



Islanding Detection with Phasor Measurement Units

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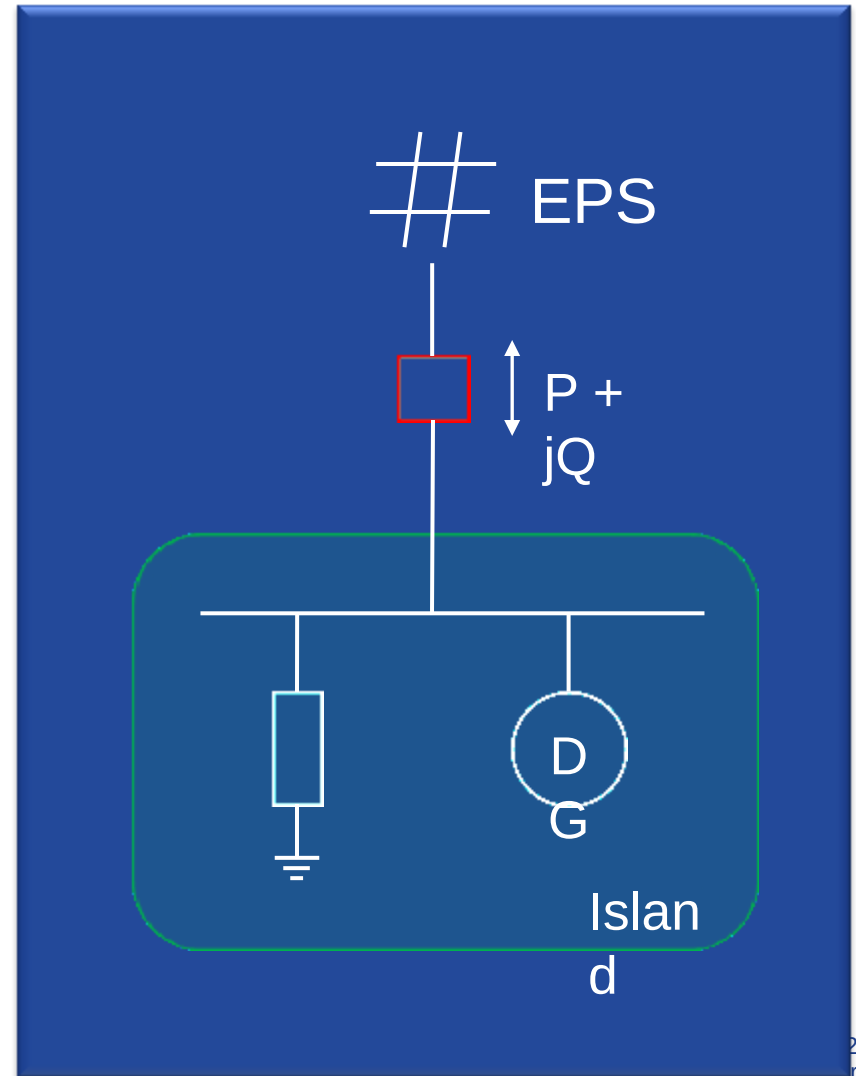
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RNC CIGRE 2015, Sochi – Russia

DEFINITION

“Islanding is a condition in which a portion of the utility system, which contains both load and generation, is isolated from the remainder of the utility system and continues to operate.”

R. M. Bower W, *Evaluation of islanding detection methods for photovoltaic utility - interactive power systems*, IEA PVPS, 2002.

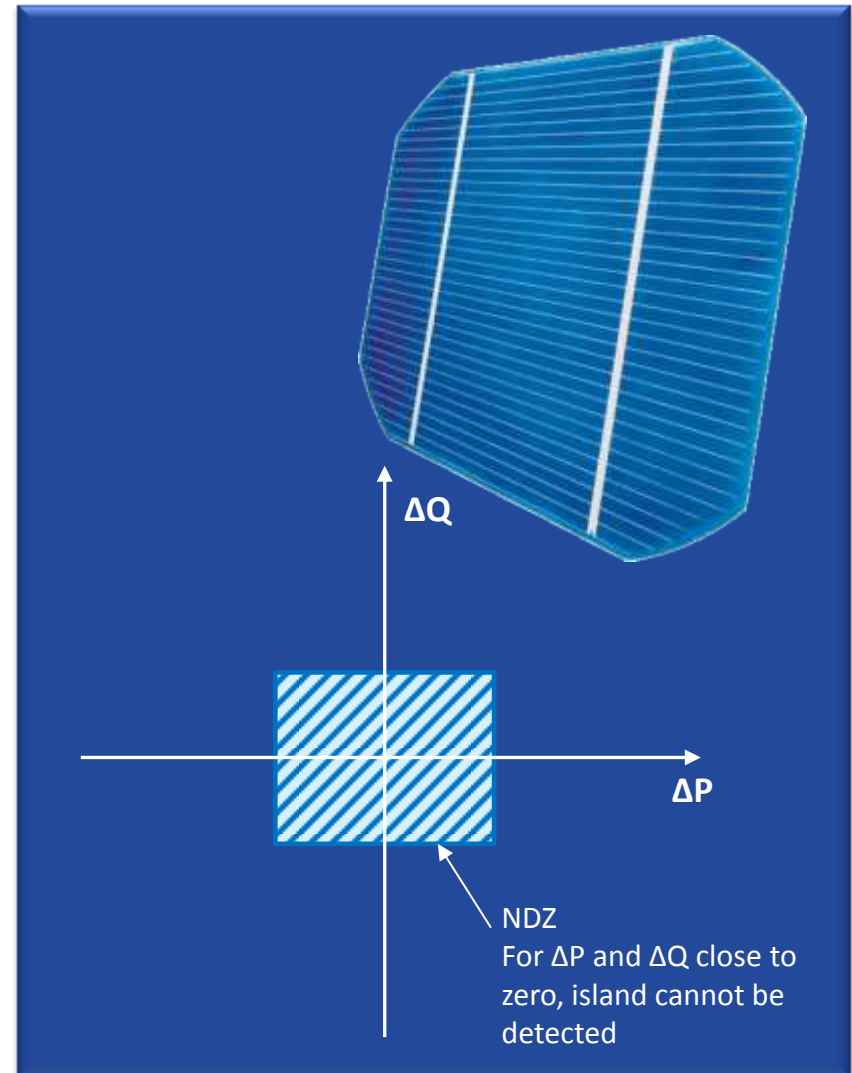


WHY ISLAND DETECTION?

