# Field Implementation of Wide-area Damping Control System in Large-scale Power Grids

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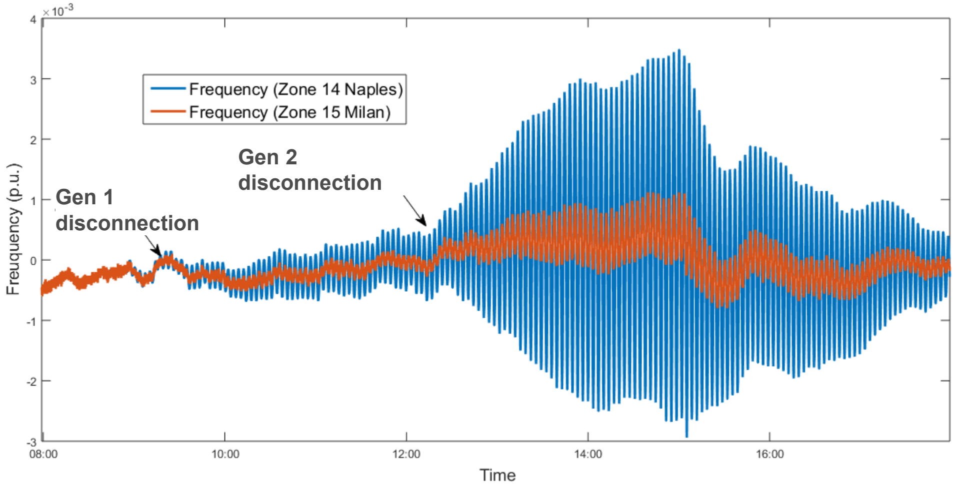
# Outline

- Introduction
- Field Deployment of WADC System: Centralized Control Structure
- Implementation of Centralized WADC System on Hardware-In-the-Loop (HIL) Platform
- HIL Test Results
- Summary

# Introduction of Continental Europe Power System

- A dominant oscillation mode between France/Germany and south Italy
  - Around 0.3Hz.
  - Damping ratio is around 7% under normal conditions.
- Dec. 3, 2017, growing 0.293 Hz oscillation was monitored.
  - Grid operated in an unusual light load condition
  - Triggered by two consecutive generation disconnections due to market operation.
  - Lasted approximately 10 minutes.


Dec. 3, 2017, growing oscillation event caused by consecutive generation disconnection

