Field Implementation and Hardware-In-the-Loop Testing of Wide-Area Damping Controller as OpenPDC Adapter

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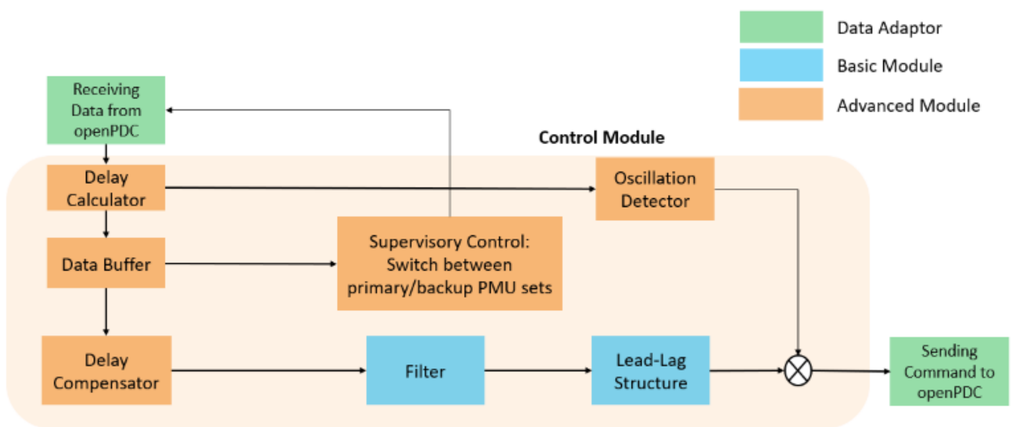
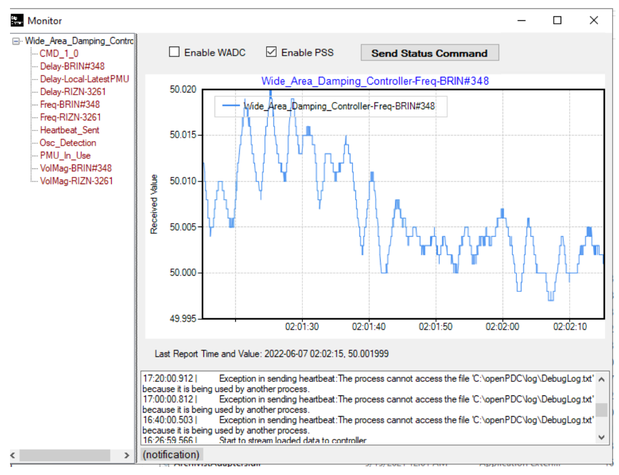
INTERDUCTION

- Poorly damped inter-area oscillations can have severe impacts on interconnected power systems
- A measurement-driven wide-area damping controller (WADC) method for suppressing inter-area oscillations has been designed and a hardware prototype was developed and validated through Opal-RT real-time simulator in previous work
- This continuation work has implemented the WADC software prototype as a openPDC adaptor, along with a graphical user interface (GUI) for WADC status monitoring
- Enhanced hardware-in-loop (HIL) testing prove WADC can deliver sufficient damping to suppress the targeted oscillation mode