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)



SUMMARY OF METHODS

Method	Type	Strenghts	Weaknesses
Under/over voltage and under/over frequency	Passive	Low-cost and used for general protection	Large NDZ and variable/unpredictible reaction time
Voltage phase jump detection	Passive	Easy implementation, not affect output PQ, not impact system transient response	Difficult to set thresholds for reliable islanding detection
Detection of Harmonics	Passive	Highly successful in detecting islanding under a wide range of conditions	Serious implementation difficulty, trip threshold
Impedance measurement	Active	Theoretically extremely small NDZ for a single PV inverter	Output variation has many weaknesses
Detection of impedance at specific frequency (special Harm. detection)	Active	Highly successful in detecting islanding under a wide range of conditions	Serious implementation difficulty, trip threshold
Slip Mode Frequency Shift	Active	Easy implementation, small NDZ	Deaccrease in the output PQ
Frequency bias	Active	In micro-controller-based inverters, this method is relatively easy to implement	Deaccrease in the output PQ
Mains Monitoring Units with Allocated All-pole Switching Devices Connected in Series (MSD)	Active	Redundant design and regular self tests on inverter startup allow user to install the unit without the need for periodic checks to determine if the anti-islanding circuitry is functional	Injections will interfere with another or interaction of multiple units cause false trips
Impedance insertion	Utility	Highly effective, capacitors of this type are readily available	Expense of the capacitor bank, multiple switches in series leading into the potential island, and possibly multiple branches capable of energizing the potential island speed of response, installation of equipment on the utility side
Use of PLC communications	Utility + Inverter	Increased connection density of distributed generation	PLCC transmitter on the utility system capable of sending signals through the distribution system to all inverters
Signal produced by disconnect	Utility + Inverter	This method would allow additional control of the distributed generators by the utility, resulting in coordination between distributed generators and utility resources	It would be necessary to instrument all series or parallel switches leading to a potential island. Additional wiring for communications, this could be avoided using a microwave link.

Source: "Evaluation of Islanding Detection Methods for Utility-Interactive Inverters in Photovoltaic Systems"

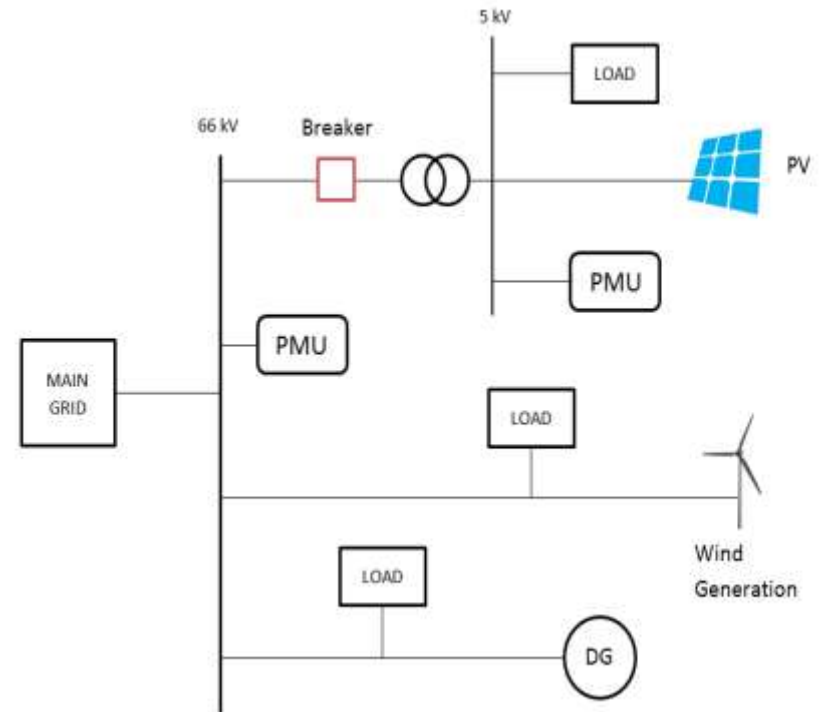
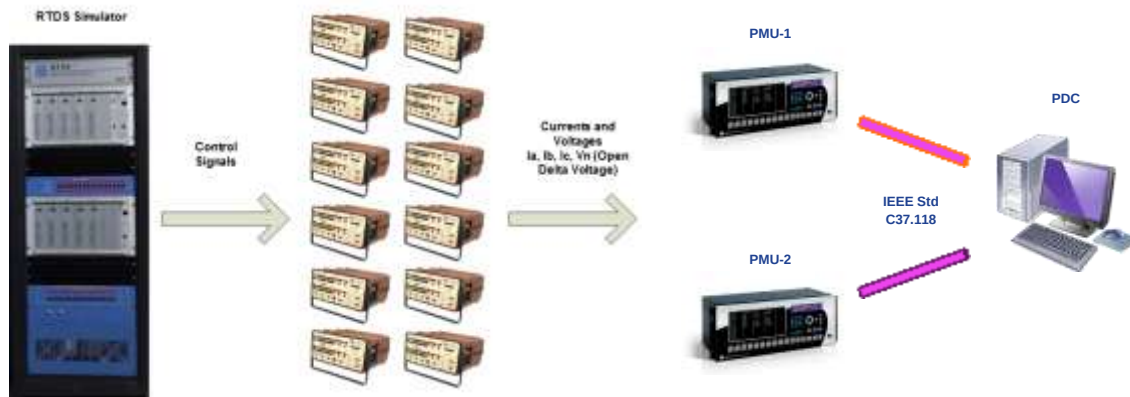
Ward Bower y Michael Ropp, Sandia National Laboratories

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 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.