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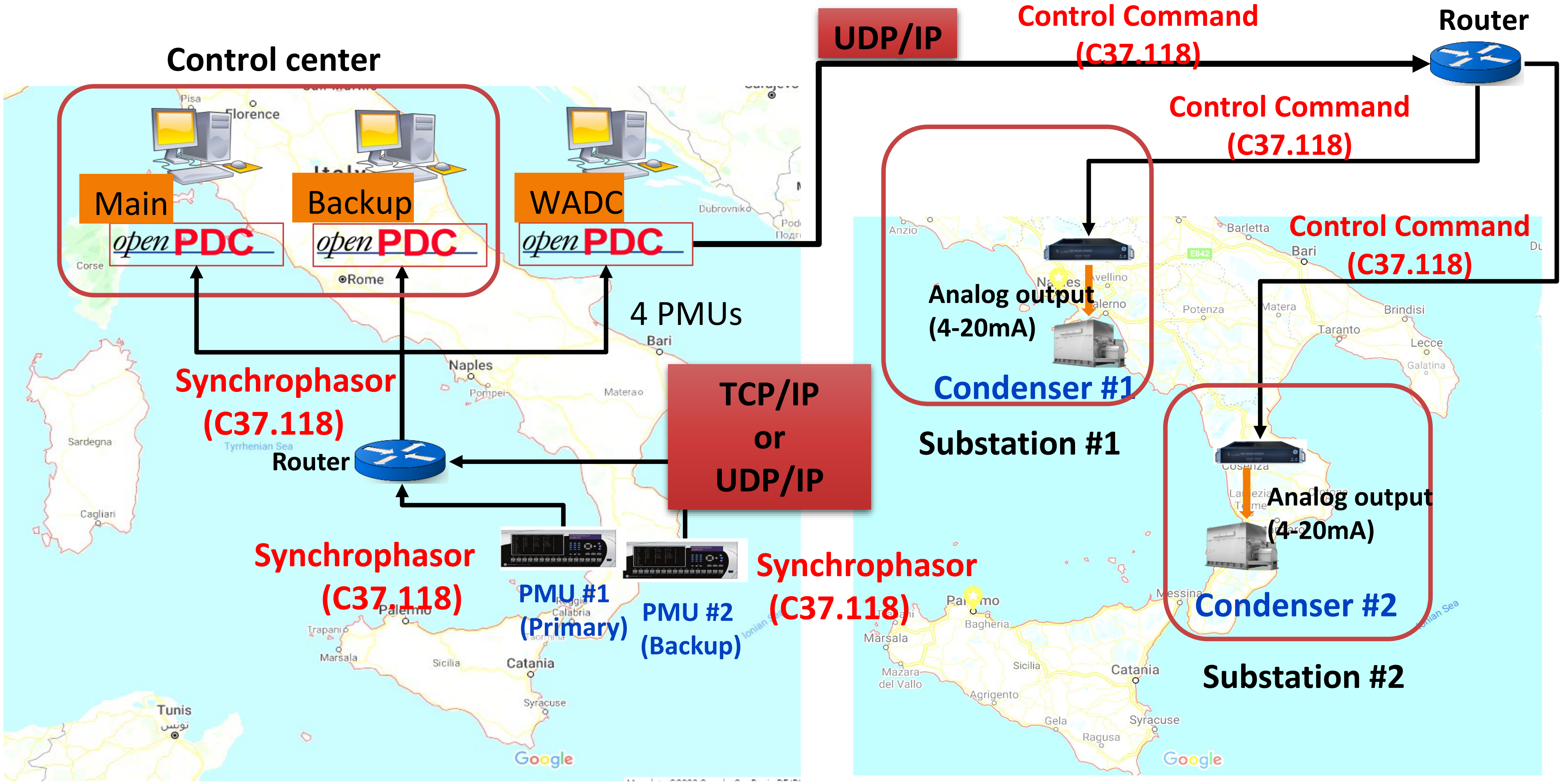