WADC SOFTWARE AND GUI IMPLEMENTATION AS OPENPDC ADAPTOR



Overall structure of WADC

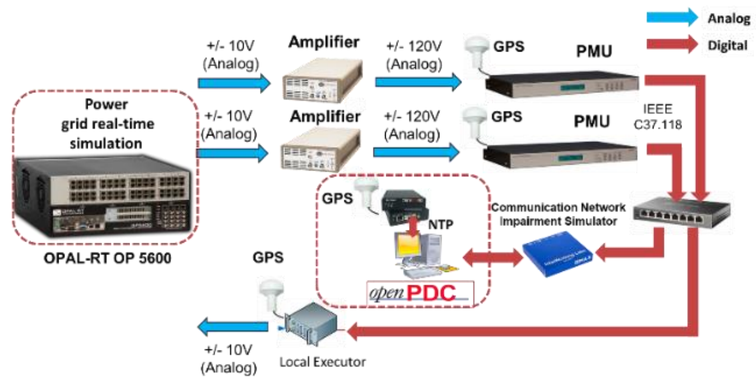


WADC monitoring GUI interface

- The openPDC is a complete Phasor Data Concentrator software tool designed to process time-series data steam in real-time
- The PMUs used as WADC inputs are configured to streaming measurements to openPDC using IEEE C37.118
- Data adaptor modules convert PMU measurements from IEEE C37.118 format into the format required by the WADC algorithm
- Function modules calculate WADC control commands based on PMU measurements
- GUI is designed to monitor PMU communication status and WADC status

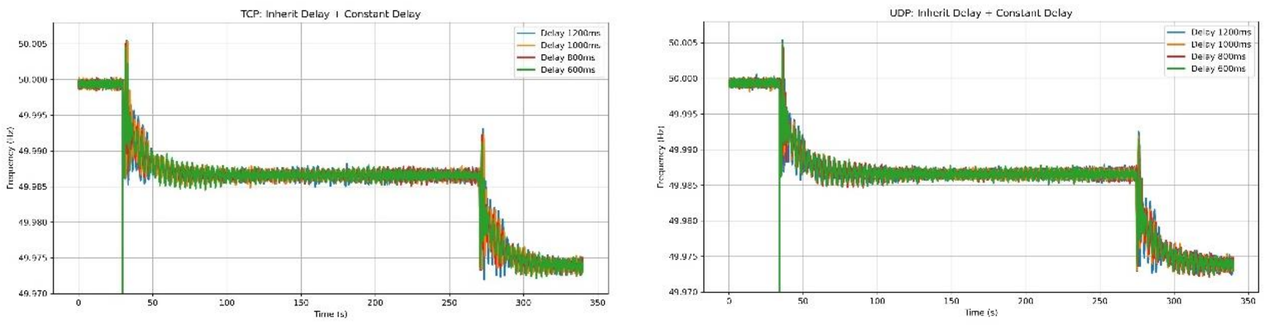
HARDWARE-IN-LOOP TEST SETUP

- Continental Europe Synchronous Area system with detailed Italy power grid models emulated on the OPAL-RT's real-time digital simulator OP5600
- The bus frequency PMU measurements are collected by openPDC and then send to WADC for real-time control command calculation
- Network simulator (KMAX) is used to mimic various network uncertainties
- LogicLab enhanced PMU device is an executor that receives the WADC control commands in a specified data frame