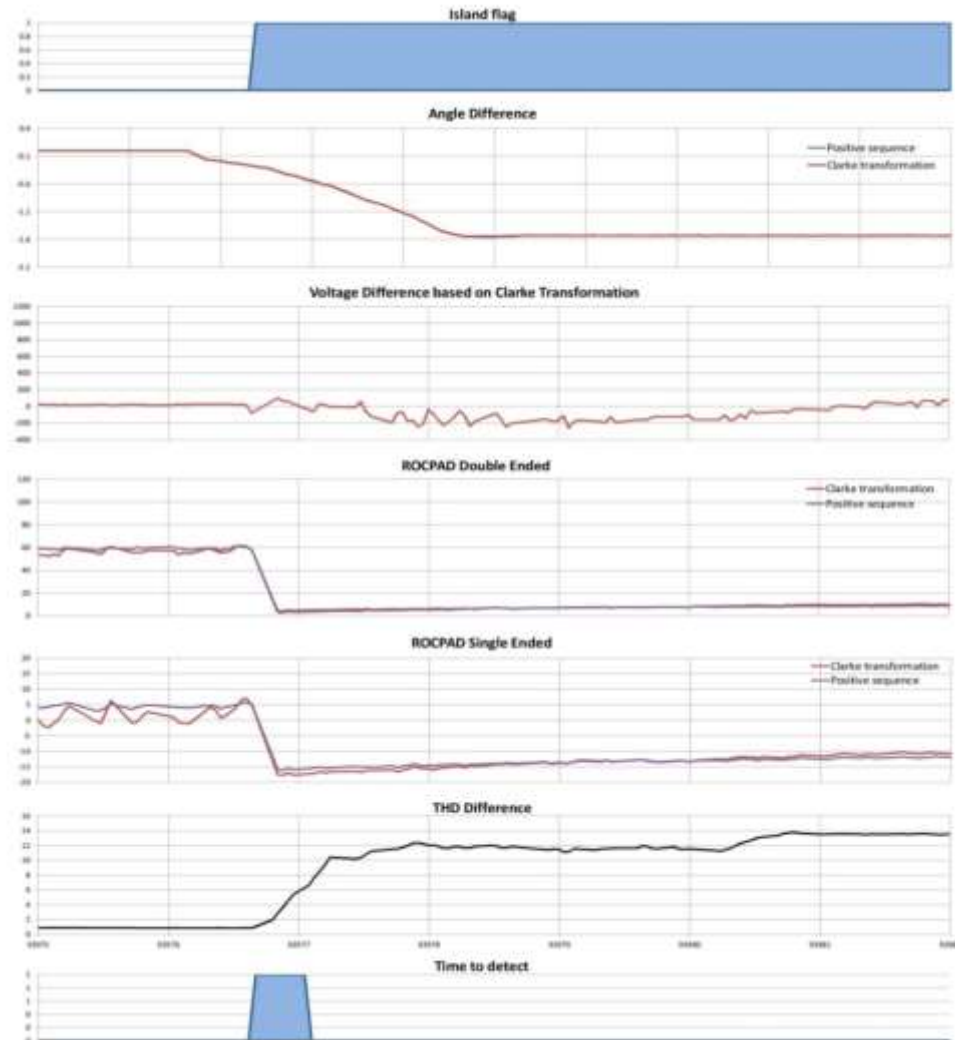


PRELIMINARY TEST RESULTS

THD Differential is monitored

Case #1
Power generated inside
the island is higher than
it's consumption

$$P_{gen} > P_{load}$$

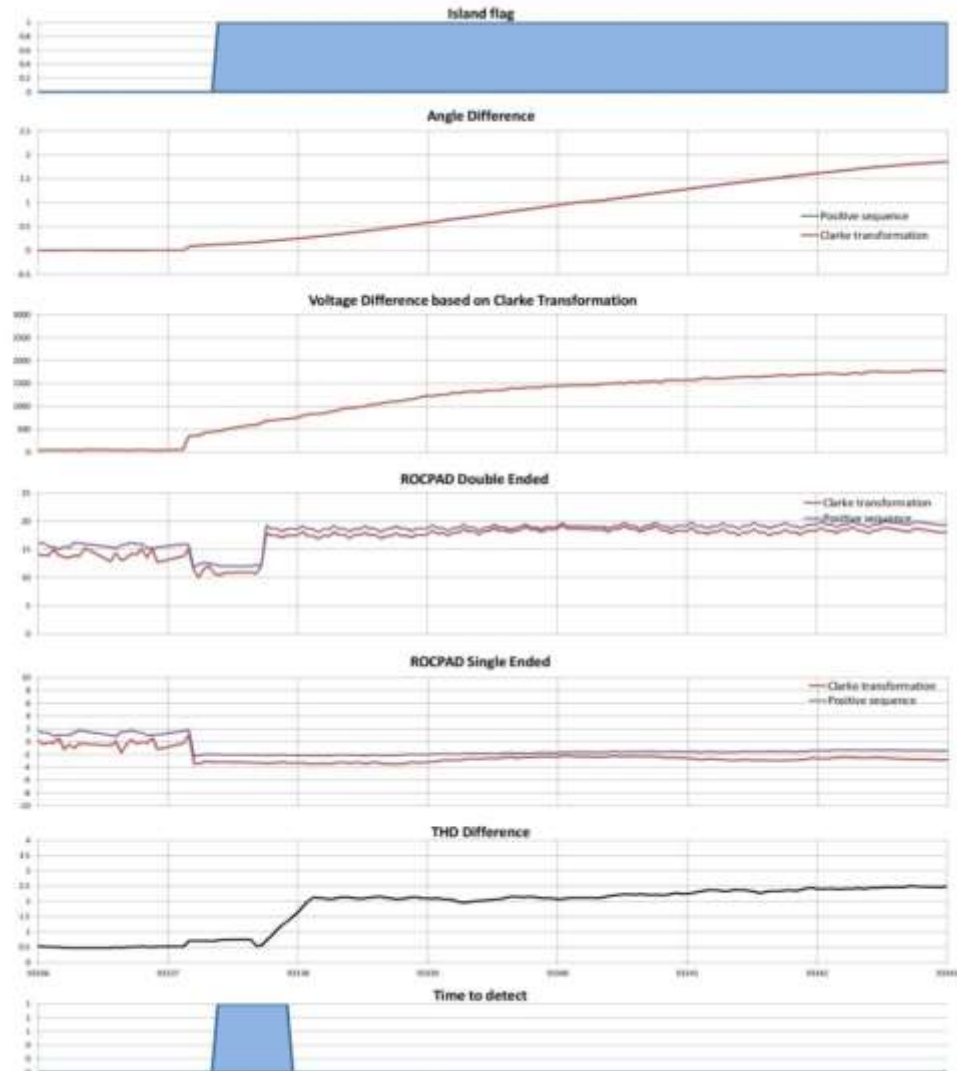


PRELIMINARY TEST RESULTS

THD Differential is monitored

Case #2
Power generated inside
the island is lower than it's
consumption

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

