Islanding Detection with Phasor Measurement Units

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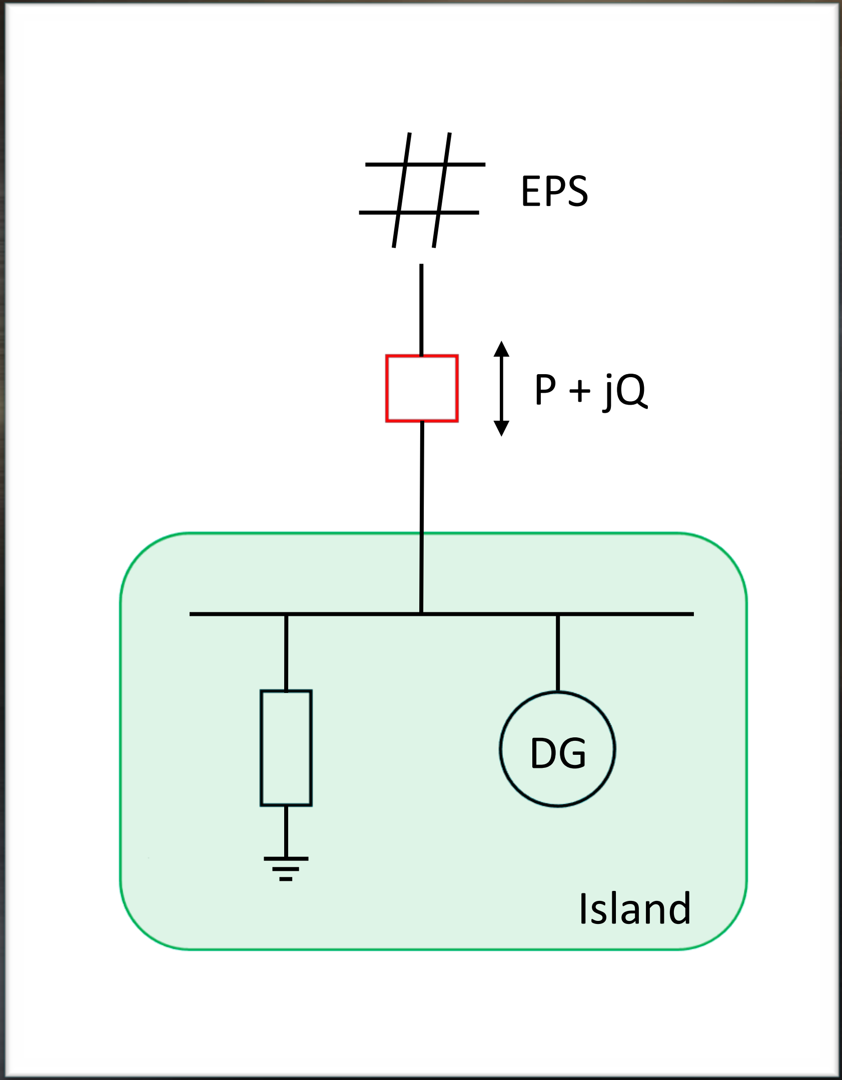
Definition

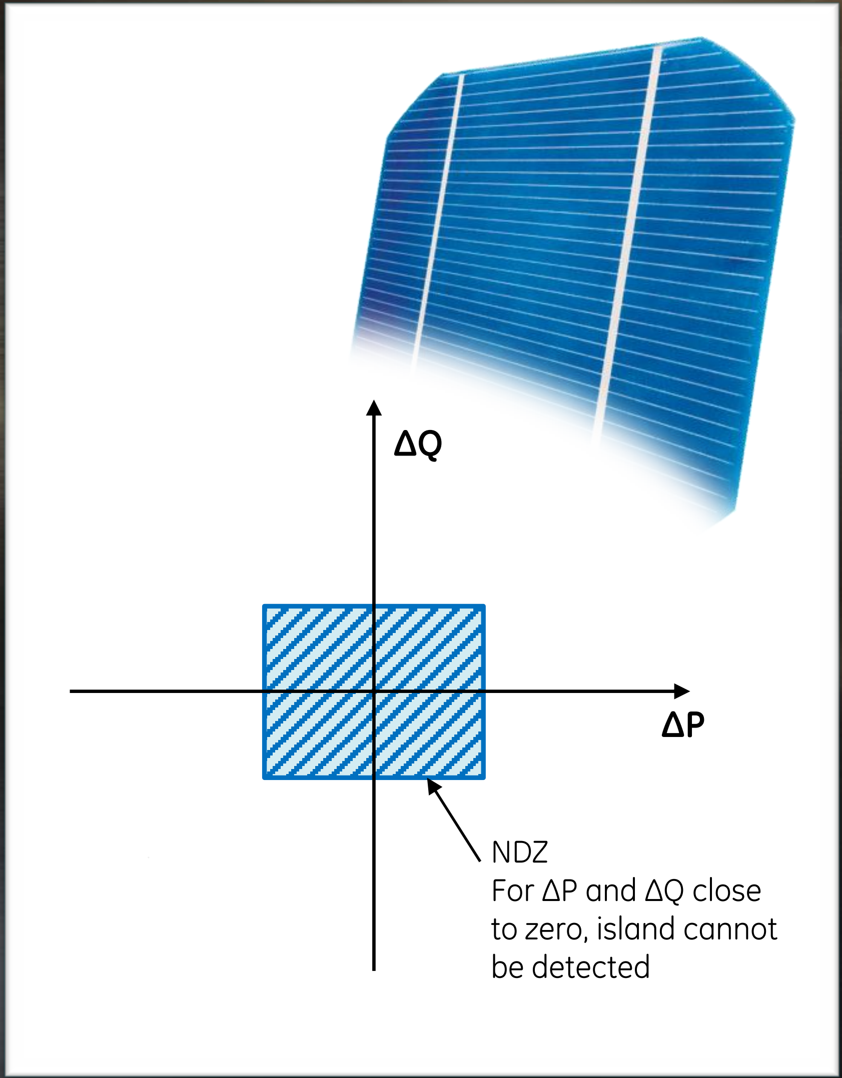
"An island is defined as a condition in which a portion of an area EPS is energized solely by one or more local EPSs through the associated PCCs while that portion of the area EPS is electrically separated from the rest of the area EPS."

IEEE Std 1547.2™-2008.



Why Island Detection?

- Islanding operation
  - The utility cannot control voltage and frequency in the island
  - Possibility of damage to customer equipment
  - Dangerous condition for personnel
  - Reclosing into an island may result in re-tripping the line or damaging the distributed resource equipment.
- NDZ (None-detection-zone)



Passive methods

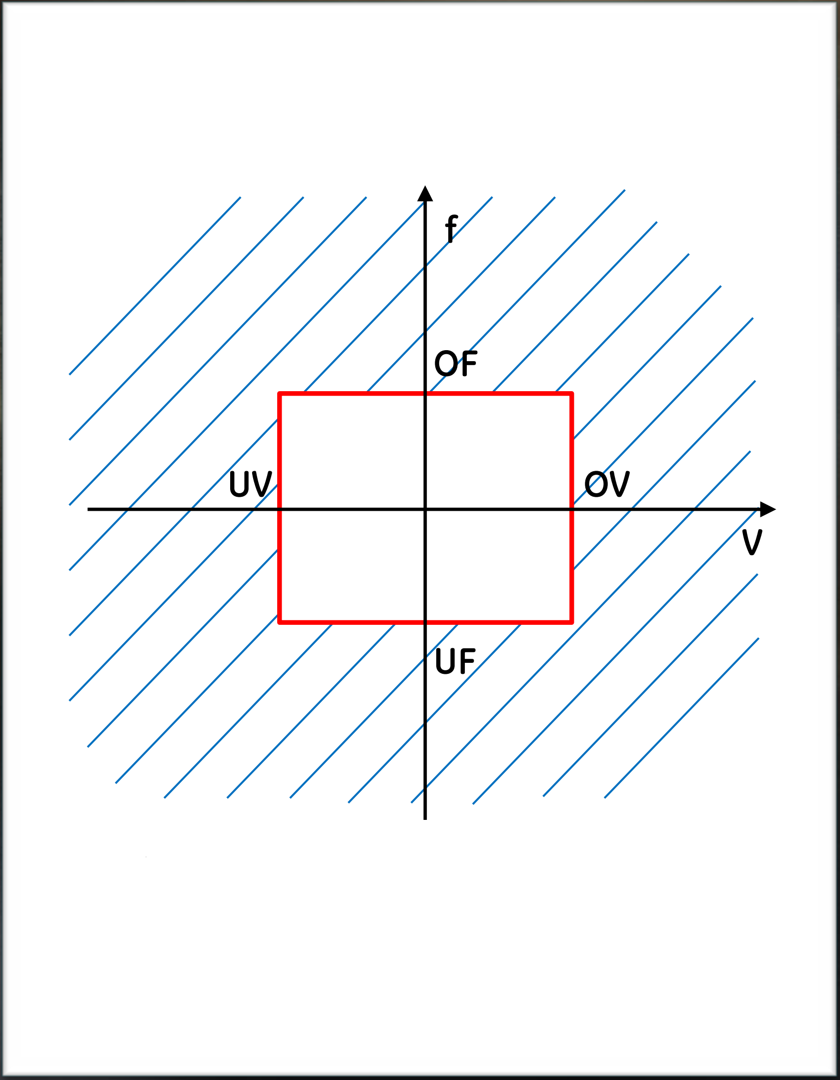
Over/under voltage and over/under frequency:

