Future Grid II

EMPIR

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

EURAMET

Overview and Progress of the EMPIR project 17IND06 „FutureGrid II“

Metrology for the next-generation digital substation instrumentation

E. Mohns

Acknowledgement: “*This project has received funding from the EMPIR programme co-financed by the Participating States and from the European Union’s Horizon 2020 research and innovation programme*”

2021/06/16, Final SH workshop, webmeeting

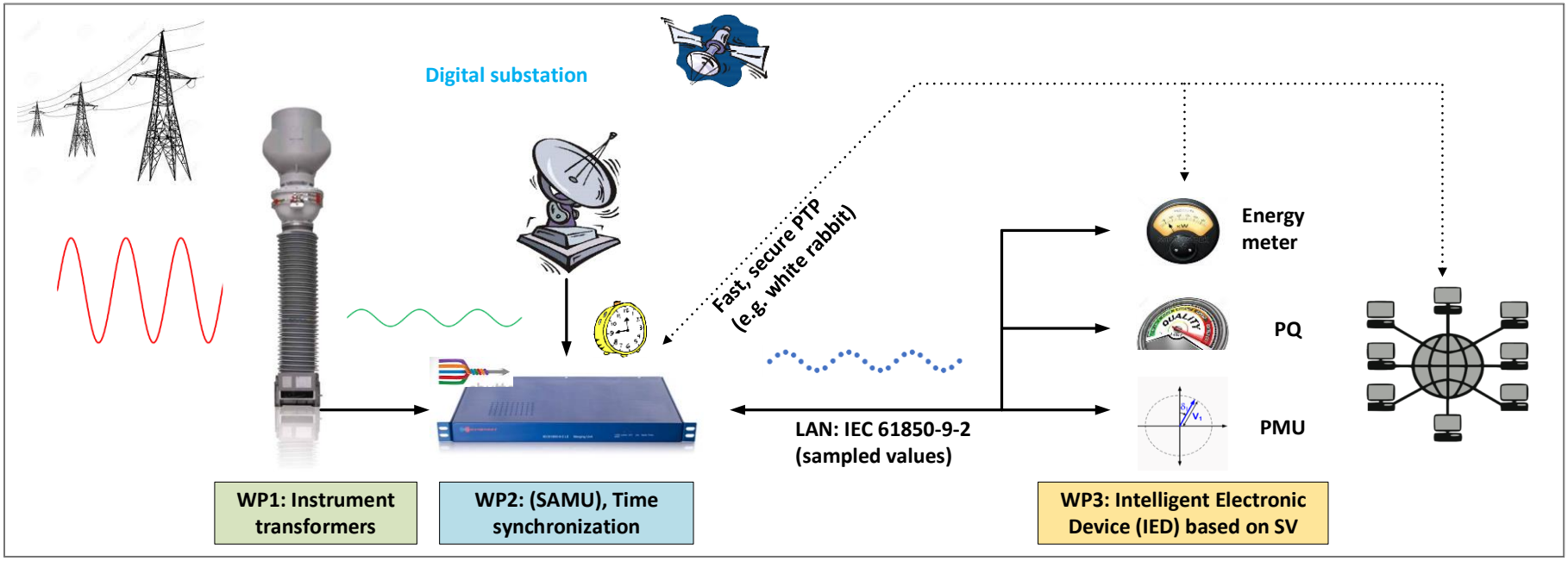
Overview of the project

- **40** months (36 + 4); from 2018-06-01 to **2021-09-30**
- **13 partners** (NMIs, Universities, Research Centers and SME)

- Many interested **stakeholders**

- 3 scientific WPs + Impact / Management

Instrumentation in a digital substation



WP1: Traceable test systems for digital instrument transformers (ITs)

WP2: Technology for substations about time synchronization

WP3: Digital metering, Phasor Measurement Units (PMU) applications and protocol enhancements with real-time (IEC 61850) communications

WP1:

Traceable test systems for digital instrument transformers

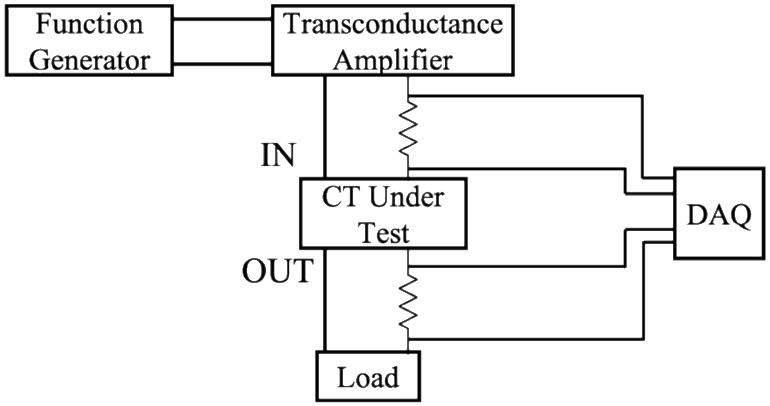
The project will establish **measurements and test systems** for the **dynamic characterisation of digital instrument transformers** for voltages up to 400/√3 kV and at least 2 kA under dynamic PQ phenomena with uncertainties from **30 ppm** under **laboratory** conditions and up to **0.1 % under on-site conditions**.