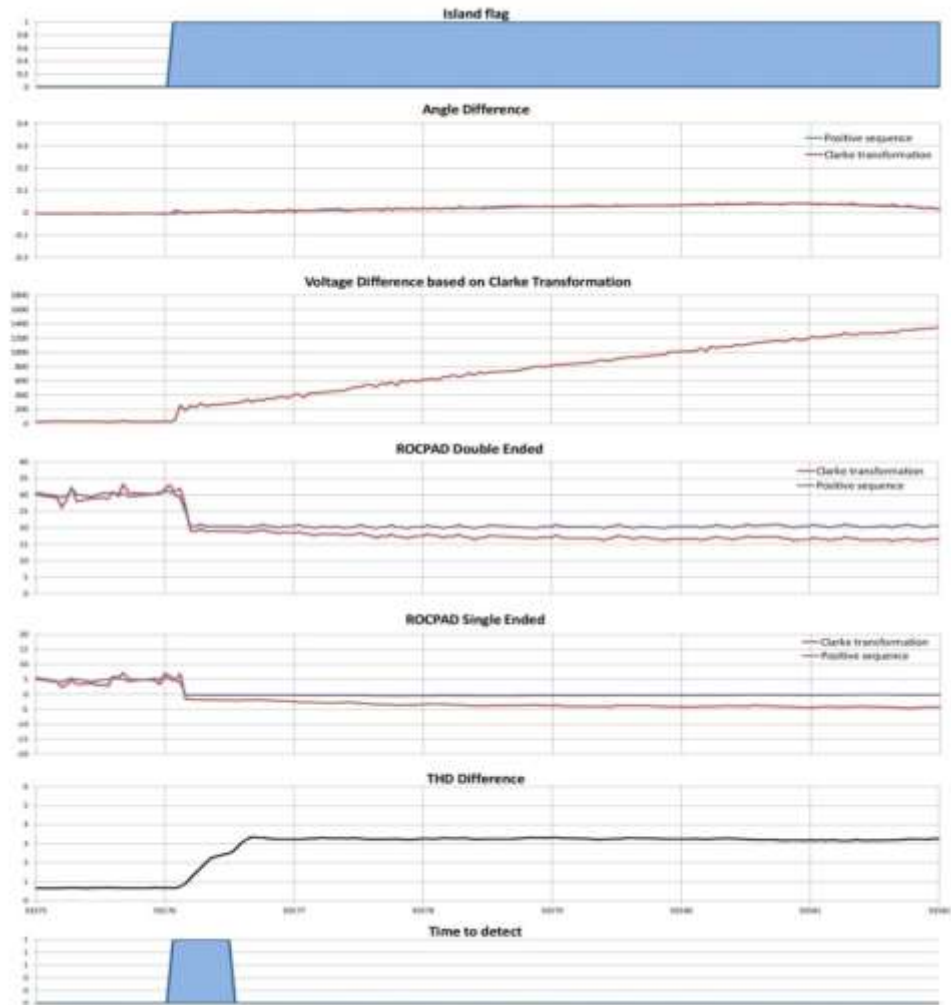


PRELIMINARY TEST RESULTS

THD Differential is monitored

Case #3
Power generated inside
the island is almost equal
to consumption

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



SOLUTION

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

SOLUTION

Angle difference:

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

+

Magnitude difference:

