Generic Anti-Islanding (AI) Detection Method Definitions-Nov 4, 2018

The most common inverter AI detection methods are defined in generic groups. These are intended to facilitate information exchange and to better defined the operation of inverter on-board islanding prevention. AI detection method may be an important factor during technical review for specific interconnections. Experience and understanding of manufactures, developers and utilities will likely reduce the need for other islanding preventions. As DER penetration levels increase, and inverter capabilities such as ride thru are added, these details are expected to have increasing importance. The groups have evolved from prior works[1][2] and others identifying typical methods with descriptors such as Over/Under Voltage or Frequency, Phase Jump, and Active Frequency Shift (also Sandia Frequency Shift). Recently these groups were defined in ***Sand2018-8431, July 2018*** (part of a joint EPRI-Sandia research project). They are further defined here, including a table of characteristics and illustrative figures.

1. **AI Group 1**: Methods in this group produce an output perturbation in positive-sequence fundamental frequency (or phase) specifically for island detection. This perturbation increases as the error increases (e.g. positive feedback on frequency error). It may be continuous or pulsed. Group 1 inverters use this positive feedback to promote instability after an island forms. Within the normal frequency operating range, feedback is key to destabilizing. Feedback continues until a frequency trip limit is reached and includes no dead zone.

2. **AI Group 2A**: Similar to Group 1 in that the method produces an output perturbation in positive-sequence fundamental frequency (or phase) and the perturbation increases with error (i.e., positive feedback on frequency error). The difference is that positive feedback, within trip bands, is not continuous. Inverters in this Group may have a stepped or otherwise discontinuous response as the magnitude of perturbation reaches a limit prior to the frequency trip thresholds. Inverters with a dead zone around 60-Hz are excluded from Group 2A.

3. **AI Group 2B**: Methods in this group have any or all the properties of Group 2A, except with a dead zone around 60 Hz where active anti-islanding is inhibited.

4. **AI Group 2C**: Methods in this group have any or all the properties of either Group 1 or Group 2A, except the feedback on frequency error is *unidirectional*; that is, feedback is in the same direction for either increasing or decreasing frequency (or phase) error.

5. **AI Group 3**: Methods in this group produce an output perturbation in positive-sequence fundamental frequency or phase and usually monitors change of impedance. However, unlike Groups 1 and 2, the magnitude of perturbation does not grow with increasing frequency error.

6. **AI Group 4**: Methods in this group produce an output perturbation at a harmonic frequency (multiple of the fundamental) specifically for detecting an island. Typically, the magnitude of perturbation is independent of frequency error.

7. **AI Group 5**: Methods in this group rely on passive methods to detect island formation (such as frequency rate of change, RoCoF, or vector shift). Also included is advanced signal processing of the measured voltage or current to detect an island. Not included are methods that drive an island to a frequency trip limit, and then rely on the frequency trip to remove the island.

8. **AI Group 6**: Methods in this group produce a negative sequence current and monitor voltage for island detection. This is achieved by several means, including altering individual phase current magnitudes or dithering the phase angle separation between the three output current phases.

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[1] M.E. Ropp, Determining the Relative Effectiveness of Islanding Detection Methods Using Phase Criteria and Non-detection Zones, IEEE Transactions September 2000

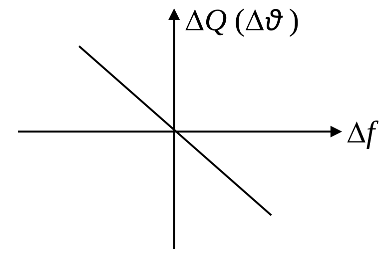
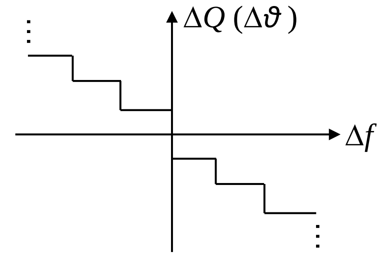
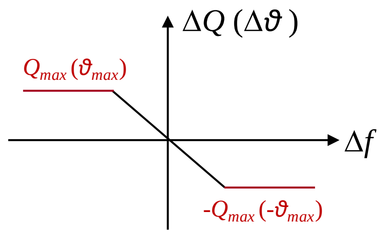
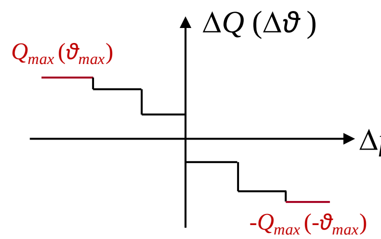
[2] Evaluation of islanding detection methods for PV utility interactive power systems, IEA-PVPS T5-09, March 2002.