Advantages

- Simplicity
- Low cost

Disadvantages

- Tripping time may be long for small mismatch
- Fails when P+jQ = 0



Passive methods

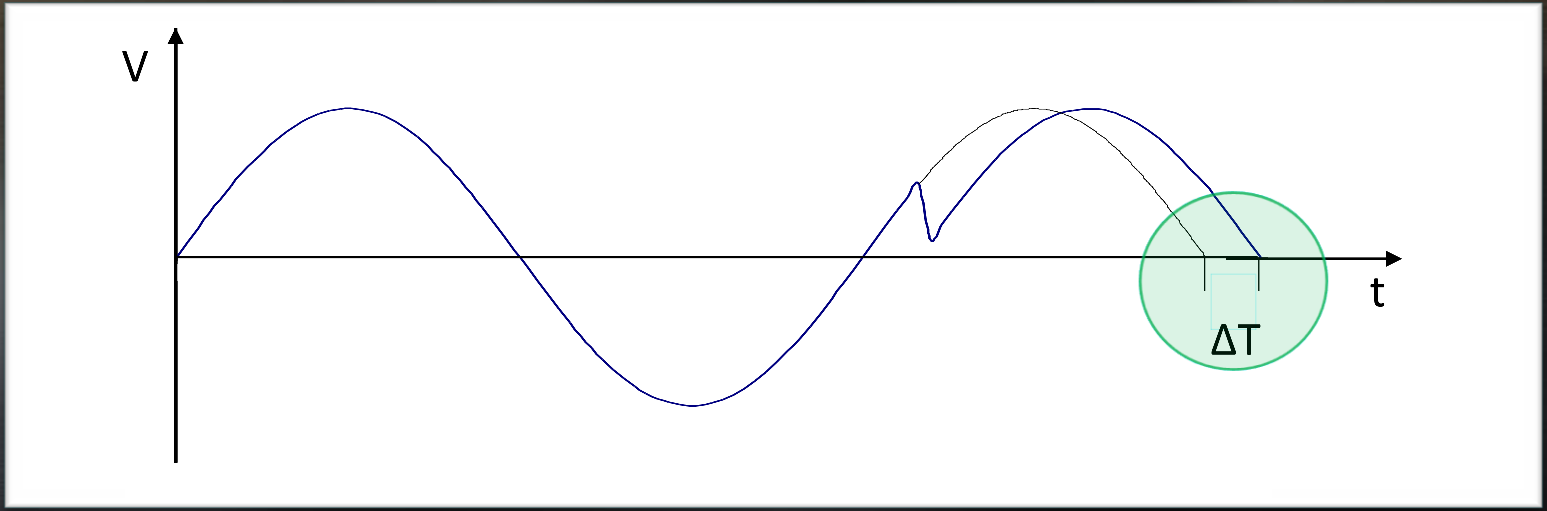
Vector jump:

Advantages

- Can operate faster than voltage/frequency protection
- Stable for single phase faults
- Applicable to any DG

Disadvantages

- Can be difficult to set
- Fails when P+jQ = 0



Passive methods

Rate of Change of Frequency:

Advantages

- Can operate faster than voltage/frequency protection
- Applicable to any DG

Disadvantages

- May be difficult to reliably discriminate between an islanding event and a system disturbance.
- Fails when P+jQ = 0

Passive methods

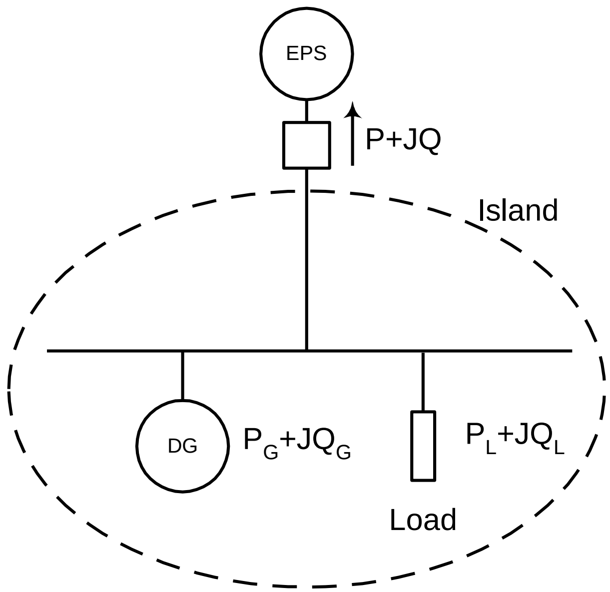
Rate of Change of Power :

Advantages

- Applicable to any DGs
- Can operate faster than voltage/frequency protection
- Stable for single phase faults

Disadvantages

- Fails when P+jQ = 0



$$\Delta P_G = \Delta P_L \cdot \frac{H_G \cdot S_G}{(H_G \cdot S_G + H_{EPS} \cdot S_{EPS})} \quad \textit{Connected to EPS}$$

$$\Delta P_G = \Delta P_L \quad \textit{Islanded}$$

Where H is the inertia constant
and S is the capacity

Passive methods

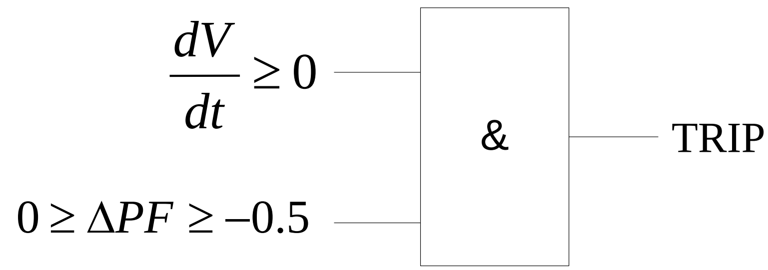
Rate of Change of Voltage & Change in PF:

Advantages

- Can operate faster than voltage/frequency protection
- Stable for system disturbances
- Applicable to any DGs

Disadvantages

- Fails when P+jQ = 0



Passive methods

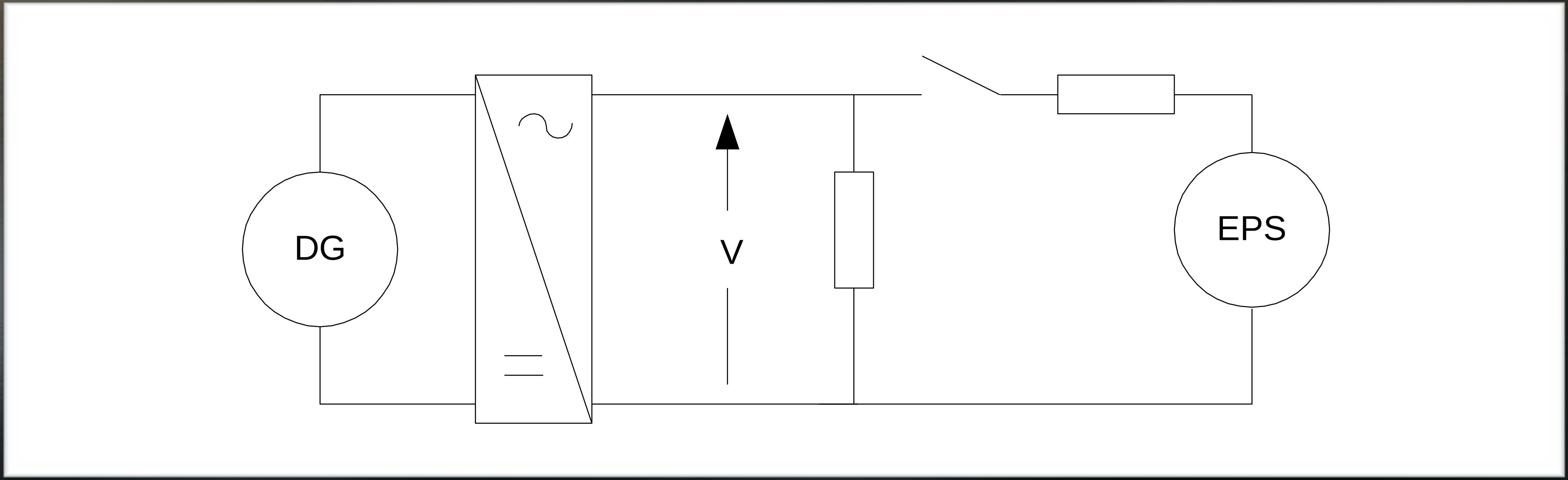
Voltage Harmonic Monitoring :