Tasks:

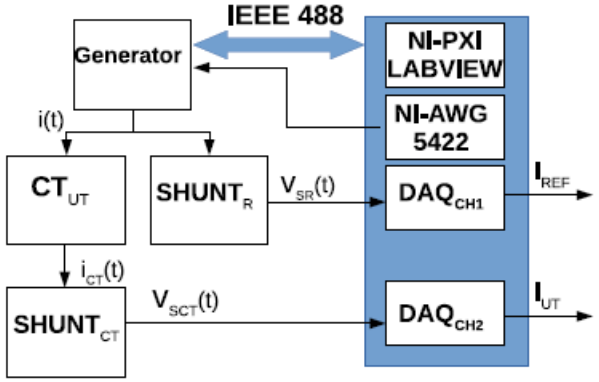
- Task 1.1: Requirements and test waveforms for PQ / PMU testing of digital IT
- Task 1.2: Systems for PQ / PMU testing of digital ITs
- Task 1.3: Definition of LPIT calibration protocols and metrics

WP1: Progress: UNIBO, SUN, CIRCE

Dynamic characterization of ITs (UNIBO)



CT Setup with AM currents (SUN)



16th IMEKO TC10 Conference
"Testing, Diagnostics & Inspection as a comprehensive value chain for Quality & Safety"
Berlin, Germany, on September 3-4, 2019

Metrological Performances of Current Transformers Under Amplitude Modulated Currents

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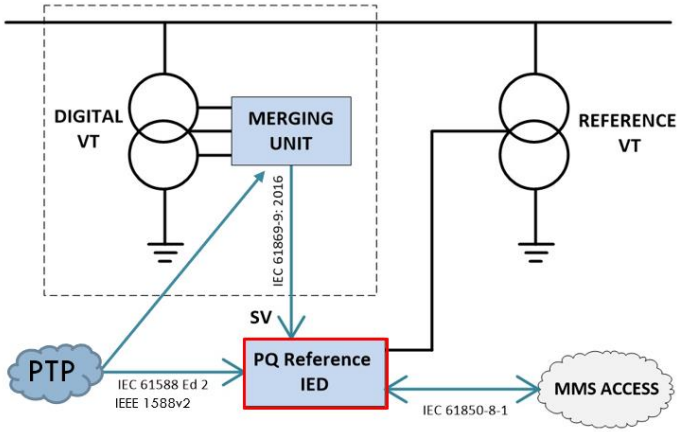
[1] *Physikalisch-Technische Bundesanstalt, Braunschweig, Germany*
[2] *Dept. of Engineering, University of Campania "Luigi Vanvitelli", Aversa (CE), Italy*