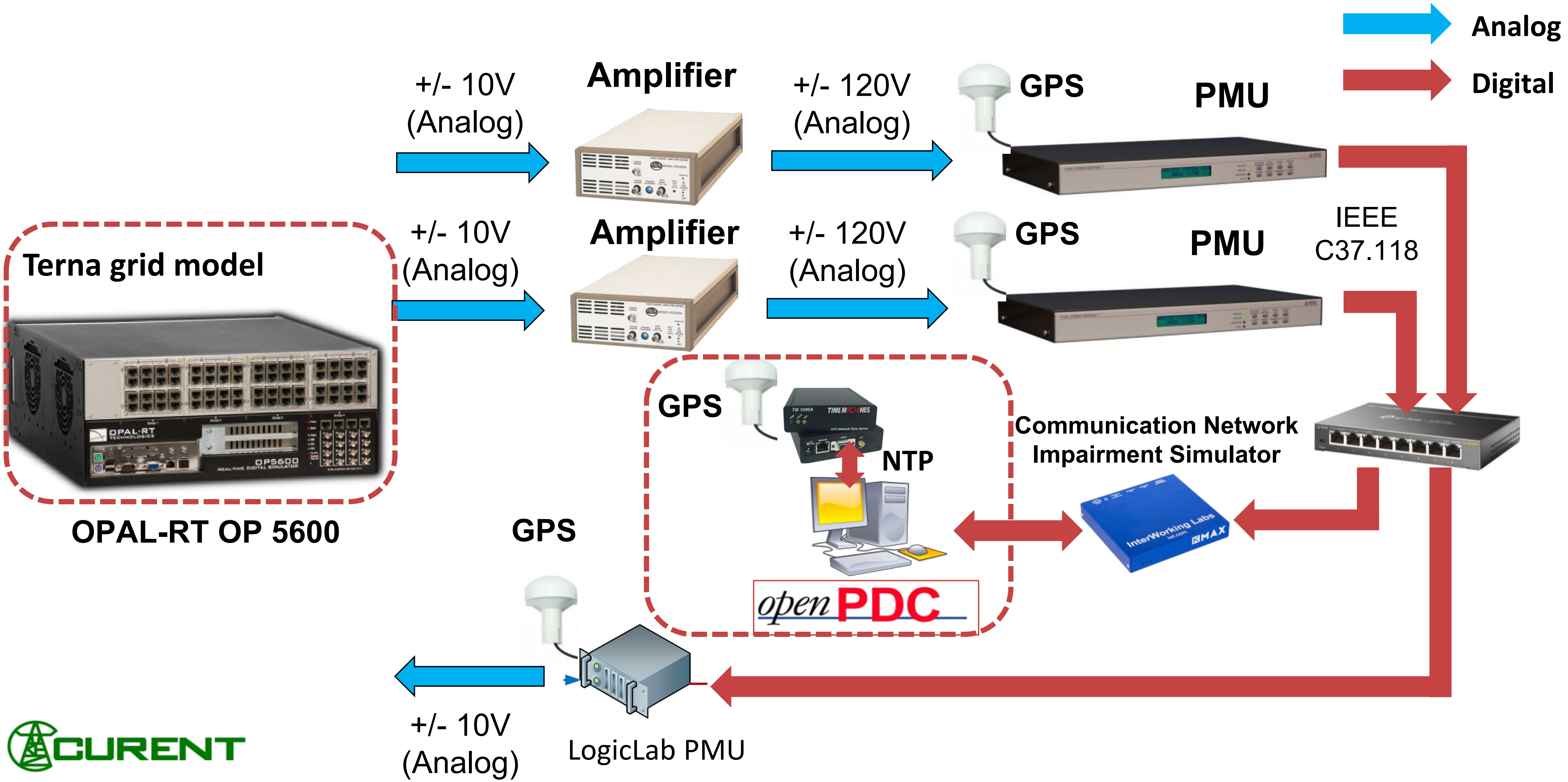
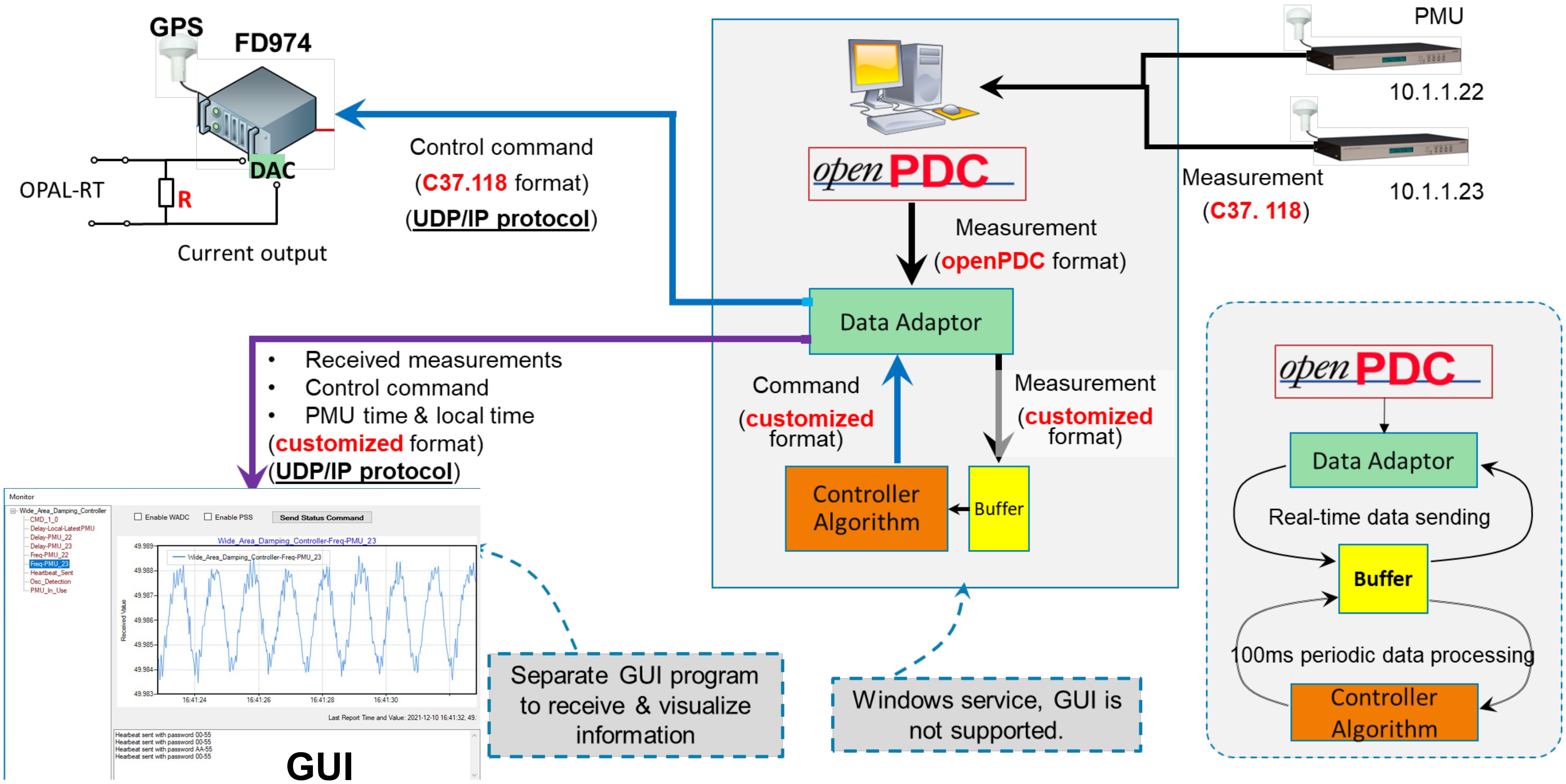
# Field Deployment of WADC