Advantages

- Can operate when P+jQ = 0

Disadvantages

- Load may filter the harmonic content
- Could be affected by transient phenomenon
- Only applicable for inverter-based DGs



Active methods

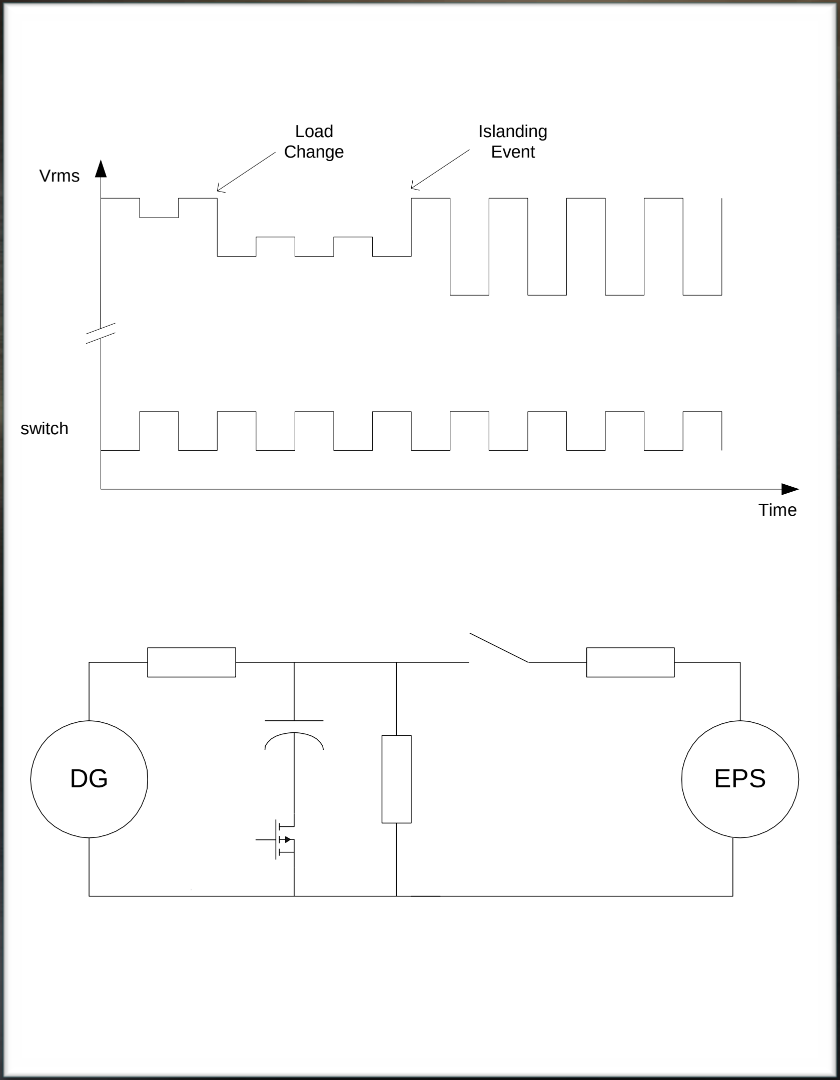
Impedance Switching:

Advantages

- Can operate when P+jQ = 0
- Applicable to any DGs

Disadvantages

- May impact on power quality
- Coordinated operation of breaker and impedance switch



Active methods

- Measurement of the system impedance
- Impedance detection at the determined frequency
- Frequency variation, jump
- Frequency derivatives
- Active Frequency Drift (Sandia Frequency Shift)
- ENS or MSD, two switching devices in series are independently monitored and controlled

Communications methods

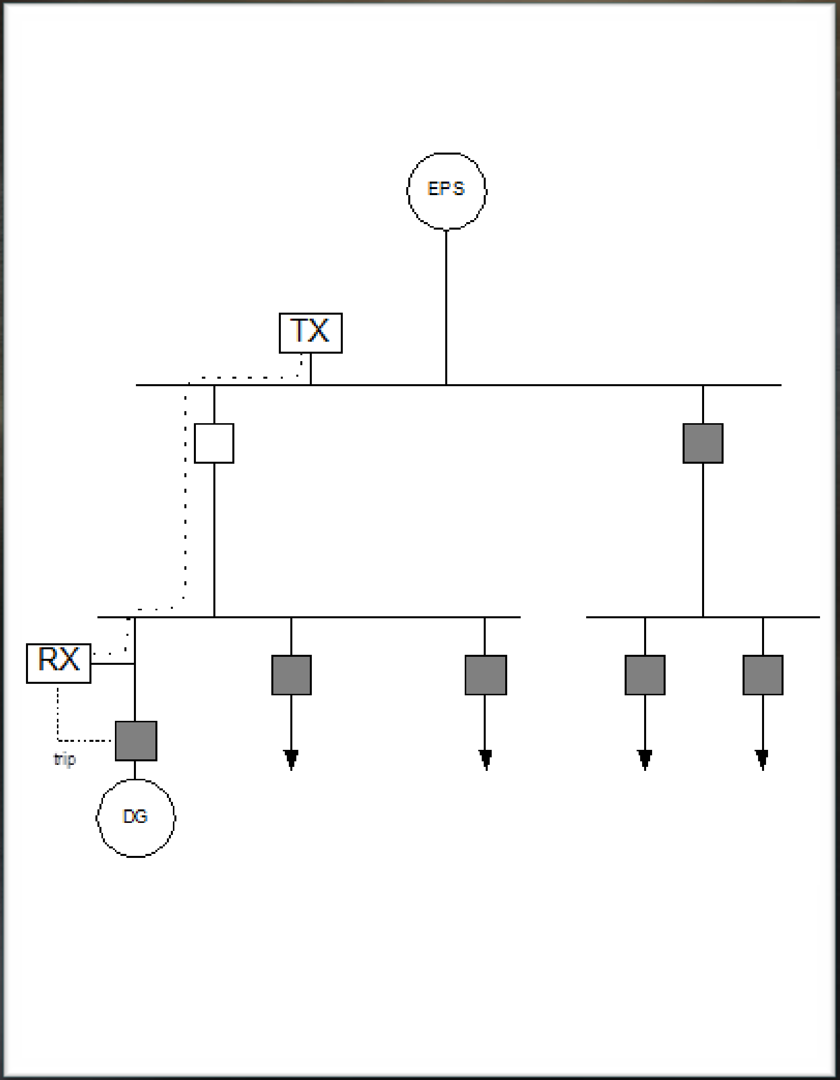
Power Line Carrier:

Advantages

- Can operate when P+jQ = 0
- No impact on power quality

Disadvantages

- Requires installation of transmitter and receiver equipment
- May mal-operate during a system fault