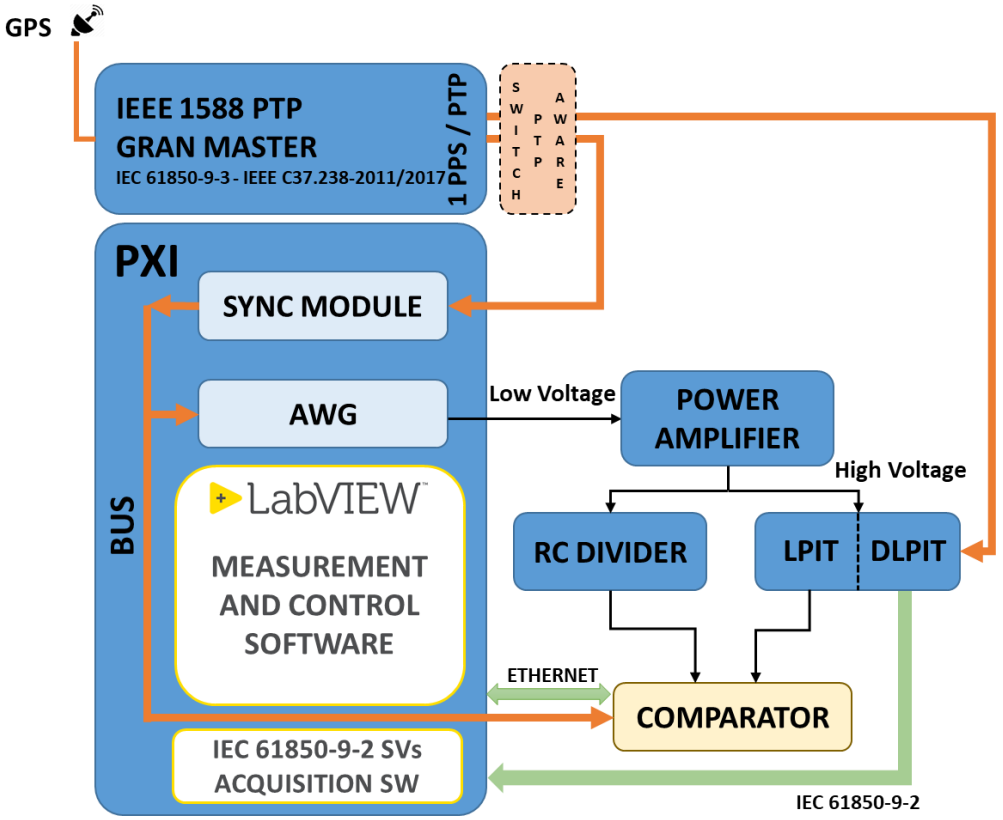


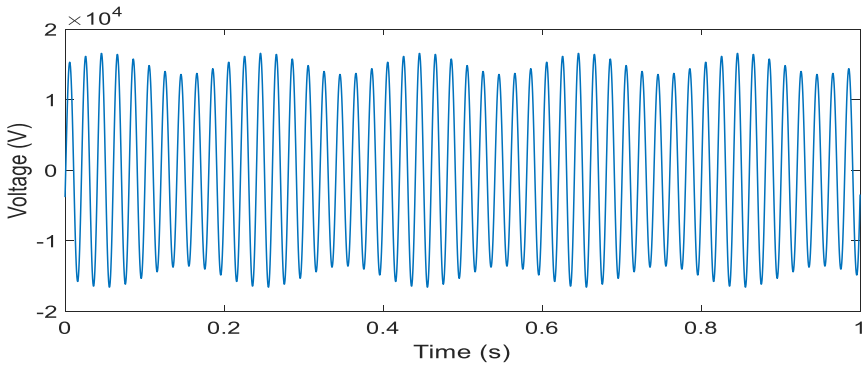
High voltage PQ analyzer to enable on-site (substation) calibration (CIRCE)

Updated PQ analyzer specifications

1. 24-Bit Sigma-Delta ADCs (204.8 kS/s)
2. SV values reading capability (IEC 61869-9)
3. Class-A PQ algorithms (IEC 61000-4-30:2015)
4. Sub-microsecond accuracy (PTP network)
5. Remote MMS Access (IEC 61850-8-1)

WP1: Progress: INRIM



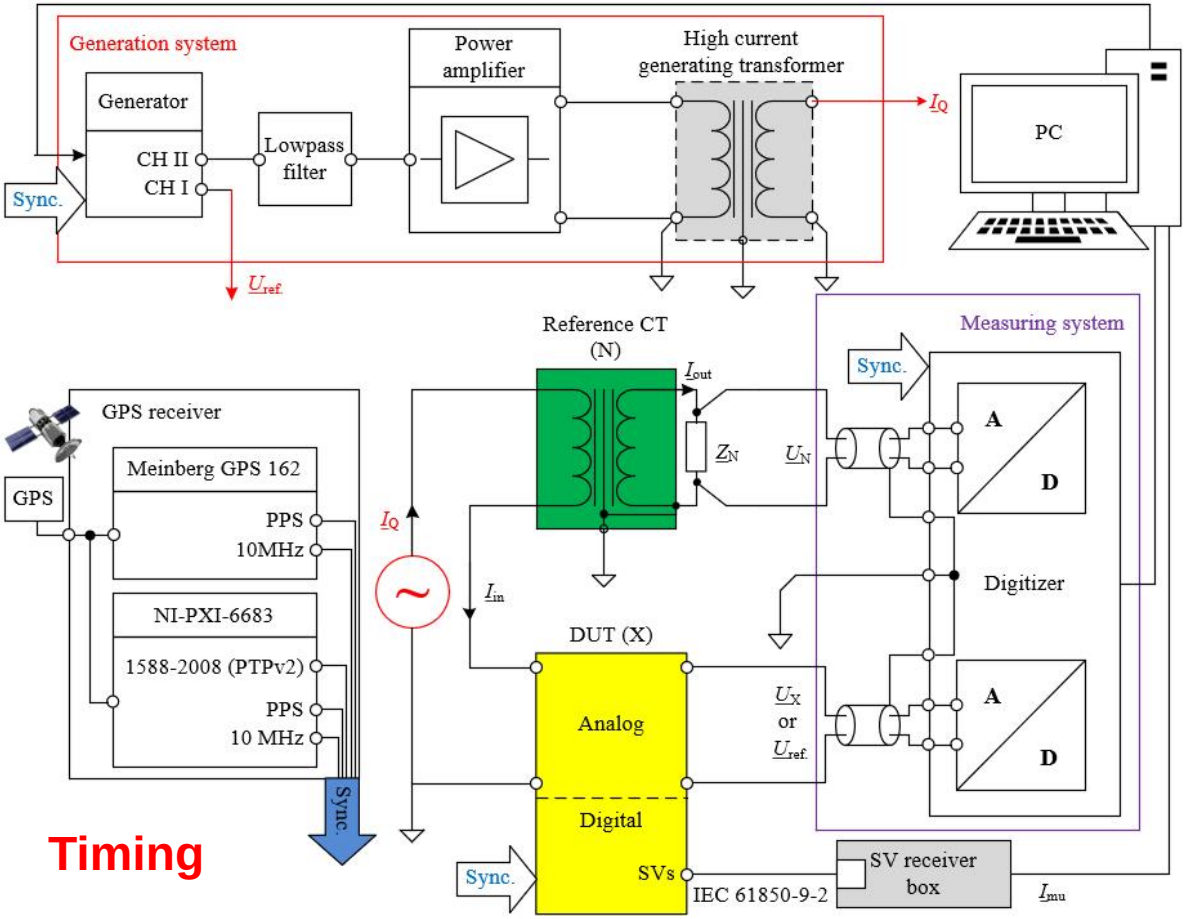


Reference system for characterization of voltage LPITs with digital output (INRIM)

