. What mitigations would be available for resolving the identified issues?

   Answer: At present, PG&E would consider the following mitigations if a machine-based distribution-level DER fails the screening process and/or ROI study. Mitigations depend on various criteria like DER capacity (MW), Generation to Load ratios, Substation transformer configuration, whether DERs are backfeeding into transmission etc.

Mitigations and various criteria for applying the mitigation are explained within PG&E's Distributed Generation Protection Requirements 094681.[6]

Mitigations could include:

- Ground Fault Protection and Reclose Blocking
- Customer Owned Telemetry
- PG&E SCADA Equipped Recloser at machine generation location
- Redundant sets of PG&E approved, protection relays installed by the customer

If the DER is backfeeding into the transmission system, then further mitigations could include:

- Tripping of feeder breakers by Transformer protection or Bus protection
- Direct Transfer Trip (DTT)

PG&E is currently exploring other mitigations that may be deemed suitable at a later time. SDG&E currently requires reclose blocking at the substation but continues to explore other approaches that suitably mitigate potential issues while still being cost effective.

4. What should the anti-islanding evaluation process entail?

   Answer: PG&E's new ROI screens outlined in Appendix D of CPUC Decision 21-06-002 appears sufficiently robust. SDG&E will monitor its own UI experience and relevant industry experience and continue to examine the need for changes to its current mitigation practices.

5. At high levels of penetration, are the power quality issues driven by anti-islanding algorithms in need of mitigation?

   Answer: None of the three California IOUs have seen power quality issues. In studies, power quality impacts from Sandia Frequency Shift (SFS) have been minimal.

6. What reclosing and system-level unintentional island mitigation solutions exist or are feasible today (e.g., reclose blocking, extending anti-islanding response time, grounding switches)?
   a. What are typical costs associated with those solutions?
   b. Do power quality concerns within an unintentional island need to be addressed if the system-level approach is used?

   Answer:

- Ground switches are not used by PG&E, SDG&E or SCE as an anti-islanding mitigation as the utilities do not want to intentionally put a fault on the system.
- Reclose blocking is not an anti-islanding mitigation per se. It instead prevents reclosing into an island. This can be installed for synchronous machine installations. SCE does not use this technique, assuming that the DERs will trip offline as required by the standards.

[6] https://www.pge.com/content/dam/pge/docs/about/doing-business-with-pge/094681.pdf

  - PG&E sparingly uses reclose blocking if a DER fails the screening and/or ROI study process. Costs can vary, ranging from ~$150,000-$325,000 depending upon whether the reclose controller and/or relays need to be replaced.
  - Line side potential transformers (PT) could eventually be used for reclose blocking if need is determined
  - SDG&E does utilize reclose blocking but has not implemented DTT.
- Other anti-islanding mitigations available today:
  - Extend the reclose time delay (default is two seconds, but 1547 allows the utility operator to extend this out to 5 seconds or more under certain circumstances)
    - PG&E utilizes this approach for certified inverters or for DERs that pass the ROI Screens
  - Operational modifications, such as enhanced communication and control strategies
  - Wireless transfer trip
  - In some instances, PG&E places a utility-owned SCADA recloser in front of the DER that is presenting issues. The distribution system operator can then terminate an island that forms via the SCADA recloser.
- No power quality issues need to be addressed if a system-level approach is used.

7. What system-level anti-islanding enabling solutions exist or are feasible today (e.g., grounding switches, power line carrier heartbeat, communications)?
   a. What are typical costs associated with those solutions?
   b. Do power quality concerns within an unintentional island need to be addressed if the system-level approach is used?

Answer:
PLC is currently being deployed by a handful of utilities in the Northeast and Midwest. One of its main advantages is that it can cover all of the DERs on a given circuit rather than point to point. However, it currently faces propagation challenges. The signal cannot pass through transformers or underground distribution. Additionally, as higher frequencies are leveraged to achieve higher bandwidth, cross coupling with distribution lines not meant to communicate these signals unfortunately becomes possible. For these reasons, the UIWG is not recommending that PG&E prioritize further exploration of utilizing PLC as a UI mitigation on its system at this time.