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

+

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

IMPLEMENTATION

First algorithm

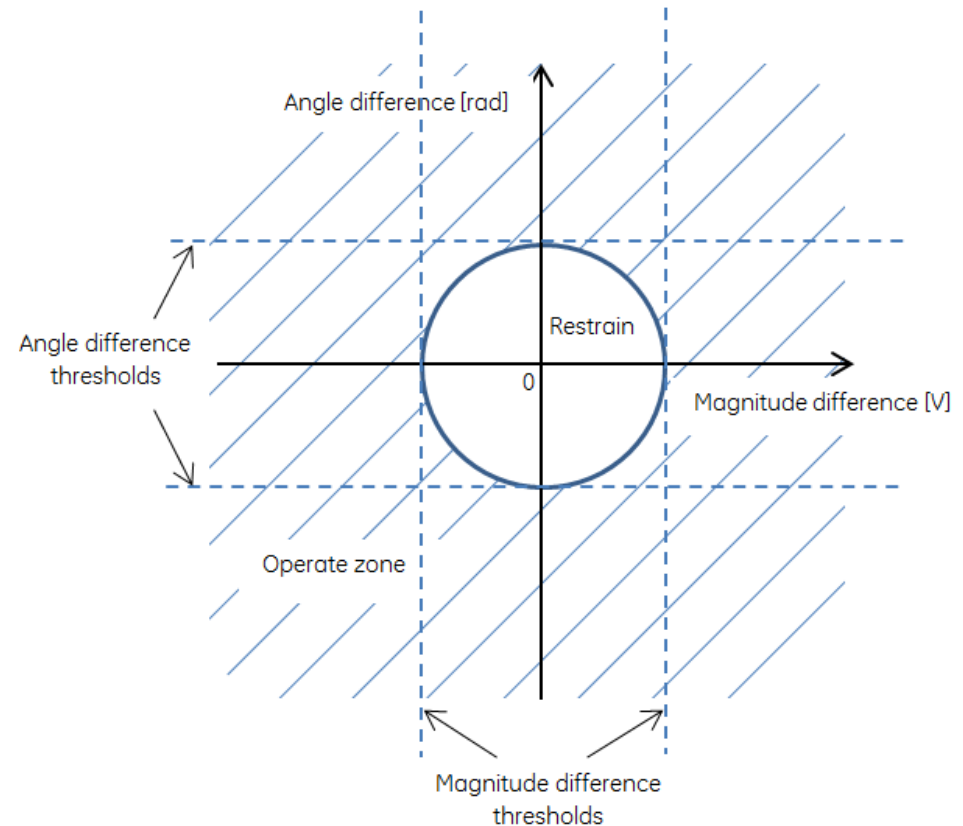
Angle difference

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

&

Magnitude difference

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



IMPLEMENTATION

Second algorithm

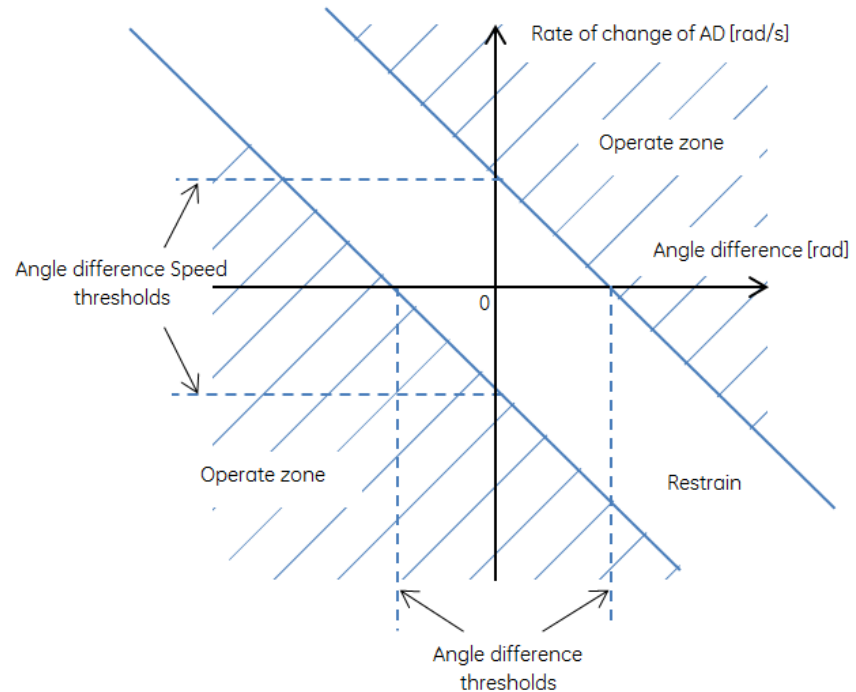
Angle Difference (AD)