- generation up to 30 kV, 9 kHz;
- IEEE 1588 PTP Grand Master clockMeinberg synchronized to absolute time via GPS/Galileo
- NI 6683 H synchronization module (GPS, IEEE 1588, PPS).
- 30 kV wideband resistive-capacitive voltage divider designed, built and characterized at INRiM.
- Comparator includes NI DAQ with modules (from ± 0.5 V to ± 425 V)

Amplitude **M**odulated voltage **S**ignal (medium voltage)

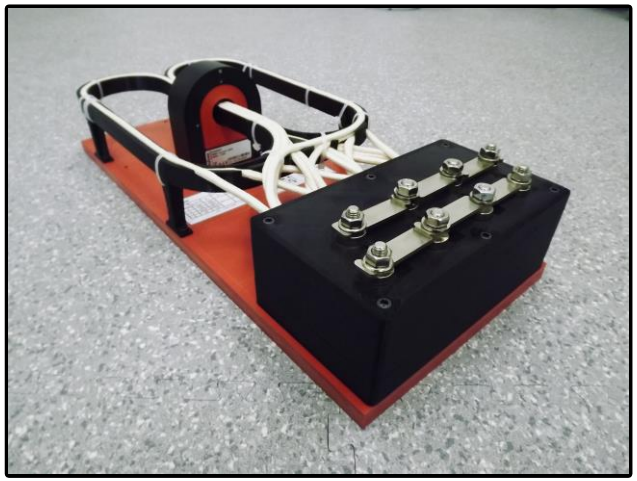
WP1: Progress: PTB



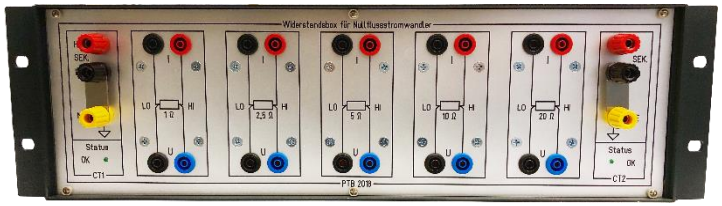
Synchronized Generator with phase reference

Timing

Symmetrical CT set 10A … 1.5kA (rated)