8. What system-level intentional island enabling solutions exist or are feasible today (e.g, communications, power line carrier heartbeat)? *Note that scoping related to intentional islanding is subject to alignment with final scoping of the proposed Microgrid Working Group as outlined within the Track Two Staff Proposal as recommended within the Microgrid OIR.*
   a. What are typical costs associated with those solutions?
   b. Do power quality concerns within an intentional island need to be addressed if the system-level approach is used?

Answer:

- Solutions used to prevent an island can also be used to open into a microgrid (e.g., reclosers, transfer trip, etc.). For example, the Redwood Coast Airport Microgrid (RCAM) uses a recloser to isolate the segment of the grid containing the microgrid at the boundary.
- Potential power quality issues (voltage, frequency, ability of DERs to pick up the load) should be studied before the microgrid becomes operational. The IEEE 1547.4 Working Group is currently looking to address power quality issues within intentional islands. The UIWG defers to any subsequent updates made to the standard.

9. What potential unintentional island mitigation solutions that do not yet exist need further evaluation and/or testing?

   Answer:
   Along with the technologies recommended for piloting, the UIWG believes an additional UI mitigation warrants further testing. The BUSTR method should be explored and eventually be evaluated in the longer term for piloting. Sandia National Laboratories is currently assembling a coalition and pursuing funding opportunities to conduct demonstration projects and pilots at-scale. Sandia will report back on its progress and findings to the utilities over the coming years. The merits of potential business models for BUSTR also need to be discussed. This topic is particularly complex because BUSTR provides broader benefits like more adaptative control of the distribution system, beyond just UI mitigation. For a utility owned and operated system, a subscription model could be leveraged. A federal ownership model could also be considered in which the federal government owns and operates the system and socializes the costs through taxes.

10. What unintentional island mitigation solutions are ripe for pilot projects and/or additional testing to ensure feasibility?

    Answer:
    In the near term, the UIWG supports PG&E's efforts to pilot cellular wireless DTT and spread spectrum broadcast (GOOSE) as potential alternatives to the current wired DTT UI mitigation. Given their broadcast radius limitations, PG&E questions whether synchrophasors are truly a cost-effective alternative to DTT.

    SDG&E will examine expansion of its existing system protection capabilities, such as use of wireless DTT, synchrophasors and GOOSE messaging, to added risk reduction for UI.

11. What coordination and cost allocation issues need to be surmounted in order to deploy the most effective/feasible/least cost unintentional island mitigation solutions?

    Answer:
    Unless and until PG&E's new ROI Screens are applied to a new distribution-level DER which then fails and is required to install mitigations, it is difficult to determine:

- The developer and utility time and costs incurred in preparing for these studies;
- The likelihood that any developer would fail the test and either pursue mitigations or abandon the project entirely; and
- The developer and utility costs associated with any resulting mitigations.

Without understanding the total costs borne by the utility and/or DER developer and the key drivers of these costs, the UIWG chose not to offer recommendations regarding changes to cost allocation at this time. As previously noted, PG&E only saw an average of one distribution-level DER fail its prior ROI screening process and need to require DTT, suggesting that this is a rare occurrence, at least historically.

Several Task Forces are underway as part of the effort to revisit the IEEE 1547 and 2030 series of standards. These represent ideal forums for continued discussion of alternatives to wired DTT. In addition to the IEEE Task Forces, the UIWG recommends that the CPUC support continued discussion amongst stakeholders on the topic of UI mitigations. This could occur informally via a quarterly call for 60-90 minutes during which stakeholders can share information and ask questions. This venue could support discussion of emerging research, pilots, industry conferences, and developments from standards development organizations (SDOs). Participants of the UIWG could be invited and other stakeholders could request to join if interested, including other IEEE members. The purpose of this call would be to support informal information sharing; it does not need to be a formal meeting with expectations that utilities prepare and have materials approved in advance.