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

&

Rate of Change of AD

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

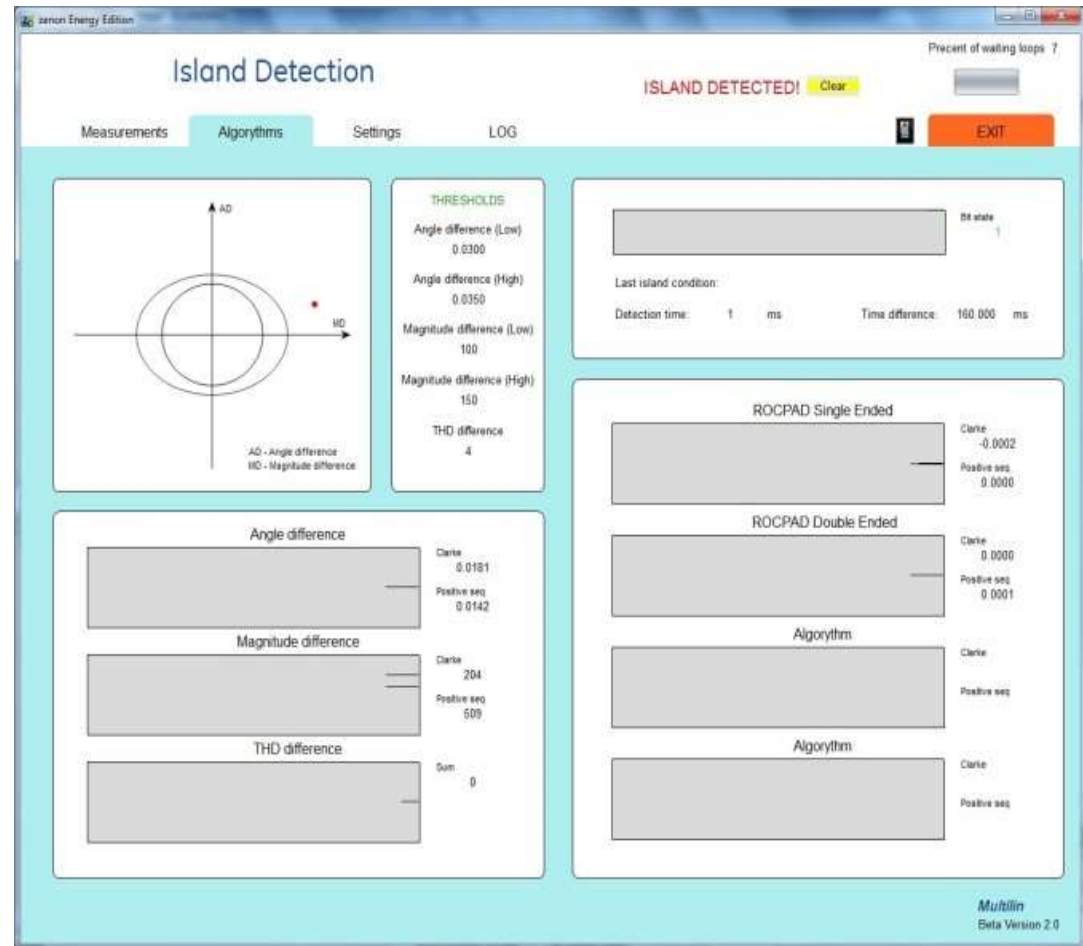


Third algorithm

$$\begin{aligned} THD_{Diff}(t) &= \\ &= [THD_{Va_1}(t) + THD_{Vb_1}(t) + THD_{Vc_1}(t)] \\ &\quad - [THD_{Va_2}(t) + THD_{Vb_2}(t) + THD_{Vc_2}(t)] \end{aligned}$$

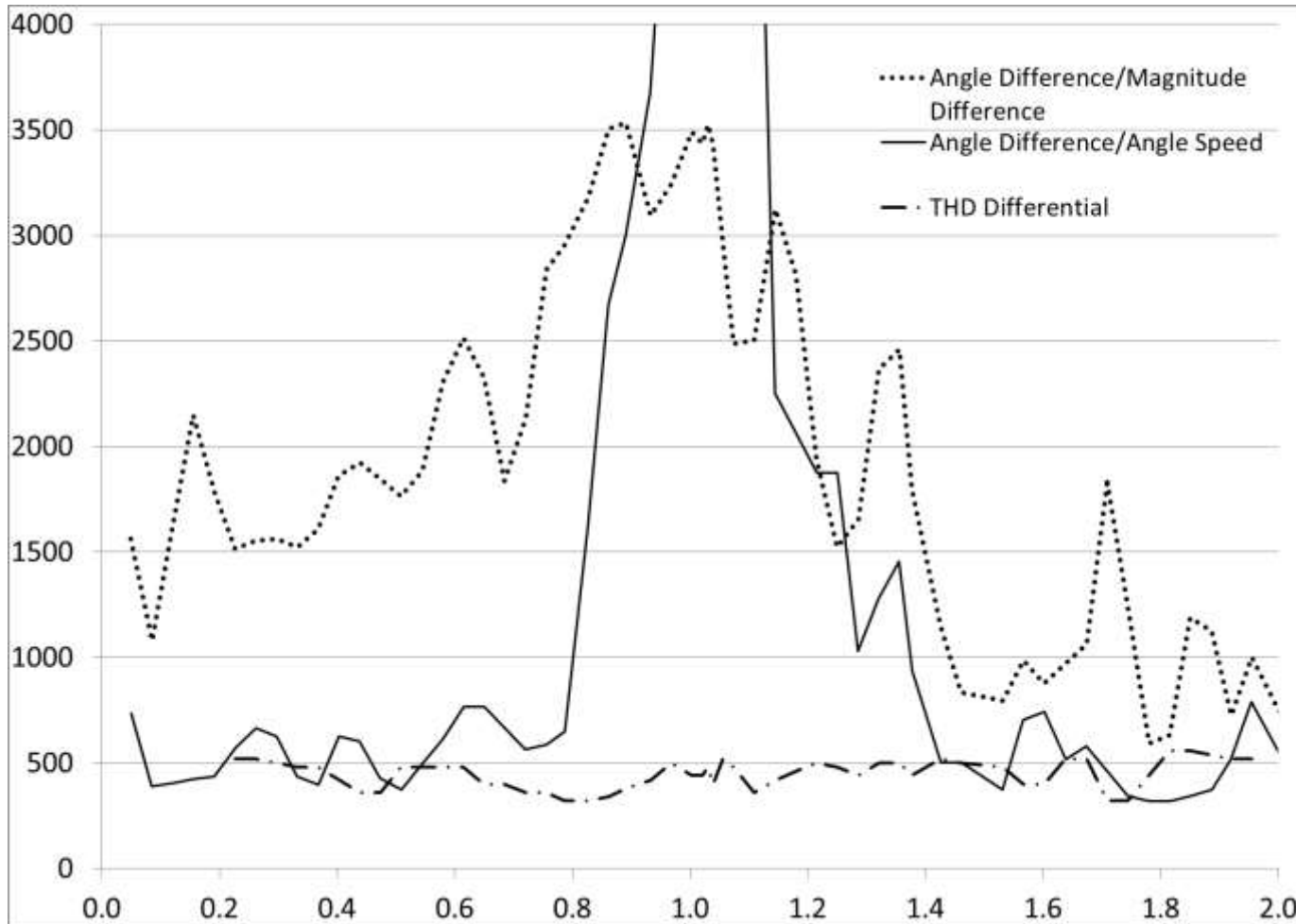
IMPLEMENTATION

All the methods
are implemented
in the soft
PLC logic software



ALGORITHM RESULTS

T(ms)