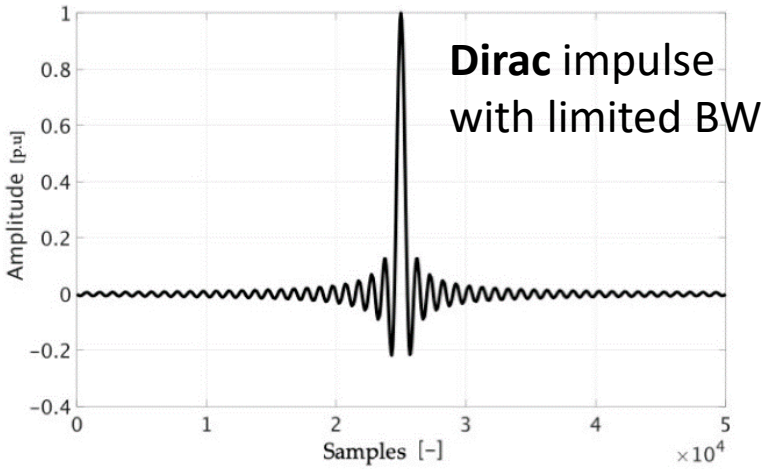


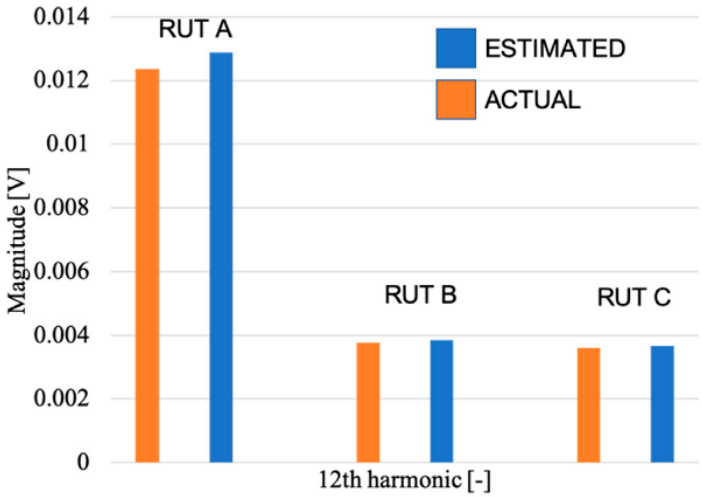
Resistor box



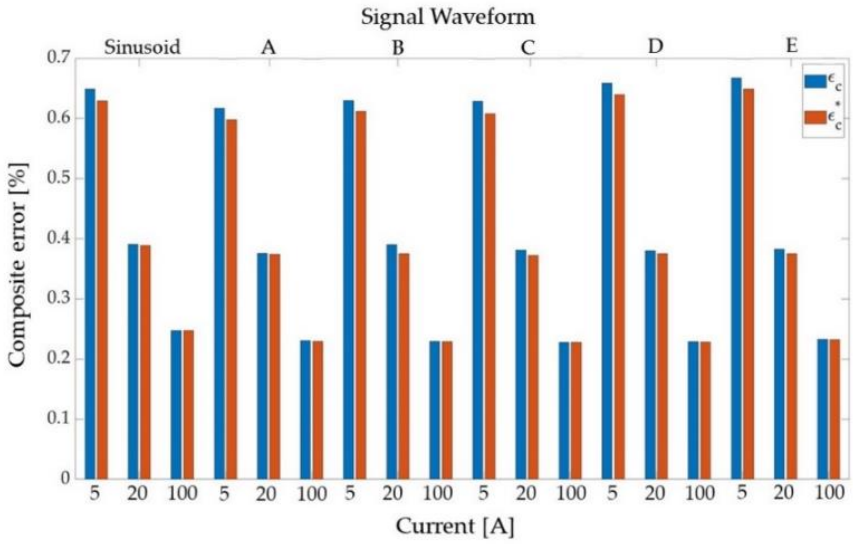
WP1: results

Characterization of **Rogowski Coils** by Using a Synthetized Signal





Are **Inductive CTs** Performance Really Affected by Actual Distorted Network Conditions?



Under realistic conditions of the network, the tested CTs show a very good behavior considering their nonlinear nature. A secondary result is that the use of the **composite error** should be more and more supported by the standards.

WP2:
Technology for substations

SCOPE

The project will provide methods and **devices for linking existing analogue high-voltage** metrology **infrastructure to** the digital domain of **time stamped sampled values**. The research focusses on setup of reference device with an error class that is ten times smaller than the defined accuracy classes of commercial instruments. Special emphasis is on the **calibration of stand-alone merging units** (SAMUs).

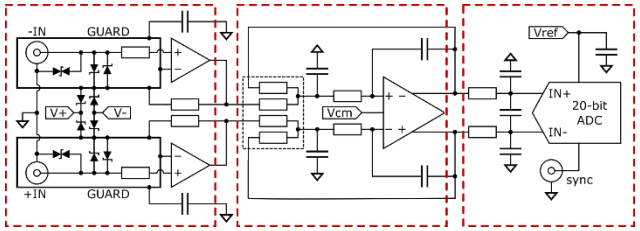
Tasks:

- T2.1. Reference SAMU for calibration of digital output instruments
- T2.2. Techniques for sampling synchronisation
- T2.3. Distributed SAMU channels for on-site calibrations
- T2.4. Secure time synchronisation for reliable timing values **(PTB)**
- T2.5. Satellite independent timing for digital substation

WP2: Progress: VSL, VTT

Joint development of metrology-grade digitizer (VTT and VSL)

- For setup of a SAMU calibration system
- For use as distributed SAMU channels to facilitate on-site (substation) measurements



Common front-end

ADC DAUGHTERBOARD:
- Signal conditioning
- Design-dependent gain
- 1MSPS 20-bit ADC
- Optional reference sources
- Floating power & ADC i/o
- i/o pins for external control