Appendix

List of Relevant PG&E AL's

Advice Number: 6614-E; 6614-E-A
Date Filed: 06/03/2022; 09/20/2022
Subject: Supplemental: Pacific Gas and Electric Company's Proposed Anti-Islanding Options Guidance Section for its Interconnection Handbooks Pursuant to R. 17-07-007 Rule 21 Working Group 4 Decision 21-06-006 Ordering Paragraph 14
Effective Date: 10/05/2022
Decision Number: D.21-06-006
Description: Proposed a new appendix to PG&E's Distribution Interconnection Handbook and Transmission Interconnection Handbook to incorporate anti-islanding
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Advice Number: 6744-E
Date Filed: 10/21/2022
Subject: Modifications to PG&E's Interconnection Application Forms to Incorporate Anti-Islanding Options in the Application Portal Pursuant to the Rule 21 Working Group 4 Decision 21-06-002
Effective Date: 12/12/2022
Decision Number: D.21-06-002
Description: Updated PG&E's processes and application forms to incorporate anti-islanding

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Advice Number: 6782-E
Date Filed: 12/07/2022
Subject: Modifications to PG&E's Electric Rule 21 to Address Anti-Islanding Pursuant to the Rule 21 Working Group 4 Decision 21-06-002
Effective Date: Pending
Decision Number: D.21-06-002
Description: Updated PG&E's Rule 21 tariff to address anti-islanding
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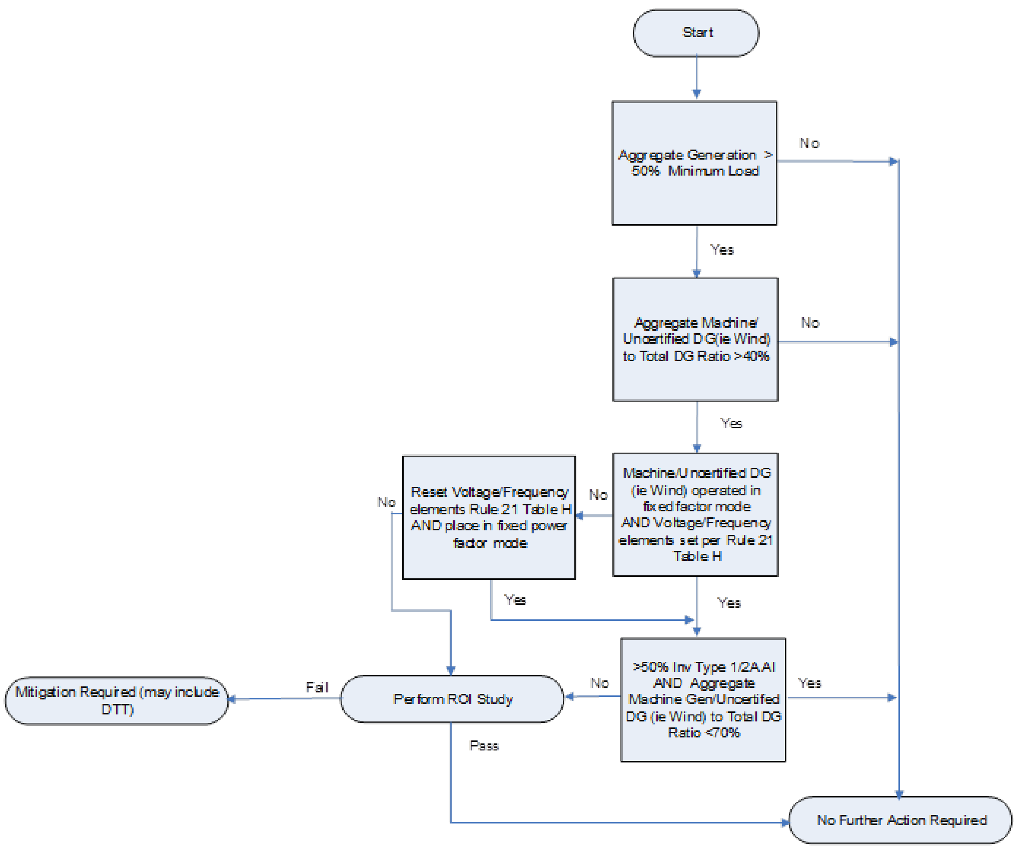
PG&E's specific ROI Study is included as one of the evaluation screens (Perform ROI Study). Please see the flow chart from Decision 21-06-002 (Appendix D, page D3).[7]



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7 https://www.pge.com/includes/docs/pdfs/shared/customerservice/nonpgeutility/electrictransmission/handbook/094681.pdf