Communications methods

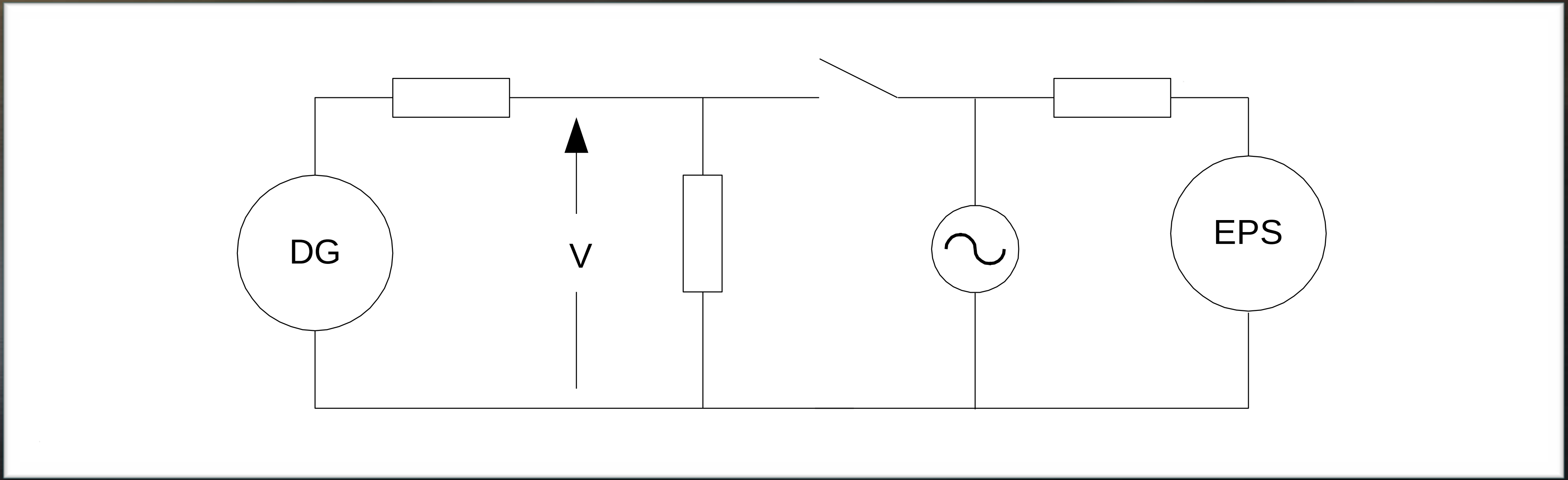
Signal Produced by Disconnect Switch:

Advantages

- Can operate when P+jQ = 0

Disadvantages

- Requires the installation of a transmitter into the EPS.
- Expensive and could involve significant permitting and design complications.

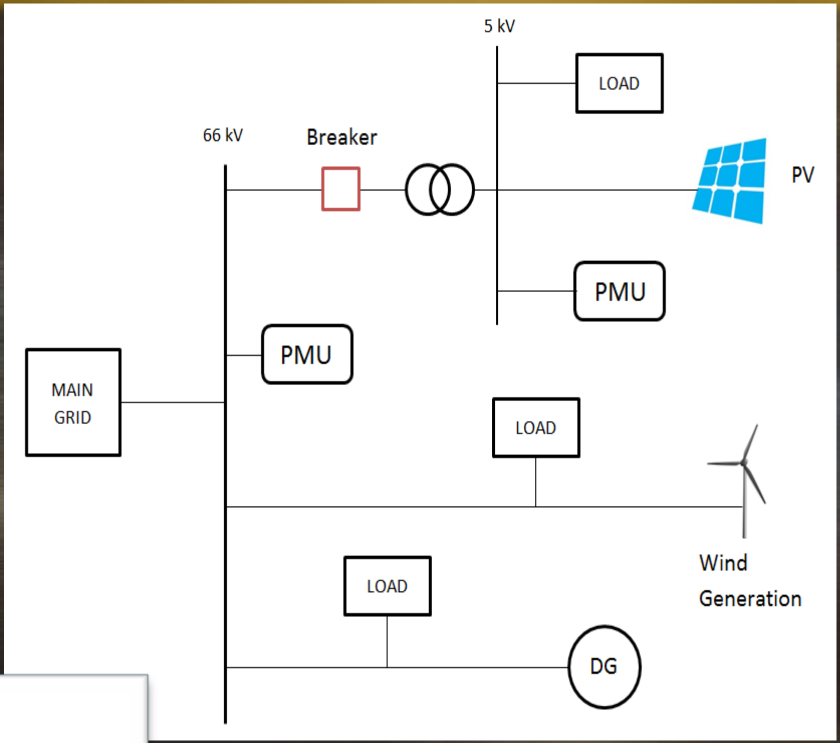


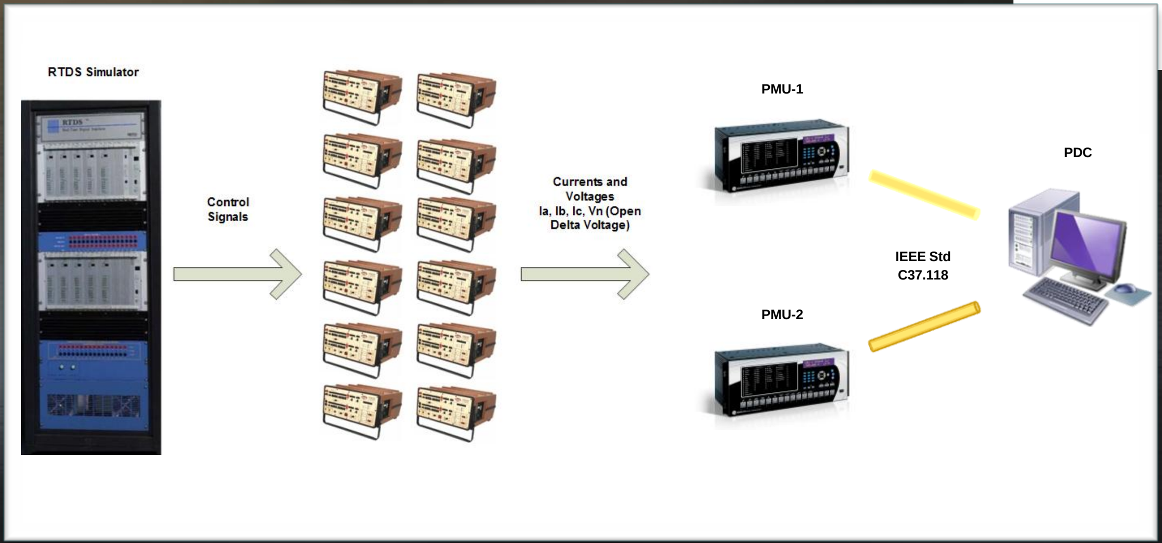
Summary of methods

- Most passive schemes cannot guarantee fast operation as the power flow across the breaker approaches zero.
- Many active schemes can quickly detect an island even when the power flow through the breaker is zero prior to islanding.
- Of the these schemes several are applicable only for inverter-based DGs.
- The remaining schemes have power quality, scalability or security issues.

Research

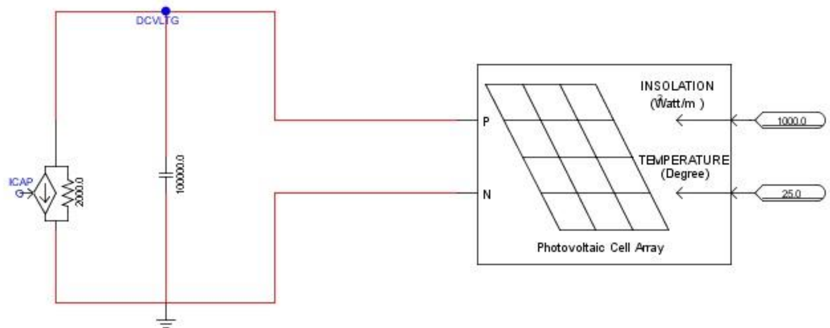
Model of distribution network contains photovoltaic, wind and other renewable sources, as well as several loads spread all of the system.