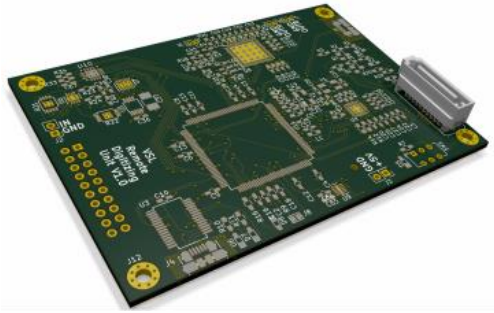
ANALOG INPUT

VTT modular digitizer

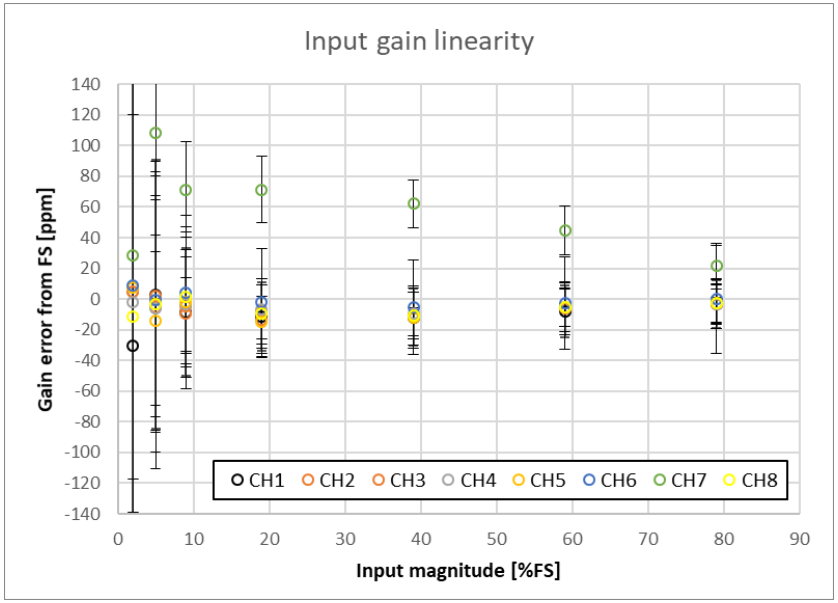
ADC MOTHERBOARD → DIGITIZER MAINFRAME → DIGITIZER FIRMWARE → DATA

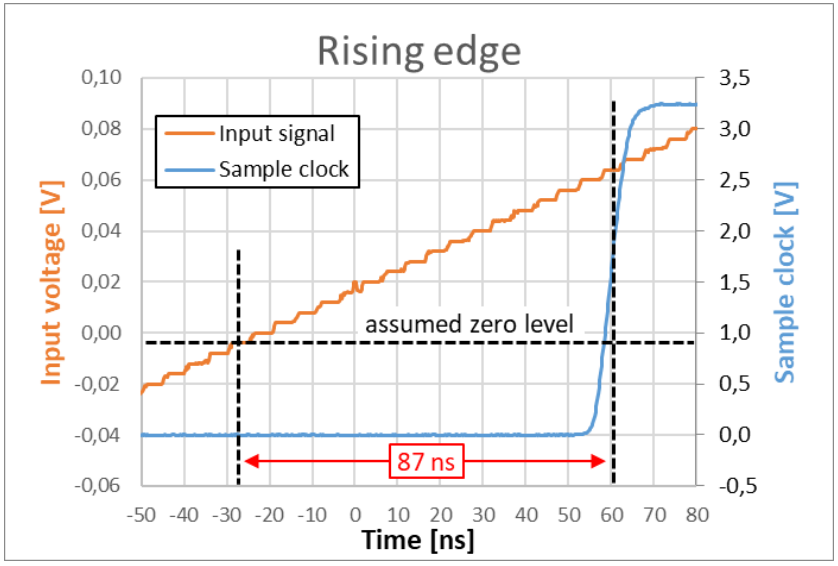
DISTRIBUTED DIGITIZER MAINFRAME → DIGITIZER FIRMWARE → DATA

VSL distributed digitizer (next slide)



WP2: VTT results of the reference SAMU

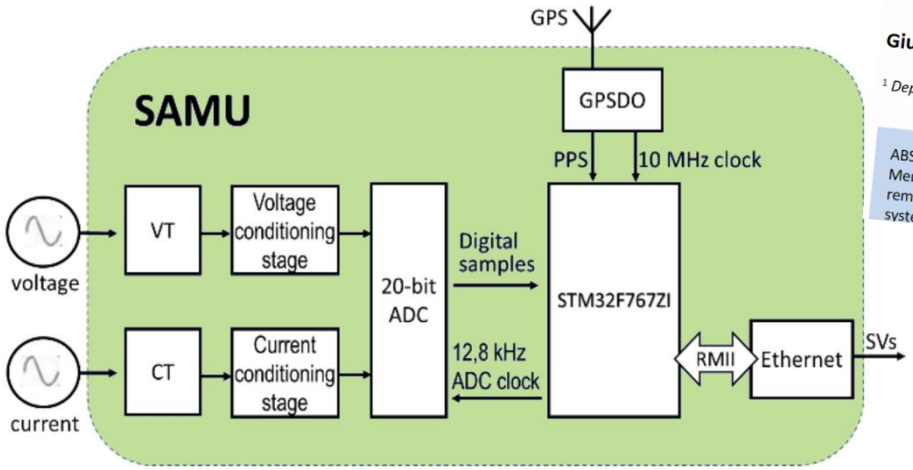




- Measured with 8-decade IVD
  - Compared to another 8-dec IVD
  - Agreement within 0.1 ppm
- **<u>Gain within 20 ppm to 5 %FS</u>**
- Especially CH8 (24-bit ADC) show best behaviour

Item	Value	Ui [ns]
U_{IN}	1 mV	1.3
U_{FE}	1 mV	1.3
U_{OSC}	8 mV	10
t_{OSC}	10 ns	10
t_{SYNC}	10 ns	10
TOTAL (k = 2)		**<u>35</u>**

WP2: Progress: SUN, PTB



ACTA IMEKO
ISSN: 2221-870X
March 2020, Volume 9, Number 1, 40 - 48

Design and characterisation of a stand-alone merging unit

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ABSTRACT
Merging Units (MUs) play a key role in enhancing the levels of security and the reliability of power systems, allowing for advanced remote diagnostics. Some of the benefits are a more efficient transmission of electricity and a better integration with renewable energy systems. In this article, an implementation of a Stand-Alone Merging Unit (SAMU), compliant with the IEC 61850-9-2 standard and based

- implementation of a SAMU based on a low-cost ARM microcontroller,
- Typical error of below 0,1 %

3-phase active current clamp

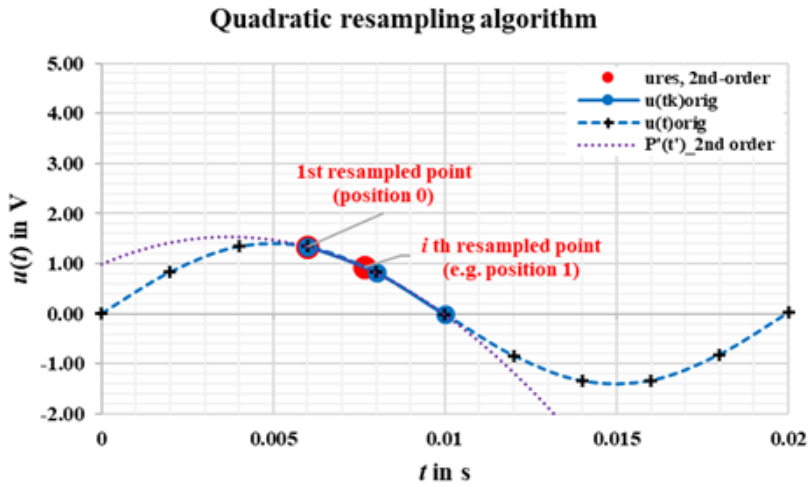
- for conventional CT's with rated secondary currents of 1A or 5A for the reference SAMU.
- Electronically error compensated
- calibrated uncertainty: 50 ppm