# HIL Testing Platform of WADC



# Software WADC based on OpenPDC

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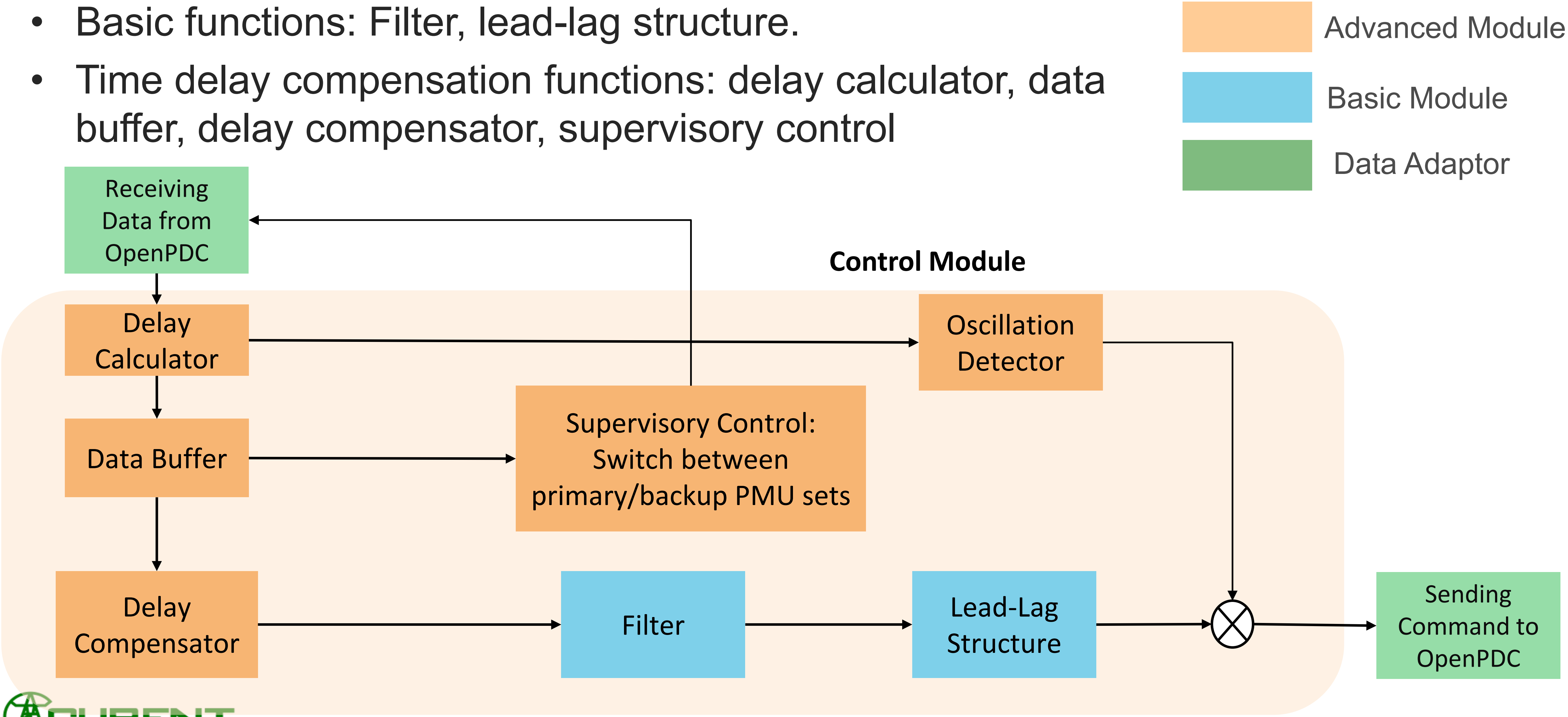
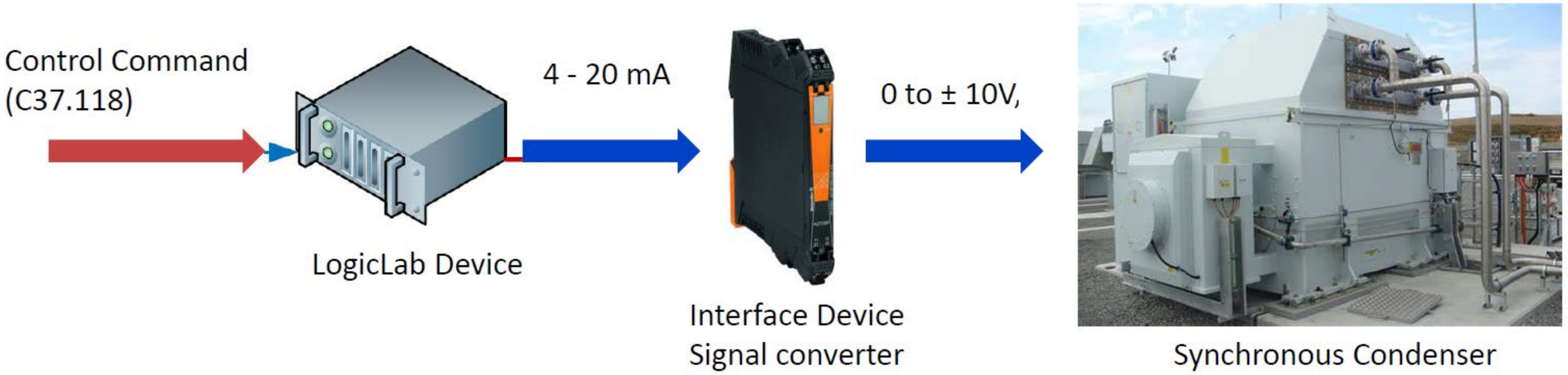
# Function Modules of WADC