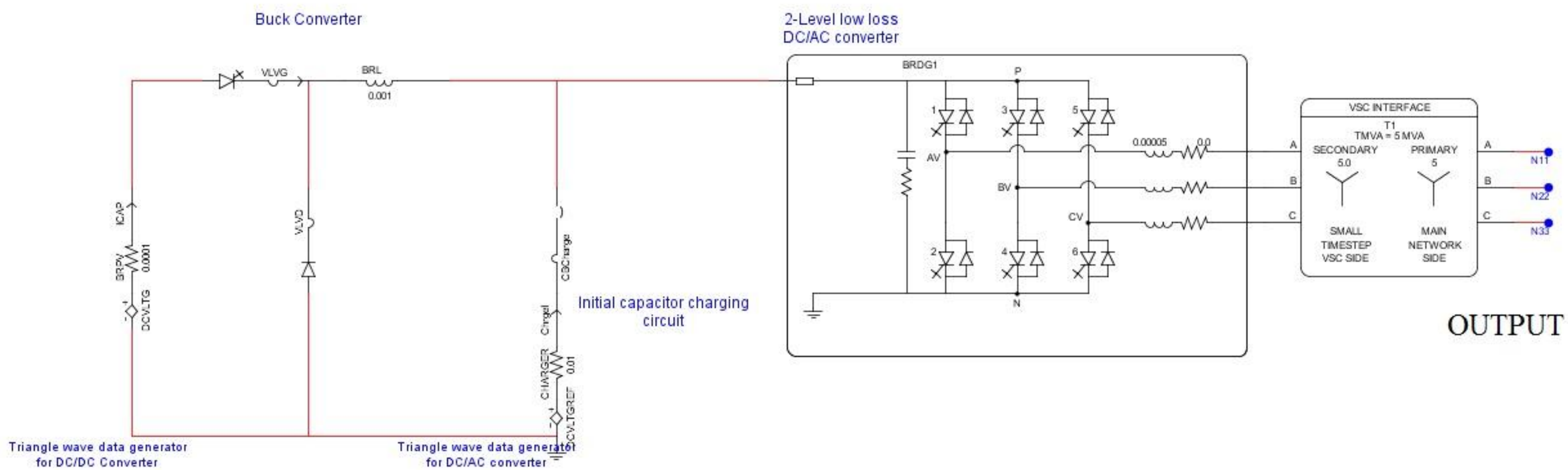


Research

RTDS PV model



Description	Value	Unit
Component name	DefaultName	
Open Circuit Voltage [V]	21.7	V
Short Circuit Current [A]	3.35	A
Voltage at Pmax [V]	17.4	V
Current at Pmax [A]	3.05	A
Assignment of Model to Processor Card	Automatic	
-if Manual: Begin on Processor Card	1	1 to 6
-if Manual: Begin on Processor	A	
-if Auto: Begin on Processor	Either	
Solve Model on card type:	GPC/PB5	