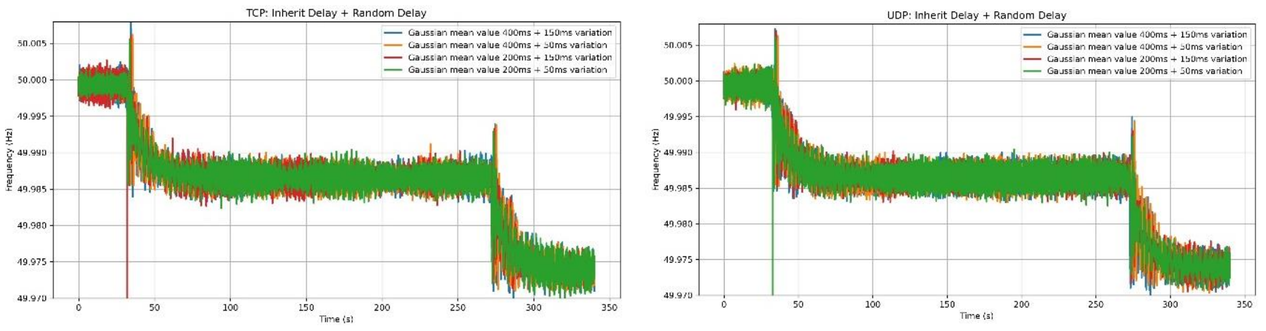


HIL test setup for WADC

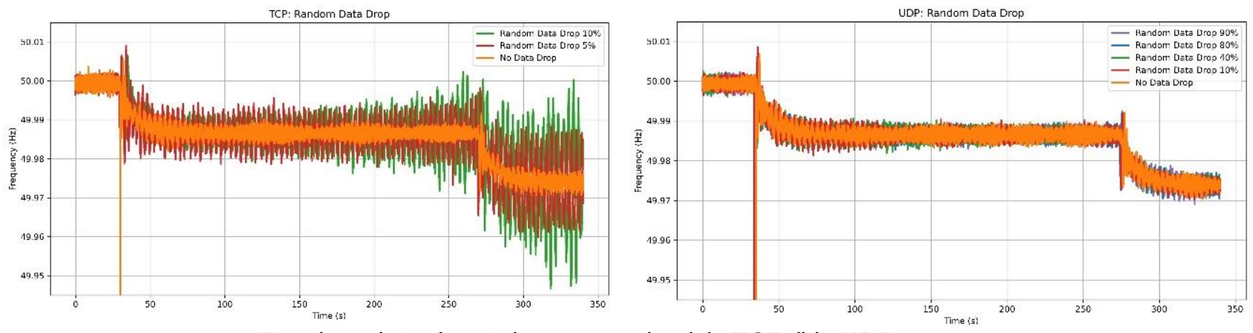
HARDWARE-IN-LOOP TEST RESULTS AND CONCLUSION



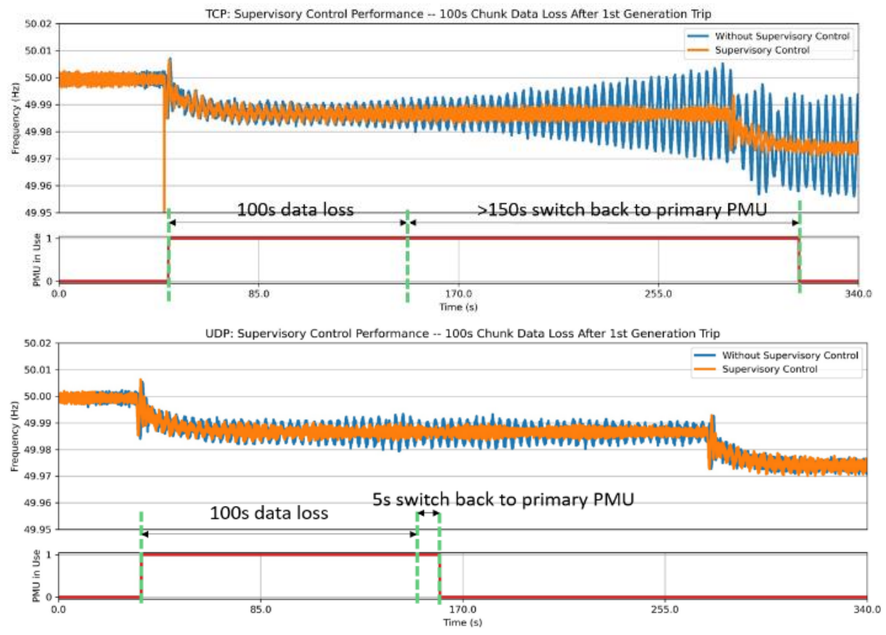
Constant delay compensation under (a). TCP (b). UDP



Random delay compensation under (a). TCP (b). UDP



Random data drop tolerance under (a). TCP (b). UDP



Supervisory control performance under (a). TCP (b). UDP

- Constant delay compensation: tolerate up to 600ms inherit delay + 600ms constant delay for both protocols
- Random delay compensation: tolerate up to 600ms inherit delay + 400ms constant delay with 150ms random variation delay for both protocols
- Random data drop: TCP tolerate ~5% / UDP tolerate ~90%
- Supervisory control: TCP has long data recovery time result in system unstable / UDP has stable damping control performance due to rapid data recovery time