- Basic functions: Filter, lead-lag structure.
- Time delay compensation functions: delay calculator, data buffer, delay compensator, supervisory control



# LogicLab PMU Device

- LogicLab PMU Device:
    - Receive WADC control command from the control center in C37.118 protocol and send to the voltage set point of synchronous condenser.
    - An interface device is interposed between LogicLab Device and Excitation system in order to ensure galvanic isolation between the two systems.

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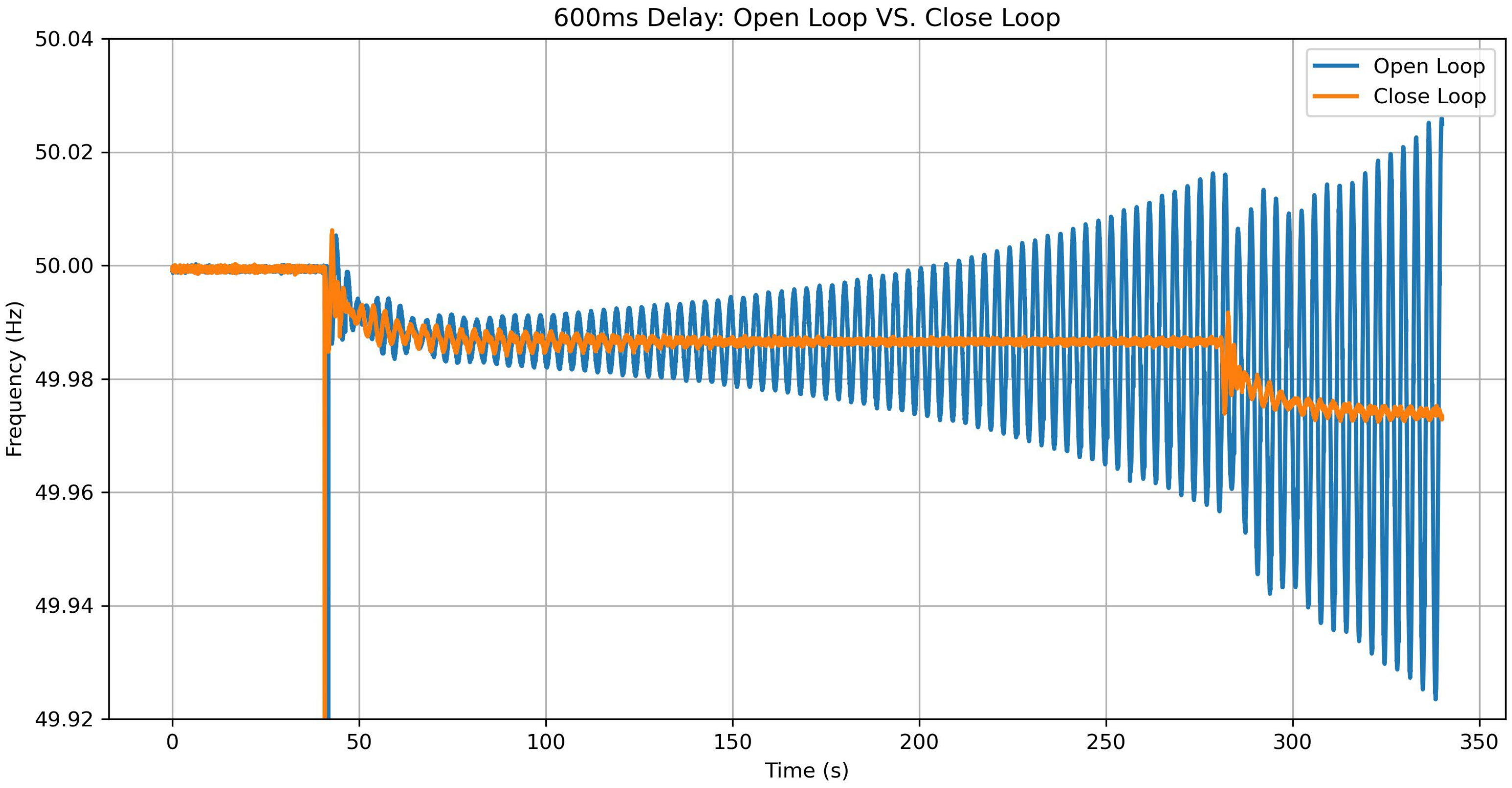
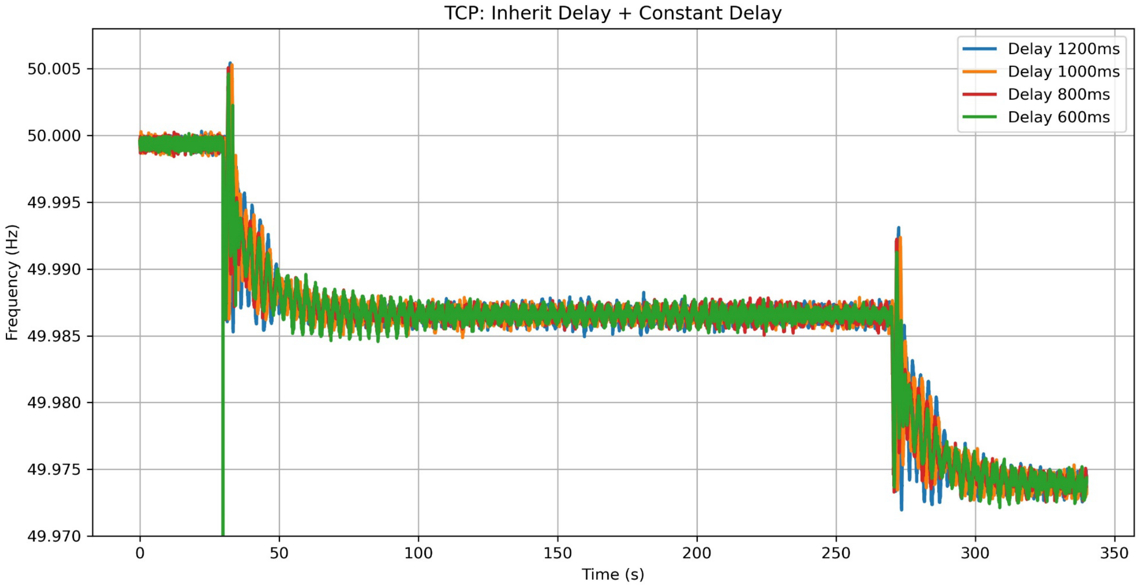
# HIL Test Results: Base case

- Control Performance Validation: with VS without WADC
  - **Inherent delay: ~600 ms**

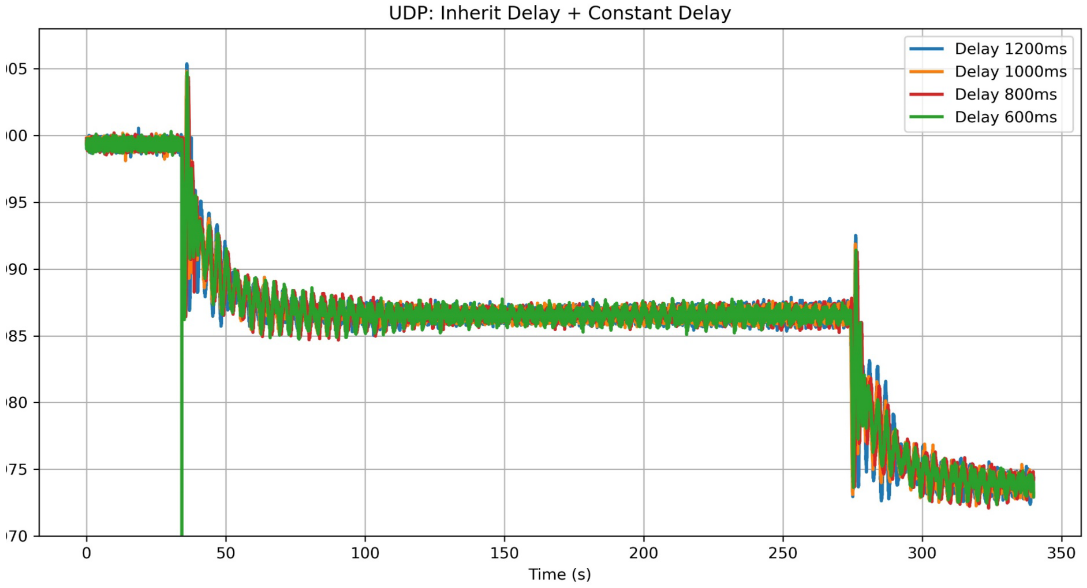


# HIL Test Results: Constant Delay Impact

- **TCP and UDP can both tolerate up to 1200 ms constant delay.**
  - **Inherent delay: ~600 ms (measurement delay, actuation delay, etc.)**
  - **Additional delay: 0/200/400/600 ms communication delay**