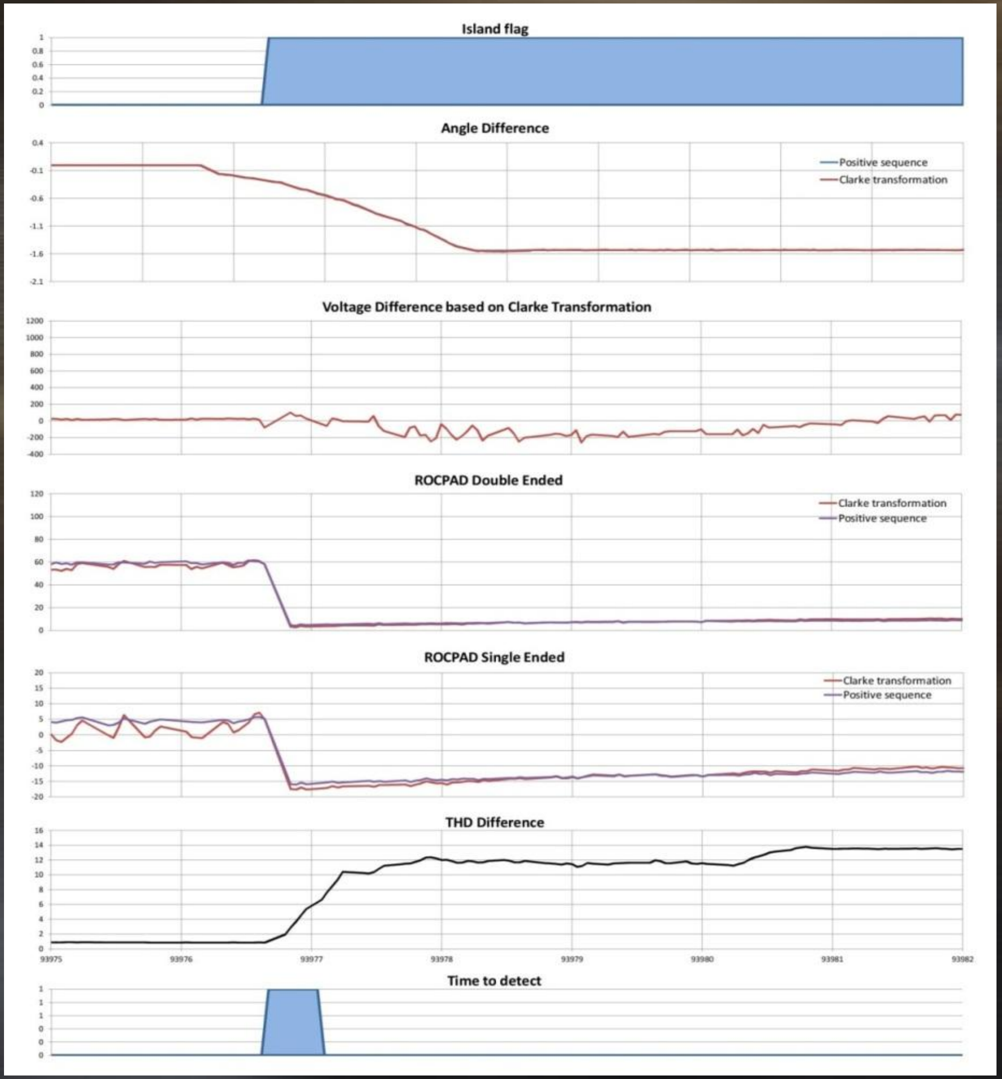
Preliminary Test Results

THD Differential is monitored

Case #1

Power generated inside the island is higher than it's consumption

$P_{gen} > P_{load}$

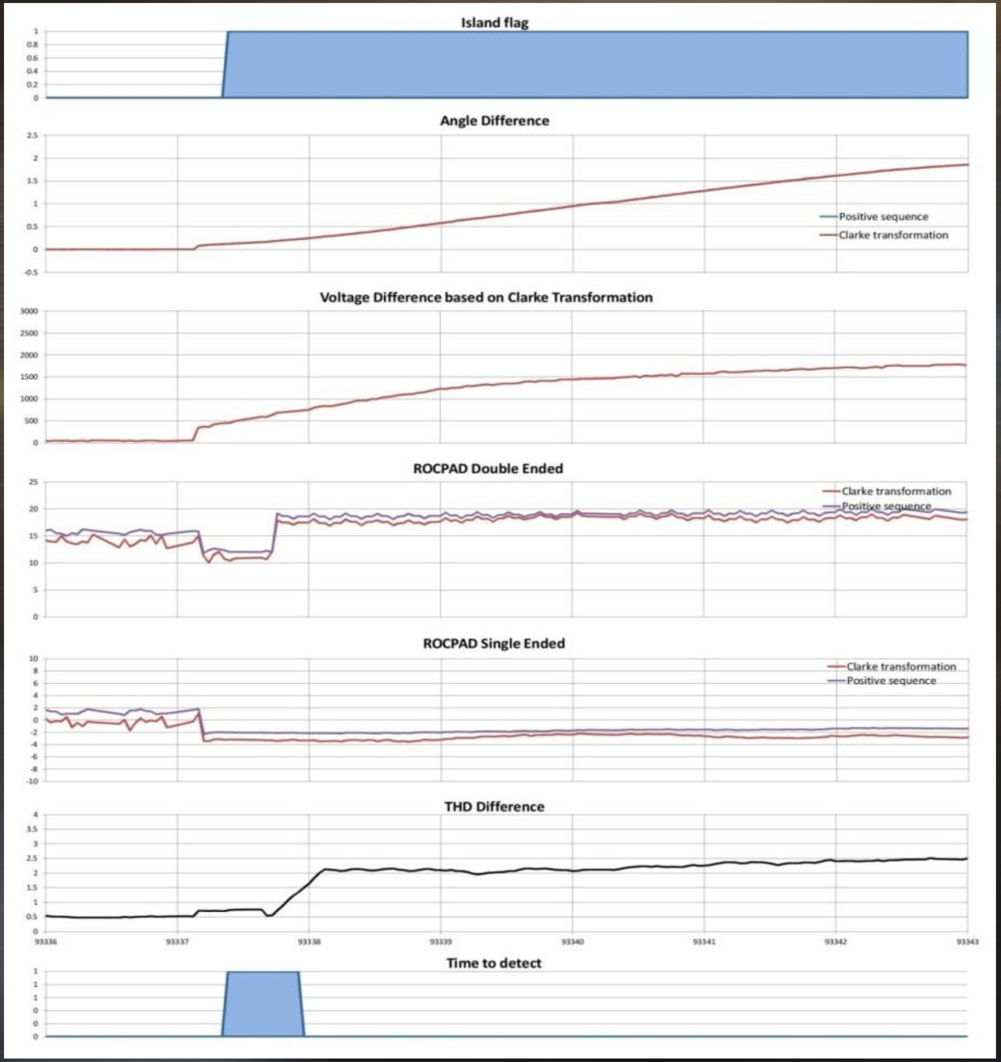


Preliminary Test Results

Case #2

Power generated inside the island is lower than it's consumption

$$P_{gen} < P_{load}$$

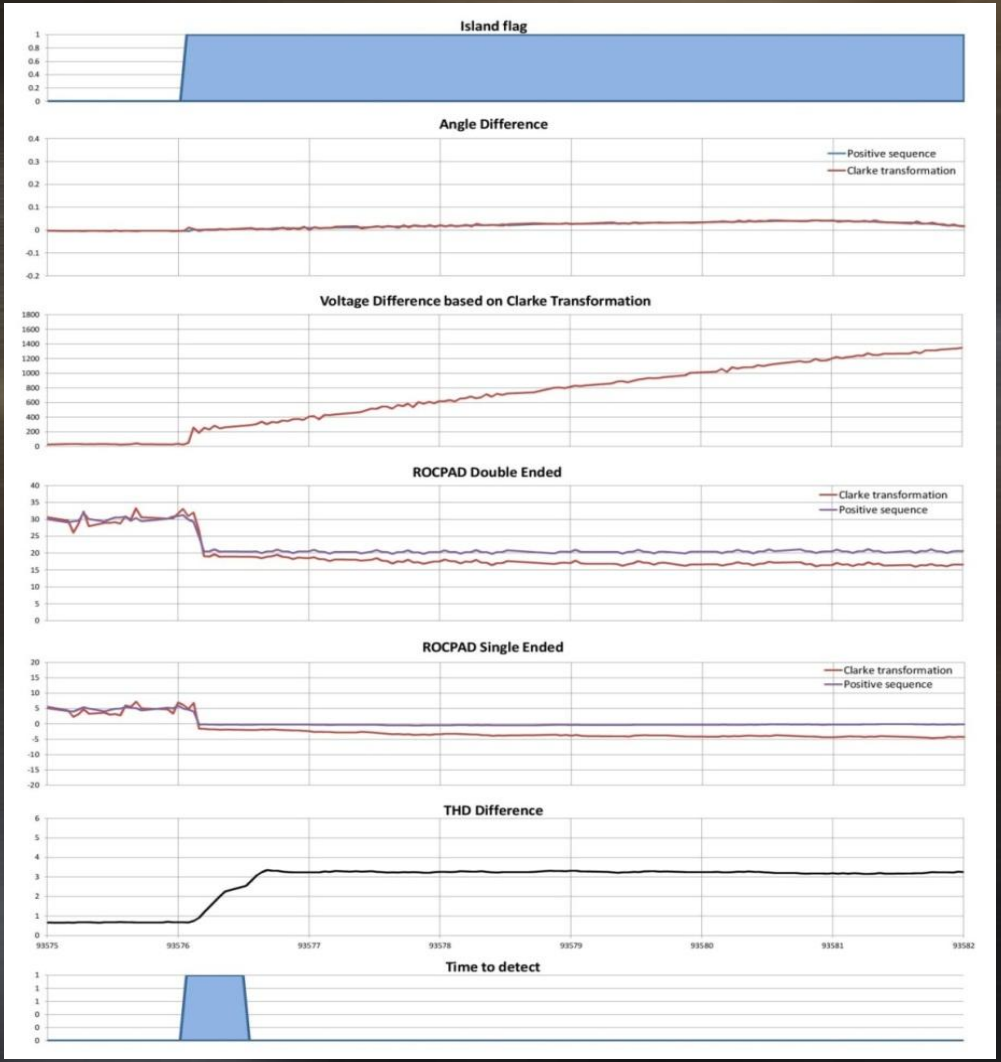


Preliminary Test Results

Case #3

Power generated inside the island is almost equal to consumption

$$P_{gen} \approx P_{load}$$



Solution

Proposed way for Island Identificaction - Combine most effective passive methods with synchrophasor technology

Solution

- ***Voltage Angle Change***:

  Angle variation during normal operation is in the range of $\pm 40°$ approx. During Island value is higher and non affected by $\Delta P + j\Delta Q$.

+

- ***Voltage Magnitude Change***:

  Magnitude shifting turned out as an effective method in high power mismathes which can decrease detection time substantially.

+

- ***Voltage THD Differential***:

  New idea which can detect island condition immediately and independently on the power flow in point of disconnection.

= **DETECTION IN MOST OPERATION CONDITIONS**

Algorithms Developed

- Phasors used for algorithms are the result of the mathematical Clarke Transformation, which simplifying three-phase system measurements into one phase system. Clark transform is given by the following equations:

$$S_X = \frac{2 \cdot S_A - b \cdot S_B - b^* \cdot S_C}{3};$$

3 inputs into algorithm

- **Voltage Angles:** $\boldsymbol{\delta_{v1}(t), \delta_{v2}(t)}$
- **Voltage Magnitudes:** $\boldsymbol{V_1(t), V_2(t)}$
- **Per phase THDs from both sides:** $\boldsymbol{THD_{Va_1}(t), THD_{Vb_1}(t), THD_{Vc_1},}$ $\boldsymbol{THD_{Va_2}(t), THD_{Vb_2}(t), THD_{Vc_2}(t)}$

Implementation

First algorithm

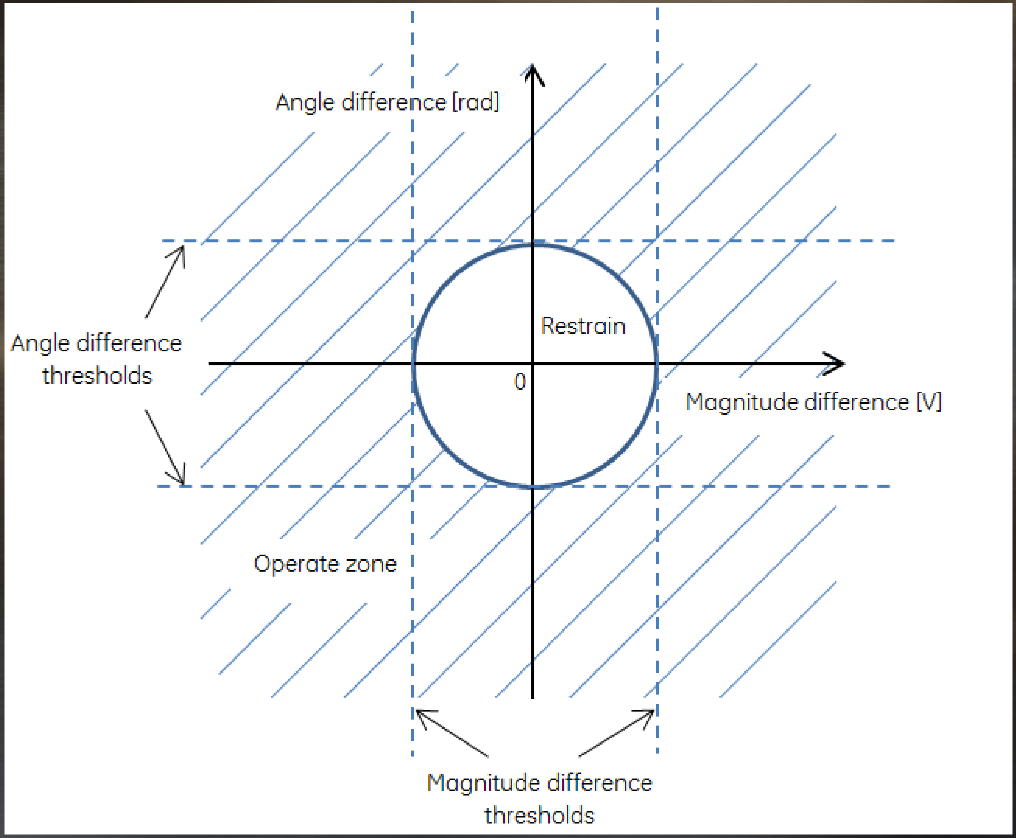
Angle difference

$\delta_{PMU1\ VClarke} - \delta_{PMU2\ VClarke}$

⟷

Magnitude difference

$M_{PMU1\ VClarke} - M_{PMU2\ VClarke}$



Implementation

Second algorithm

- Angle Difference (AD)