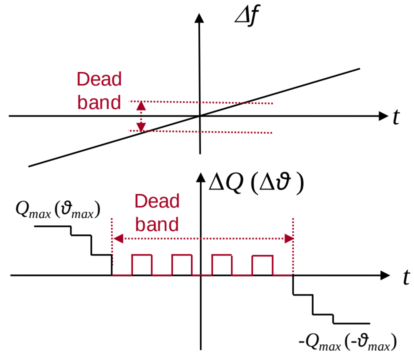
Comparison

	Group 1	Group 2A	Group 2B	Group 2C	Group 3	Group 4	Group 5	Group 6
Active or Passive AI methods?	Active	Active	Active	Active	Active	Active	Passive	Active
One example of the AI scheme*	Classic Sandia Frequency Shift (SFS)	Group 1, Classic SFS with limits	Impedance detection with positive feedback, and includes a small dead zone	Group 1 or 2A unidirectional positive feedback	Fixed pulse of reactive power	Injection of specific harmonic	RoCoF (Rate of Change of Frequency) Phase jump Harmonic detection	Negative sequence disturbance (3-phase only)
Monitored variable	Frequency or phase angle of voltage	Frequency or phase angle of voltage	Frequency or phase angle of voltage	Frequency or phase angle of voltage	Magnitude, frequency or phase angle of voltage	Harmonic voltage	Frequency change rate Voltage phase angle Voltage harmonics	Negative sequence voltage
Perturbation (Output)	Reactive power or phase shift	Reactive power or phase shift	Reactive power or phase shift	Reactive power or phase shift	Reactive power or phase shift	Harmonic current	NA	Negative sequence current
Dead band	None	None	Yes	None	Either	Either	Yes	Either
Shape of perturbation	Continuous or pulsed	Continuous or stepped	Pulsed or non-pulsed	Continuous or pulsed	Pulsed	AC current at harmonic frequency	NA	AC current at negative sequence
Magnitude of perturbation	Frequency or phase error dependent	Frequency or phase error dependent up to a limit within thresholds	Does not change within dead band, otherwise same as group 2A	Same as group 1 or group 2A, depends on whether limits are applied	Does not grow with increasing frequency error	May or may not increase with harmonic voltage at POI	NA	May or may not increase with negative sequence voltage at POI
Impact on power quality	Slightly degrade	Slightly degrade	Slightly degrade	Slightly degrade	Degrade	Degrade	Minimal	Degrade
Impact on system transient stability	Degrades at high penetration	Degrades at high penetration	Degrade at high penetration	Degrade at high penetration	Minimal	Minimal	Can impact transient stability if false trips	Minimal

*Note, these are detection examples for each group. Also, it is possible that a single inverter may use more than one group type.

Illustrative examples of AI schemes in each Group

Group 1 *Example: Classic SFS* *- Positive feedback involved*	Continuous perturbation	 Positive Q means reactive power generation; Negative Q means reactive power absorption
	Stepped perturbation	 Positive Q means reactive power generation; Negative Q means reactive power absorption
Group 2A *Example: Classic SFS with limits* *- Positive feedback involved*	Perturbation with limits	 Positive Q means reactive power generation; Negative Q means reactive power absorption
	Stepped perturbation with limits	 Positive Q means reactive power generation; Negative Q means reactive power absorption

<table>
<tr>
<td>Group 2B
Example: Impedance detection with positive feedback, and includes a small dead zone</td>
<td colspan="2">

Positive Q means reactive power generation;
Negative Q means reactive power absorption</td>
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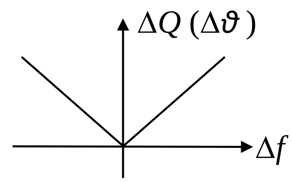
<tr>
<td rowspan="2">Group 2C
Example: SFS in group 1 with unidirectional positive feedback</td>
<td>Continuous perturbation</td>
<td>

Positive Q means reactive power generation;
Negative Q means reactive power absorption</td>
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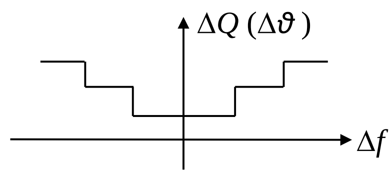
<tr>
<td>Stepped perturbation</td>
<td>

Positive Q means reactive power generation;
Negative Q means reactive power absorption</td>
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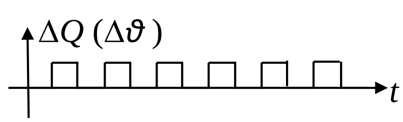
<tr>
<td>Group 3
Example: Fixed pulse of reactive power</td>
<td colspan="2">