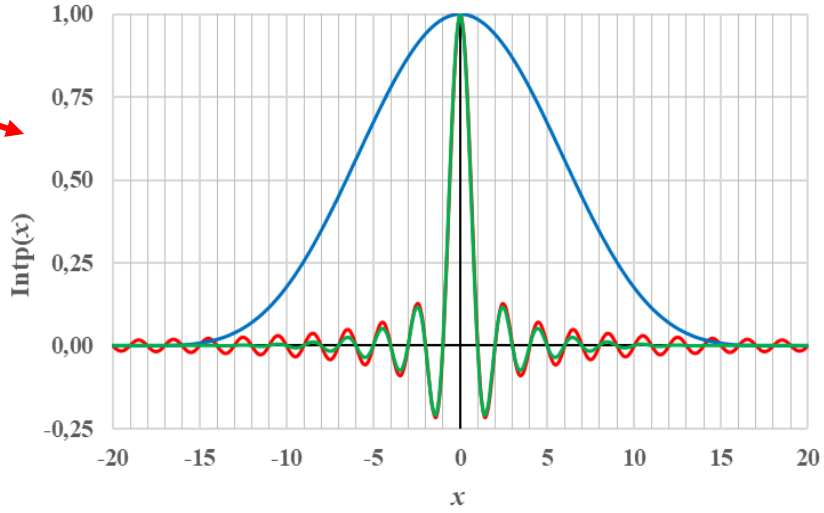
WP2: Progress: PTB Resampling algorithm

- *Precise Amplitude and Phase Determination using Resampling Algorithms for Calibrating Sampled Value Instruments*:

  - quadratic polynomial
  - cubic polynomial
  - modified sinc function ★

★ Error in the order of 10^{-8} V/V (or rad) for 20 % *fs*





WP3:

Digital metering, PMU applications and protocol enhancements

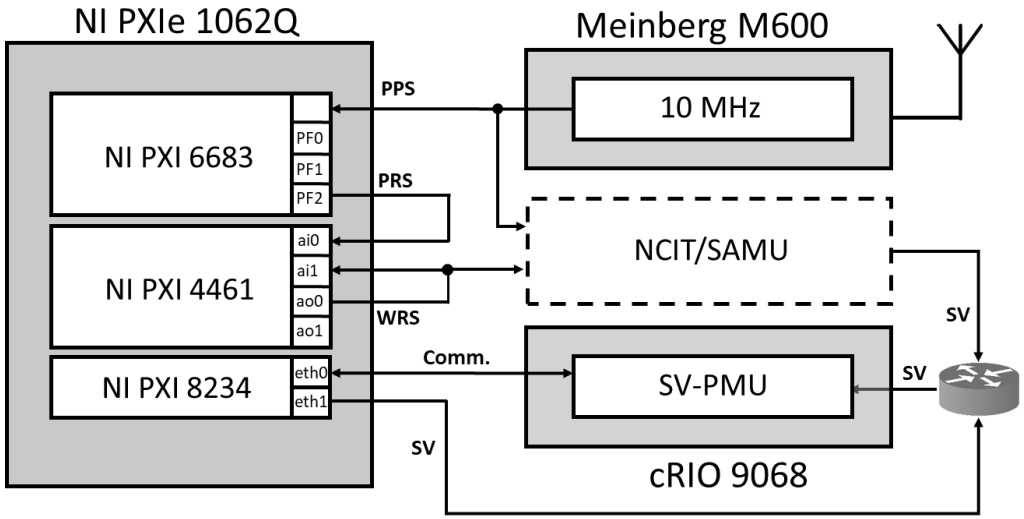
Scope

In this objective, **metrological tools** for the **characterisation of devices that exploit sampled values** (SV) in digital substations are developed; e.g. **all-digital power** and **power quality meters** and **phasor measurement units** (PMUs). This includes **studies on limitations** due to **latency** and computation time, and characterisation of error sources to provide **proposals for an enhanced protocol for sampled values**.