  $\delta_{\text{PMU1 VClarke}} - \delta_{\text{PMU2 VClarke}}$

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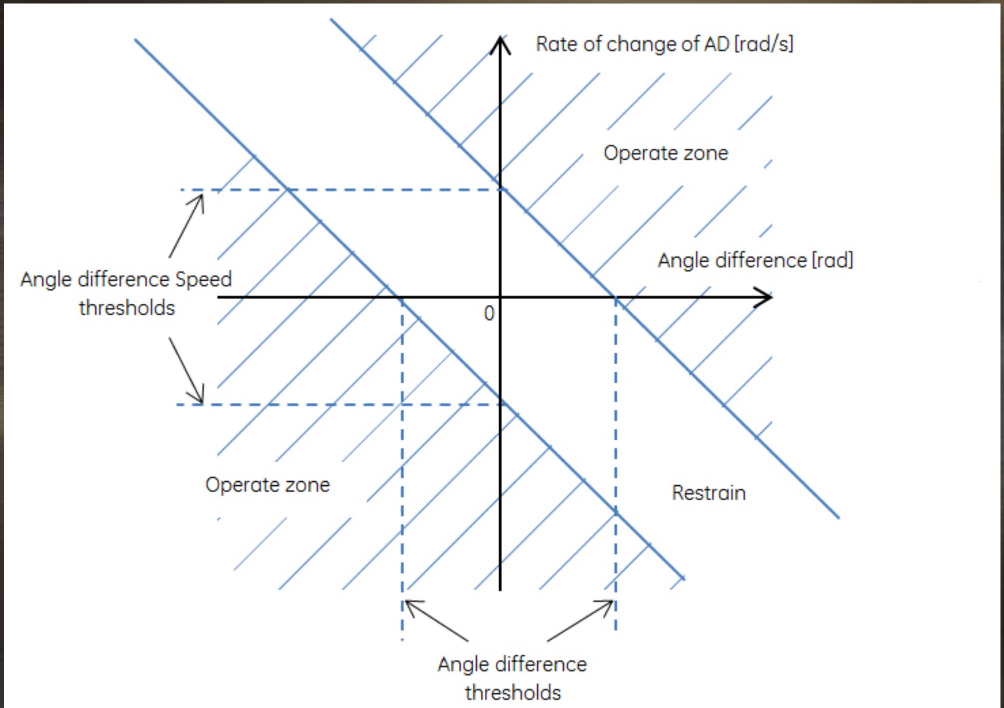
  Rate of Change of AD

  $$\frac{\Delta \text{ Angle Difference}}{\Delta t}$$

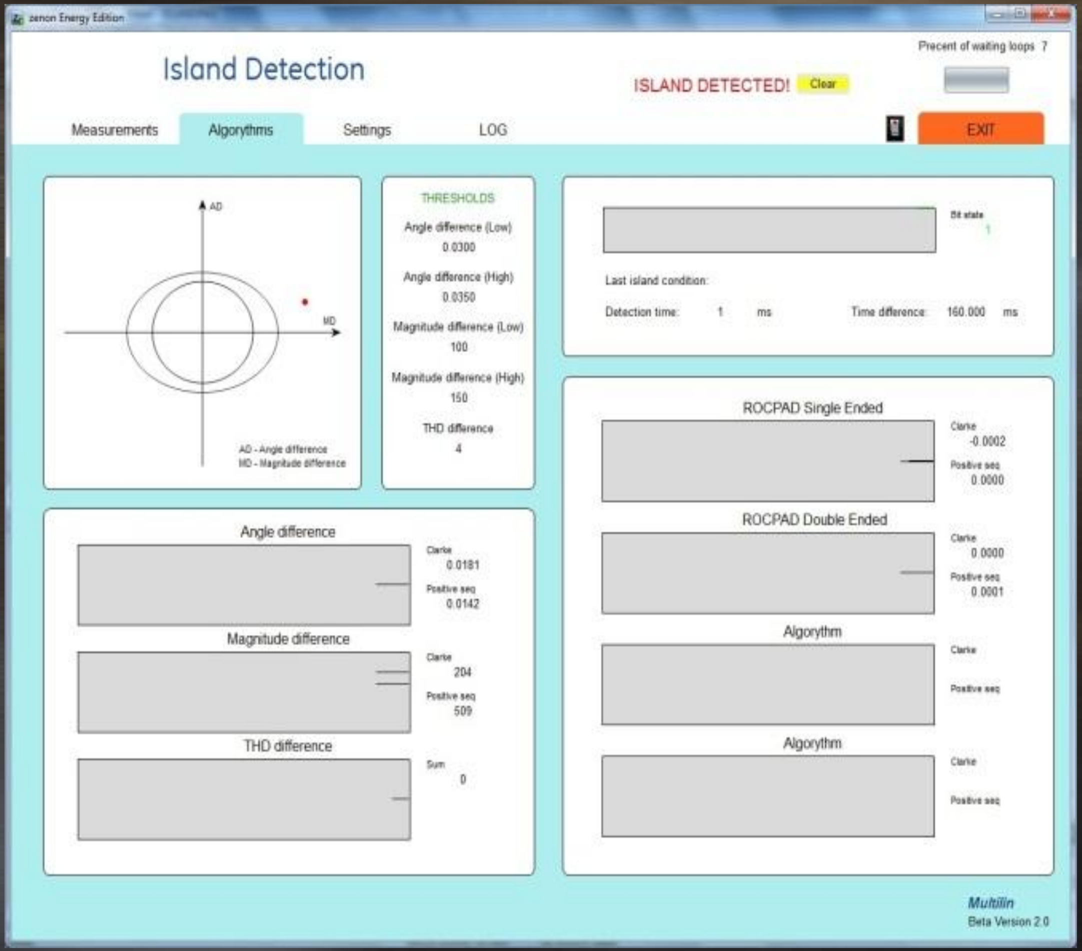


Third algorithm

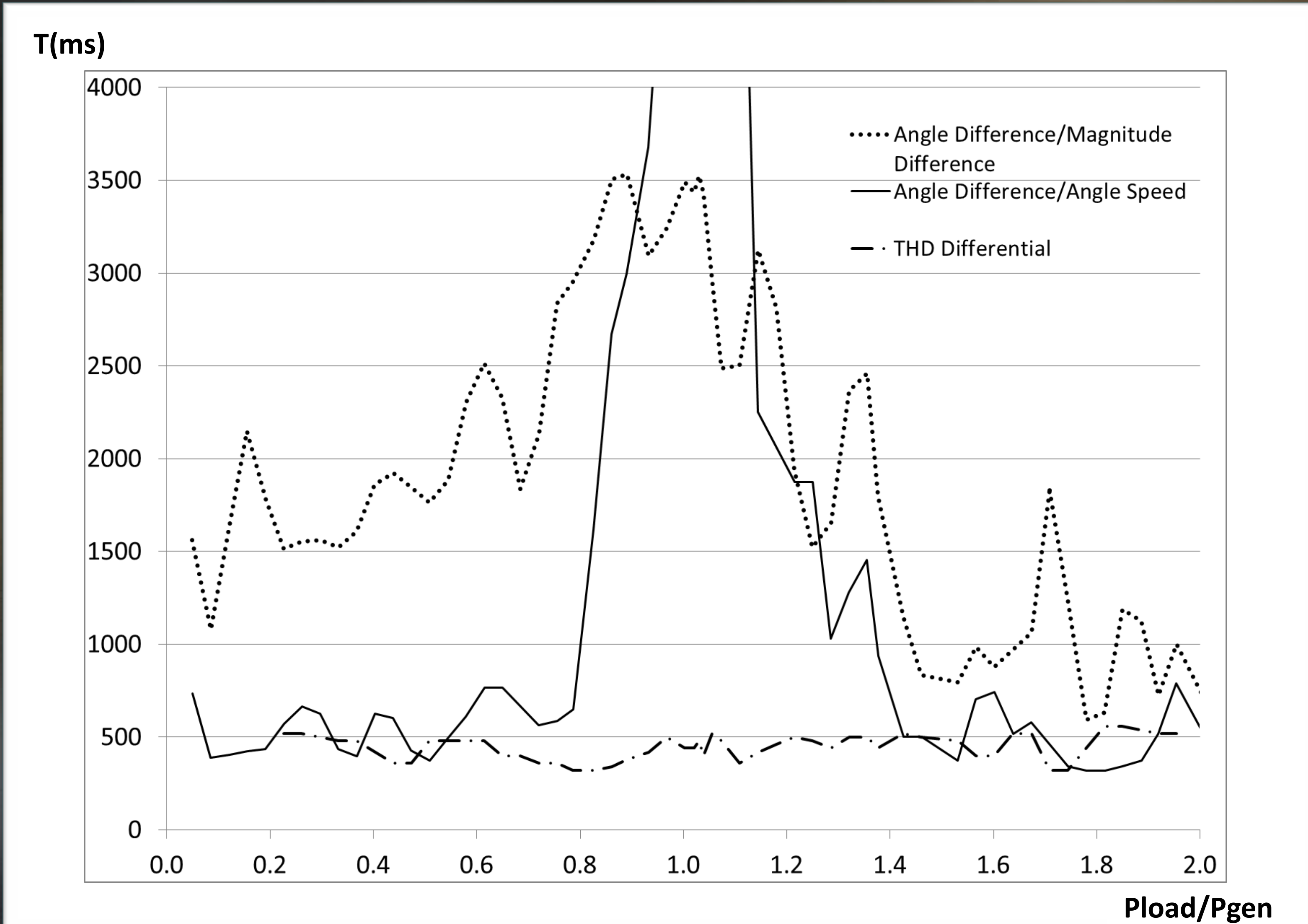
$$THD_{Diff}(t) =$$
$$= [THD_{Va_1}(t) + THD_{Vb_1}(t) + THD_{Vc_1}(t)] - [THD_{Va_2}(t) + THD_{Vb_2}(t) + THD_{Vc_2}(t)]$$