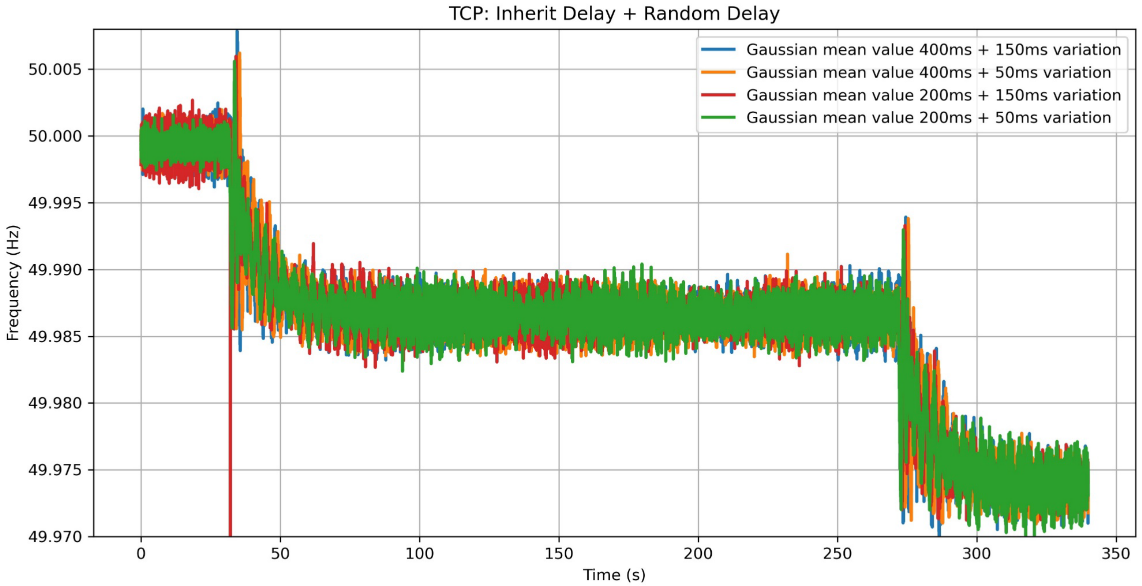

**TCP**



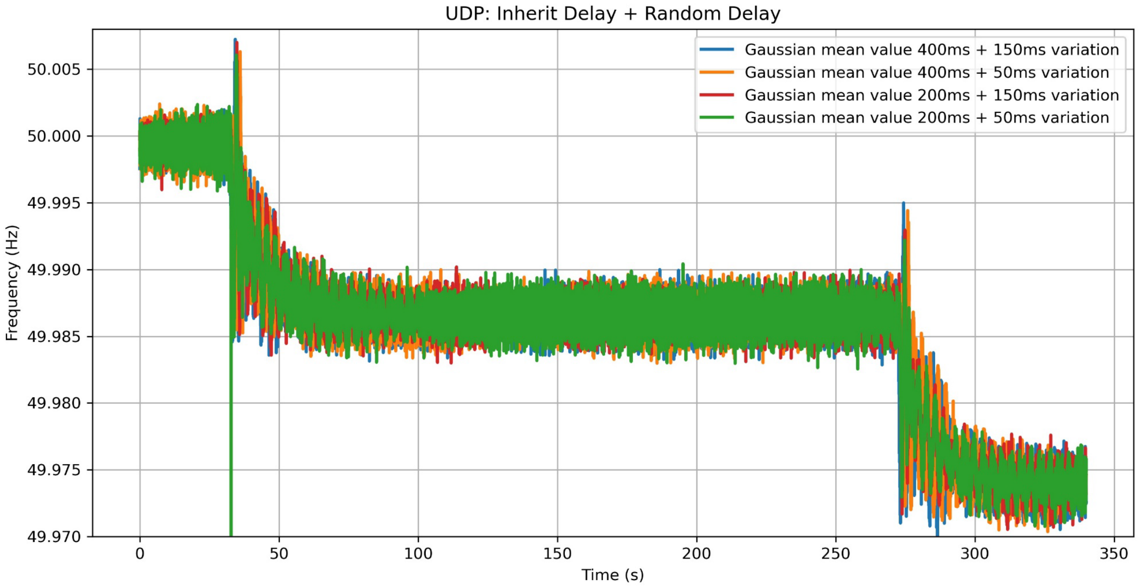

**UDP**

# HIL Test Results: Random Delay Impact

- **TCP and UDP can both tolerate a wide range of random delay (Gaussian distribution).**
  - **Mean = 400 ms, std. = 150 ms**
  - **Mean = 400 ms, std. = 50 ms**
  - **Mean = 200 ms, std. = 150 ms**
  - **Mean = 200 ms, std. = 50 ms**