Positive Q means reactive power generation;
Negative Q means reactive power absorption</td>
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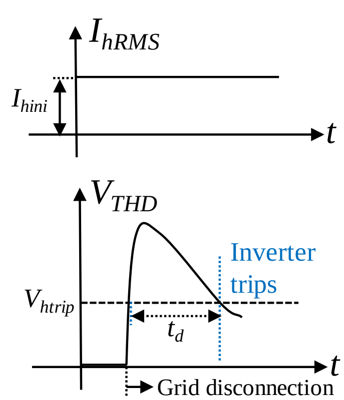
<tr>
<td>Group 4
Example: Injection of specific harmonic</td>
<td>No positive feedback</td>
<td>

I_{hini} is the initial harmonic current, injected as soon as AI schemes are enabled V_{htrip} is the harmonic threshold to trip DER inverters</td>
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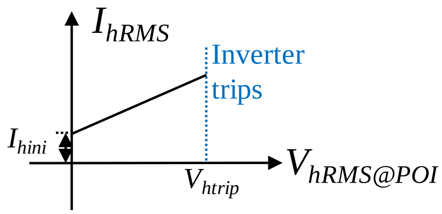
<td></td>
<td>Positive feedback involved</td>
<td>


I_{hini} is the initial harmonic current, injected as soon as AI schemes are enabled V_{htrip} is the harmonic threshold to trip DER inverters
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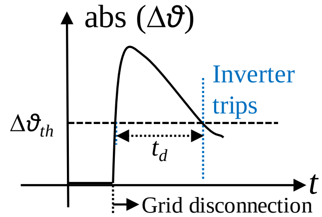
<td>Group 5
Example: Passive methods - No perturbation involved, events caused by island or other AI schemes</td>
<td>Phase jump</td>
<td>


Δθth is the threshold of phase angle change to trip the timing
t_d is duration of the event (phase angle stays higher than the threshold Δθth) before inverter trips. Normally used to avoid nuisance
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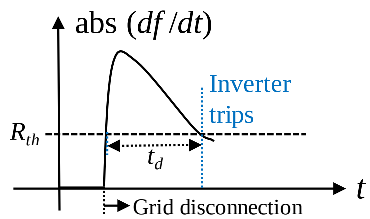
<td>RoCoF</td>
<td>


R_{th} is the threshold of RoCoF to trip the timing
t_d is duration of the event (RoCoF stays higher than the threshold R_{th}) before inverter trips. Normally used to avoid nuisance
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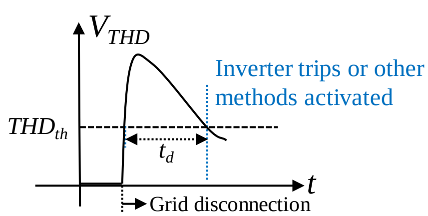
<td>Harmonic detection</td>
<td>


THD_{th} is the threshold of harmonic detection method to trip the timing
t_d is duration of the event (voltage THD stays higher than the threshold THD_{th}) before inverter trips. Normally used to avoid nuisance
The event may activate other measures instead of inverter trip, such as reducing the power by 50%, or activating an impedance-detection pulse
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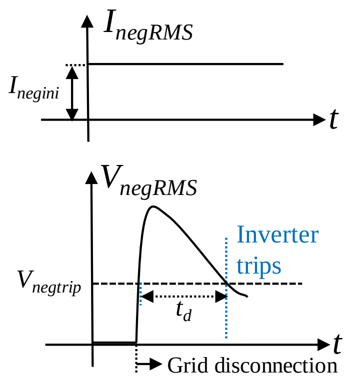
<td rowspan="2">Group 6
Example: Negative sequence disturbance</td>
<td>No positive feedback</td>
<td>


I_{negini} is the initial negative sequence current, injected as soon as AI schemes are enabled
$V_{negtrip}$ is the negative sequence voltage threshold to trip DER inverters
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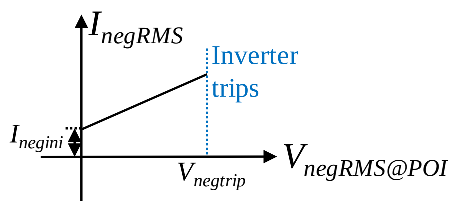
<tr>
<td>Positive feedback involved</td>
<td>


I_{negini} is the initial negative sequence current, injected as soon as AI schemes are enabled
$V_{negtrip}$ is the negative sequence voltage threshold to trip DER inverters
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</tr>
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