Implementation

All the methods are implemented in the soft PDC logic software



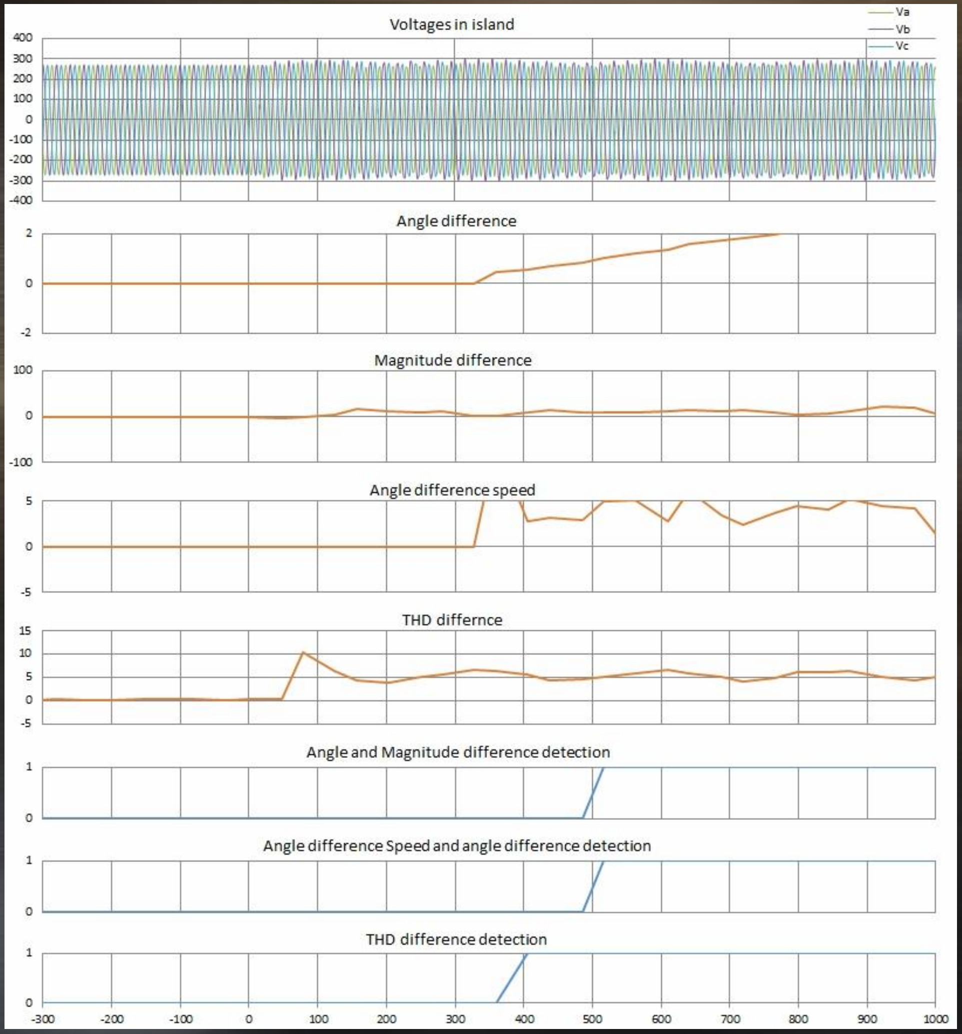
Algorithm results



Tests in an external laboratory

Implemented algorithms has been tested in a small test grid in the external laboratory, with real inverter connected.

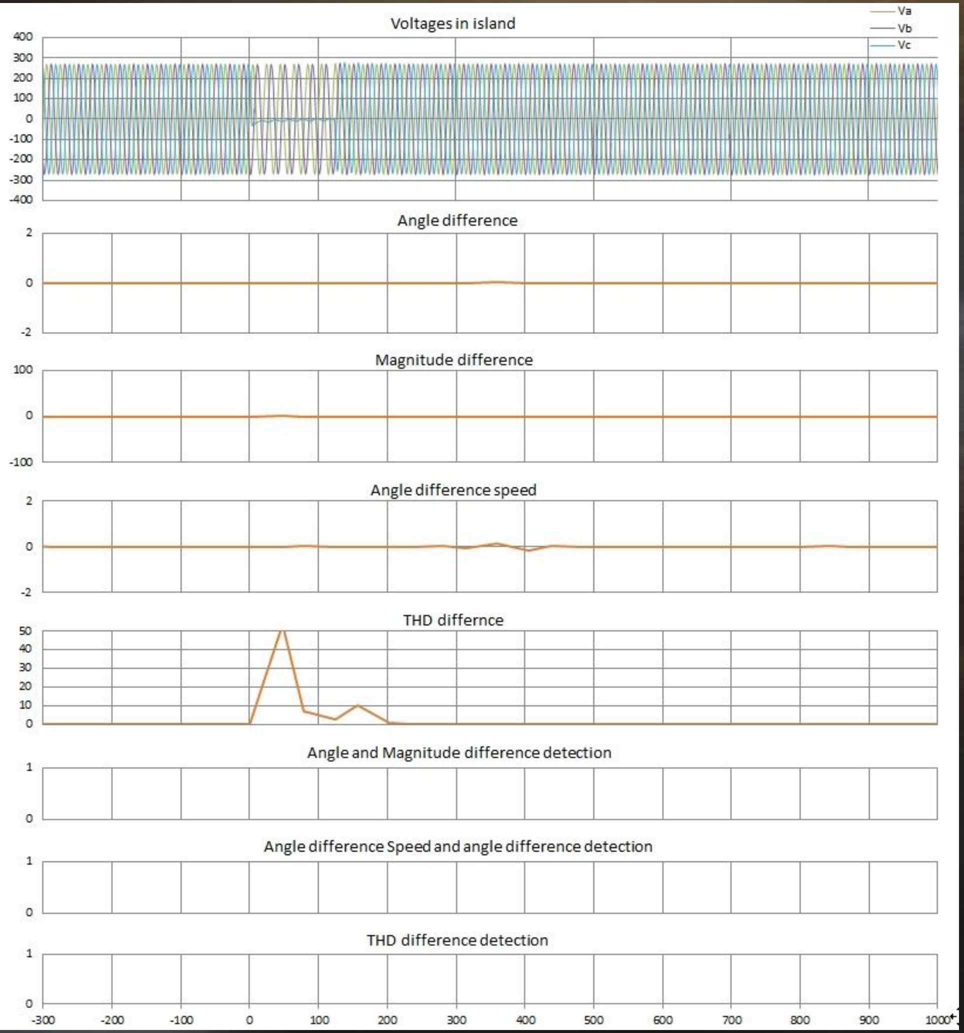
Result = passed



Tests in an external laboratory

Also sensitivity for other conditions including fault events has been tested

Result = passed



Conclusions

- Paper presents a research result, including a novel THD differential algorithm which has been presented as an enhancement of present methods for decreasing the total Non Detection Zone.
- Developed methods have been tested with a Real Time Digital Simulator and scaled grid model with several scenarios.
- The laboratory test results were positive, which renders the methods ready to be used in the field. The thresholds and time delays should be set based on real system readings and in coordination with other protection functions installed in the system.
- PMU and PDC can communicate via radios, which results in a flexible and cost efficient installation. Present and future work involves testing different radio techniques for the best cost effectiveness<->performance ratio.

Thank You

Questions?