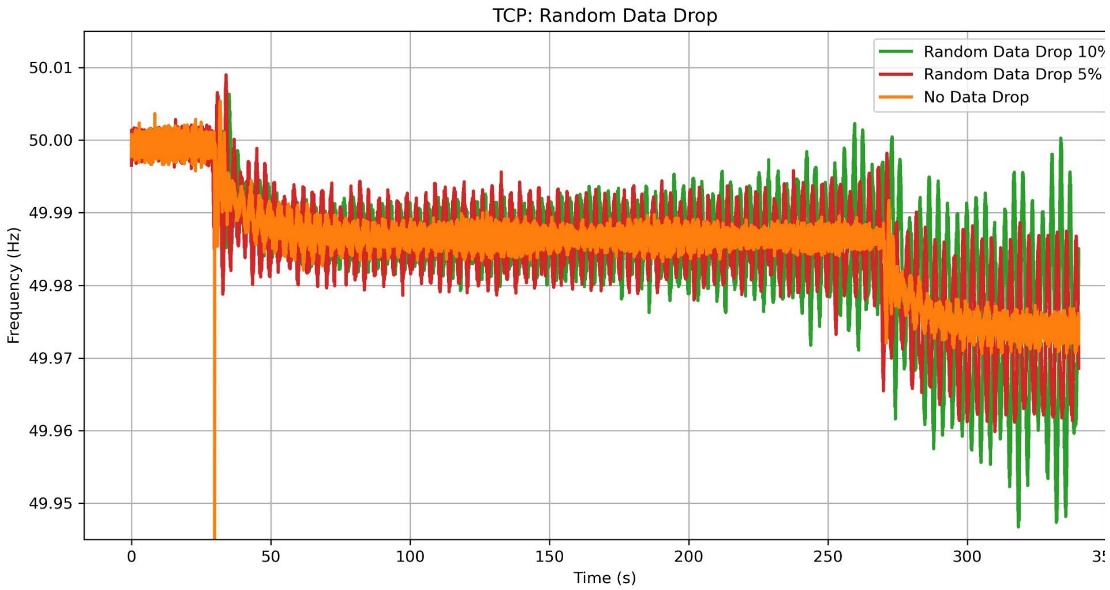

**TCP**



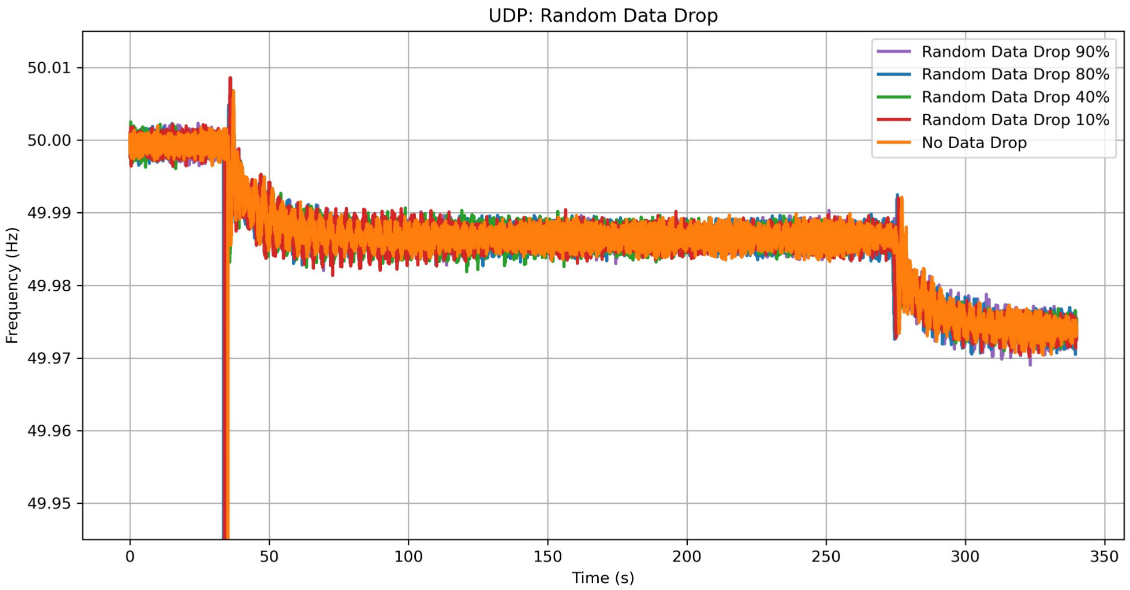

**UDP**

# HIL Test Results: Random Data Loss Impact

- **TCP: Tolerates less than 10% random data drop**
- **UDP: Tolerates up to 90% random data drop**