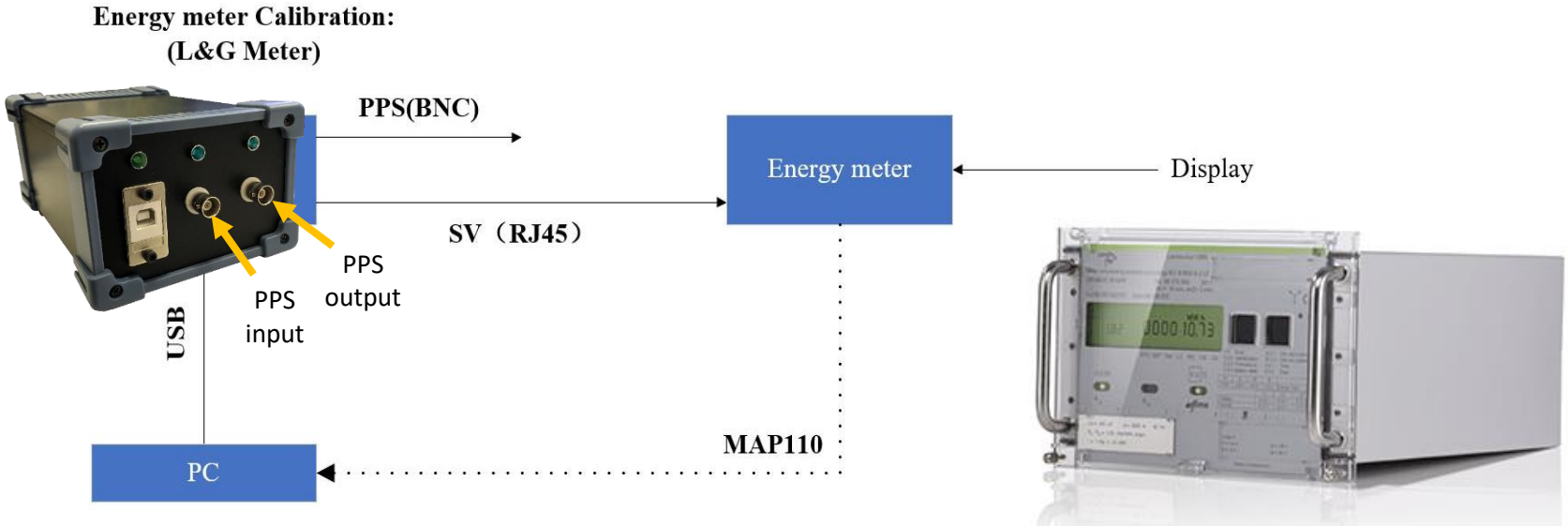
Tasks:

- Metering
- Grid control (through PMU with digital input)
- Enhancements to the existing SV protocol

WP3: progress: METAS, PTB



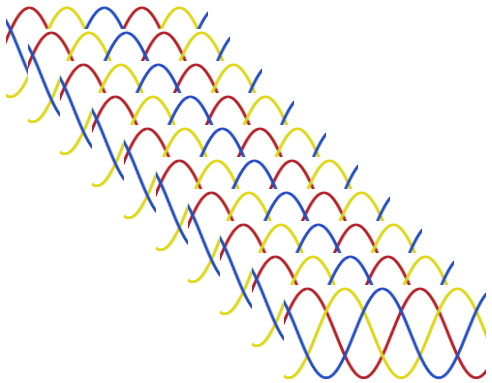
A **Software Platform (Metas)** has been used to validate a **stand-alone PMU with SV** input

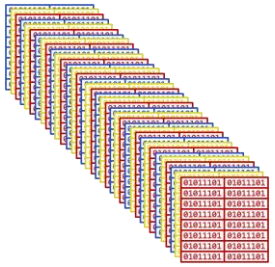


Another **Software Platform (PTB) for reading and sending SV for testing energy meters**

WP3: Data compression: Strathclyde, Synaptec

The role of a Merging Unit





do this every 69-250 microseconds

total: 6.9 megabytes every second (55.2 Mbps)

14.4 kHz sampling:

218 terabytes every year

WP3: Data compression: Strathclyde, Synaptec

01011101	00010101
01010101	10010101
01001101	10010101
01011101	10100110
01011001	11110101
11010101	10010101
01011111	00010101
11010101	10010101

at 0 seconds

	00010100
	10010111
	10010110

at 0.00025 seconds

delta-delta encoding or differential compression

Sampling rate (Hz)	Samples per message	Message size (bytes)	Size
4000	10	210	16.4%
4000	4000	46250	9%
14400	6	134	17.4%
14400	14400	97083	5.3%
150000	150000	431339	2.2%

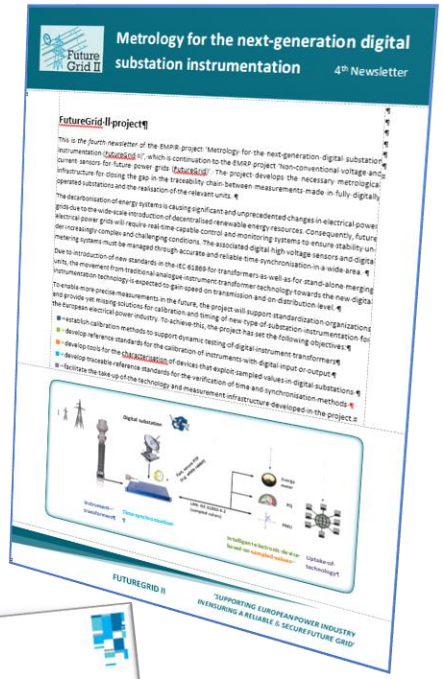
compressing is faster (x10) than not compressing!

WP4: Impact

Scope

to ensure that the project results will have an impact and are aligned to industrial-, standardization- or scientific needs

- Regularly updated website
- Newsletter every 9 months
- 30 **open access** peer-reviewed publications
- 21 Presentations and Posters in conferences
- 23 other disseminations
- Contributions to IEC TC38 (Instrument transformers) and to IETF (Internet Engineering Task Force) standardization work
- 2 Workshop (AMPS ‘19, web in ‘21)



End of the Workshop

Project website: https://www.vtt.fi/sites/FutureGrid2/

Euramet Website

Zenodo Community

Metrology for the next-generation digital substation instrumentation

Short Name: FutureGrid II, Project Number: 17IND06

In case of being interested → contact either:

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Jari.Hallstrom@vtt.fi