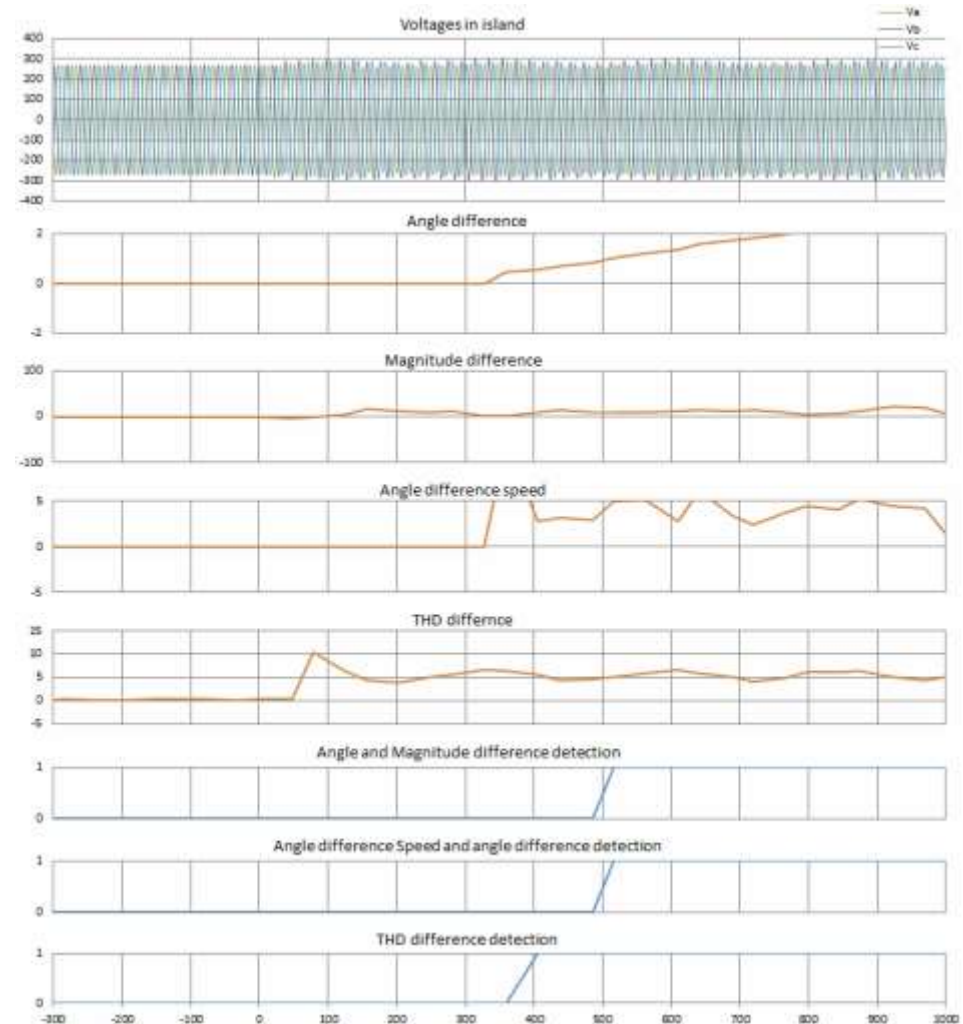


Pload/Pgen

TESTS IN AN EXTERNAL LABORATORY

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

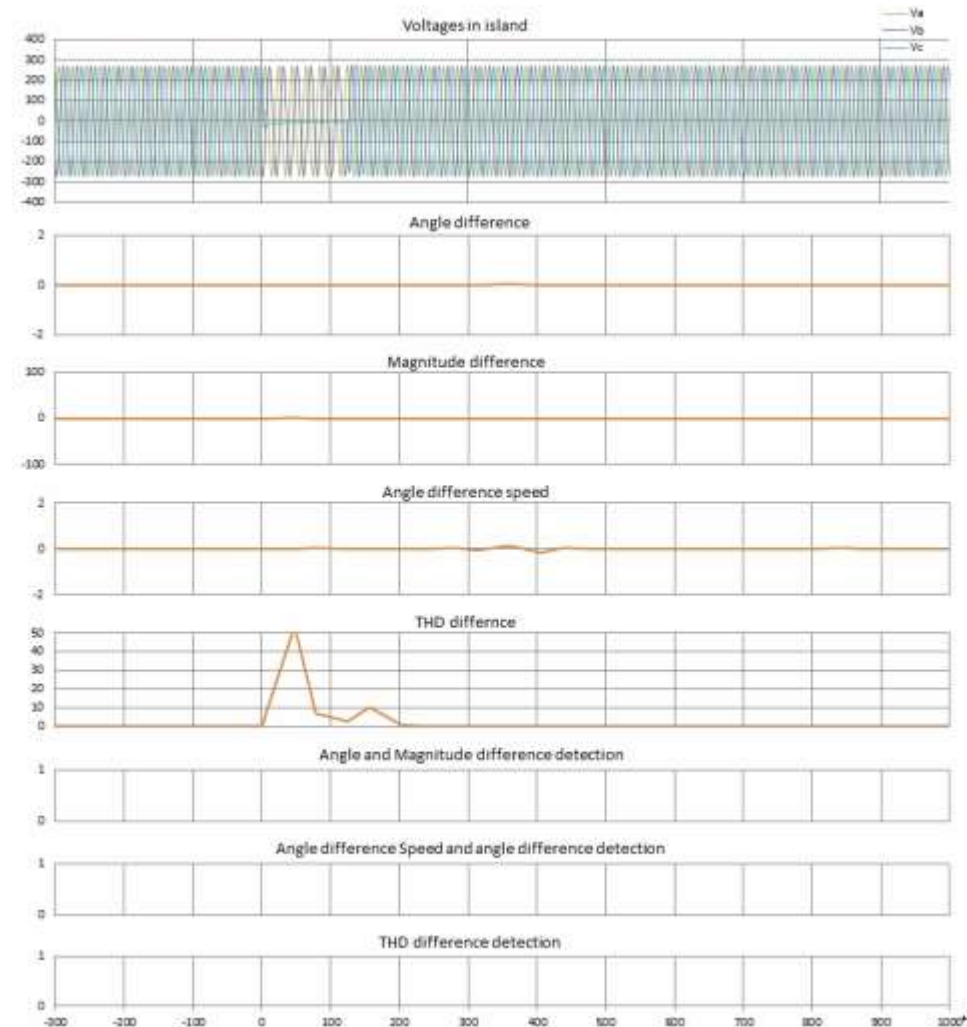
Result = **passed**



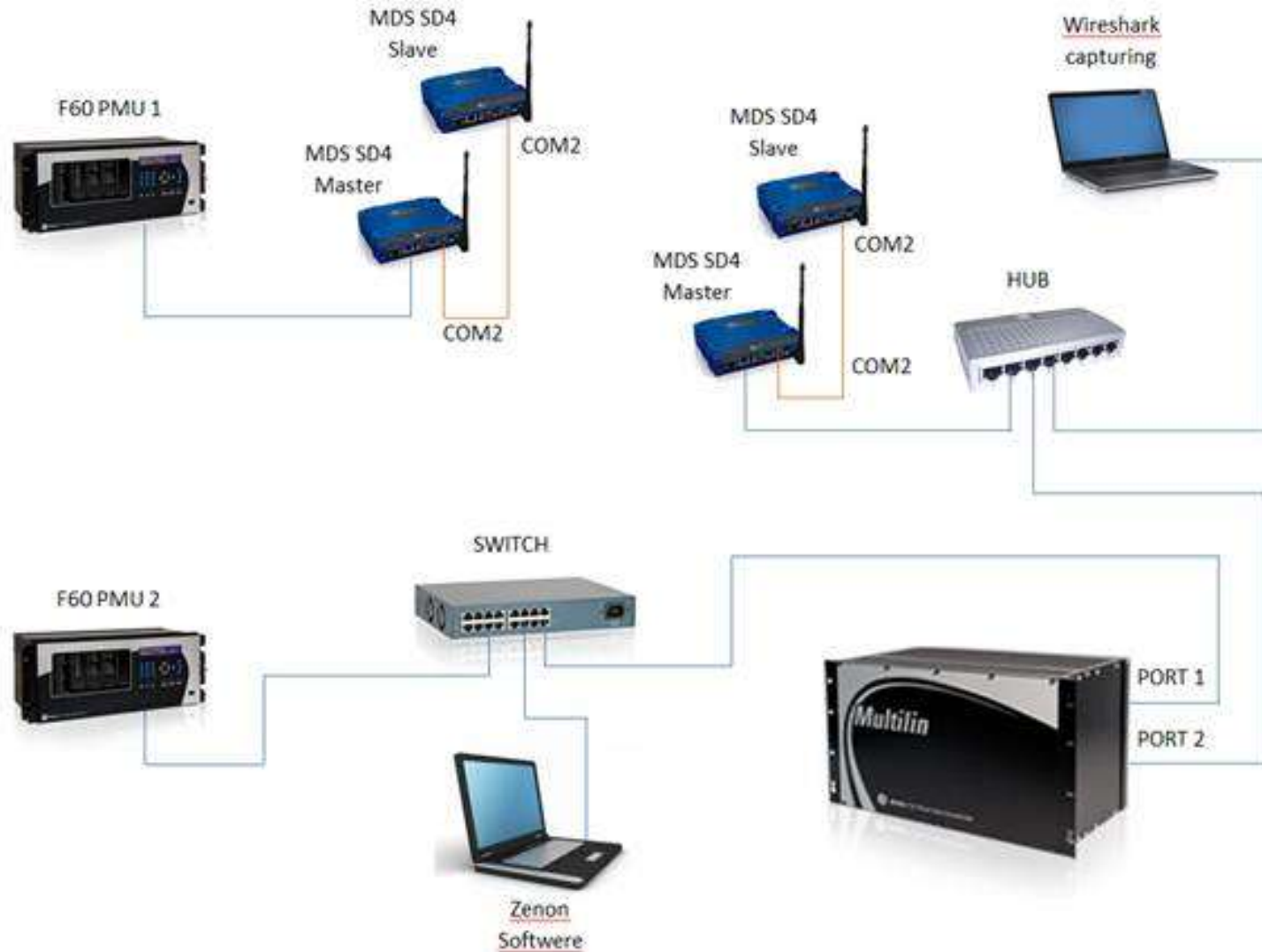
TESTS IN AN EXTERNAL LABORATORY

Sensitivity for other conditions including fault events has been tested

Result = **passed**



TESTS USING RADIO FOR COMMUNICATION



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 Simulator 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 and performance ratio.



Thank You



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