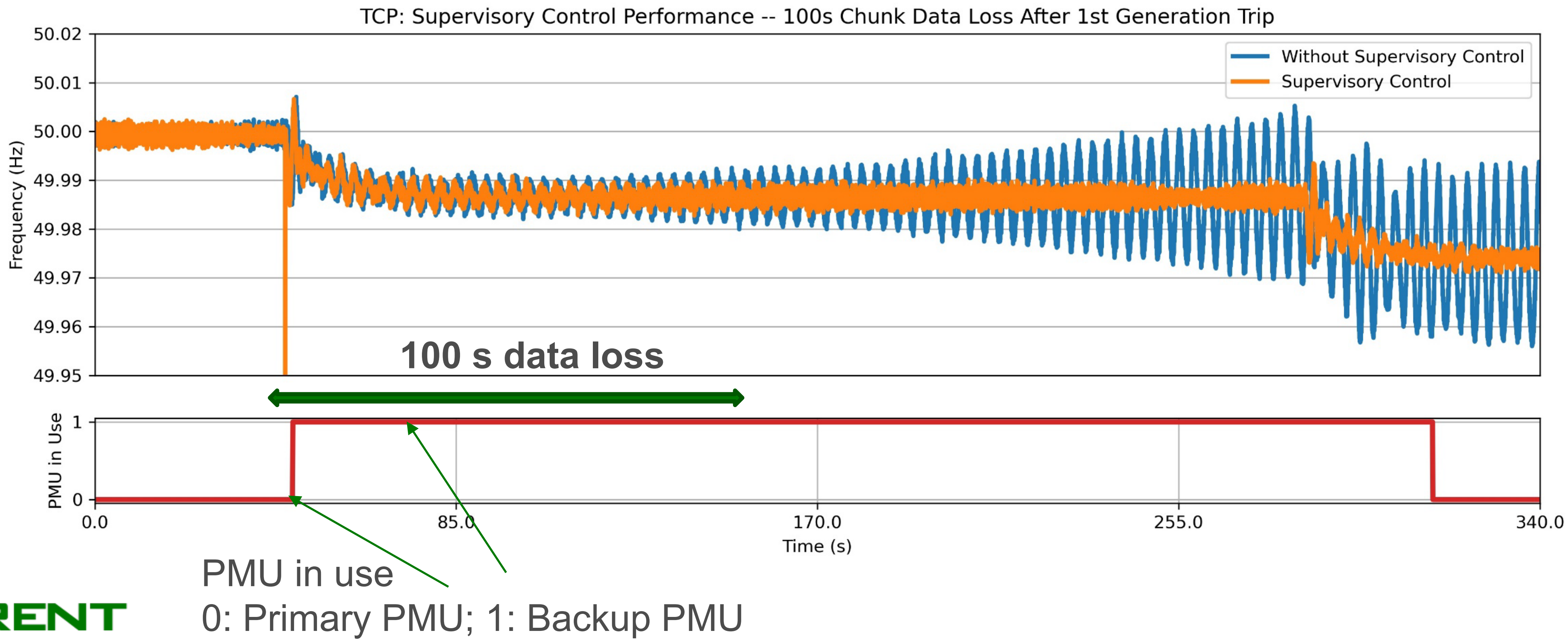

**TCP**




**UDP**

# HIL Test Results: Chunk Data Loss Impact

- **Data Loss Scenario: 100s data loss.**
- **TCP needs additional waiting time to receive data, supervisory control is very important for keeping the system stable.**

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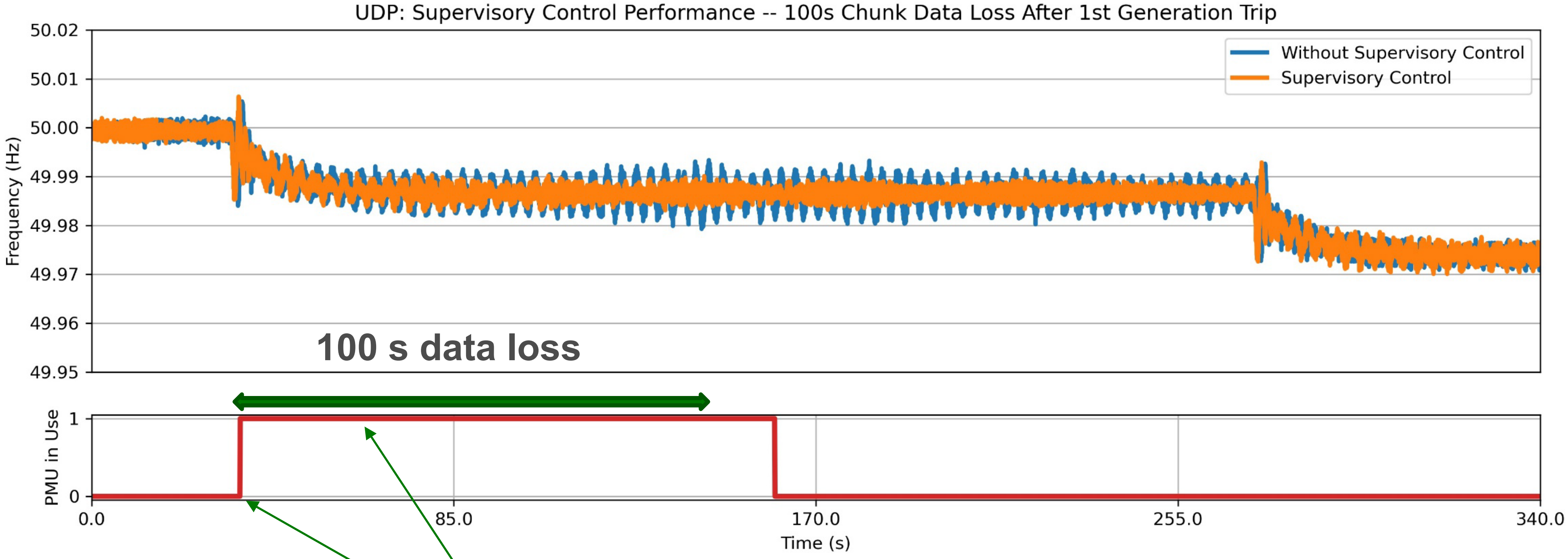
# HIL Test Results: Chunk Data Loss Impact

- **Data Loss Scenario: 100s data loss**
- **UDP can receive data quickly after the primary PMU data recovers.**




PMU in use
0: Primary PMU; 1: Backup PMU

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# HIL Test Results Summary

| | Inherit Delay + Constant Delay | Inherit Delay + Random Delay | Random Data Drop | Supervisory Control |
|---|---|---|---|---|
| TCP | tolerate up to 600ms inherit delay + 600ms constant delay | tolerate up to 600ms inherit delay + 400ms constant delay with 150ms random variation delay | tolerate less than 10% random data drop | start receiving data with additional waiting time (~150s) after chunk data loss |
| UDP | tolerate up to 600ms inherit delay + 600ms constant delay | tolerate up to 600ms inherit delay + 400ms constant delay with 150ms random variation delay | tolerate up to 90% random data drop | start receiving data immediately after chunk data loss |
| Performance Comparison | Almost the same | TCP performance slightly better when the random delay goes over 400ms +150ms variation | UDP better | UDP better |

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# Summary and Future Work

- Centralized WADC system based on openPDC has been implemented.
- Effectiveness of centralized WADC system has been tested through HIL platform.
- Various communication uncertainty operating scenarios have been mimicked on HIL platform to test the performance of the WADC.
- WADC system is being field deployed at Terna power grid.
    - ➢ Field testing scheduled in late April.

# Thank You!

# Q&A