MARS ENERGO
INSTRUMENTS FOR POWER INDUSTRY

D.I. Mendeleev Institute
for Metrology (VNIIM)

Reference instruments for digital substations

Relevance of the job

VNIIM and Mars-Energo in cooperation

Measurement channels as key components of an energy management system of new generation - *digital substation (DSS) -* are built on IEC 61850-compliant electronic current and voltage transformers (ECTs and EVTs) and IEDs.

Steady growth of IEC 61850-based devices in the energy distribution infrastructure means that the demand for associated testing/calibration tools will be increasing from year to year.

The job is being fulfilled by

VNIIM and Mars-Energo in cooperation

Developing and manufacturing of such reference equipment is a task that requires combined efforts (VNIIM and Mars-Energo in our case). The scope of the task includes:

- **Development of measurement and test procedures;**
- **Development, design and manufacturing of the system of reference standards intended for testing DSS measurement channels under both laboratory and field conditions.**

Prospective customers

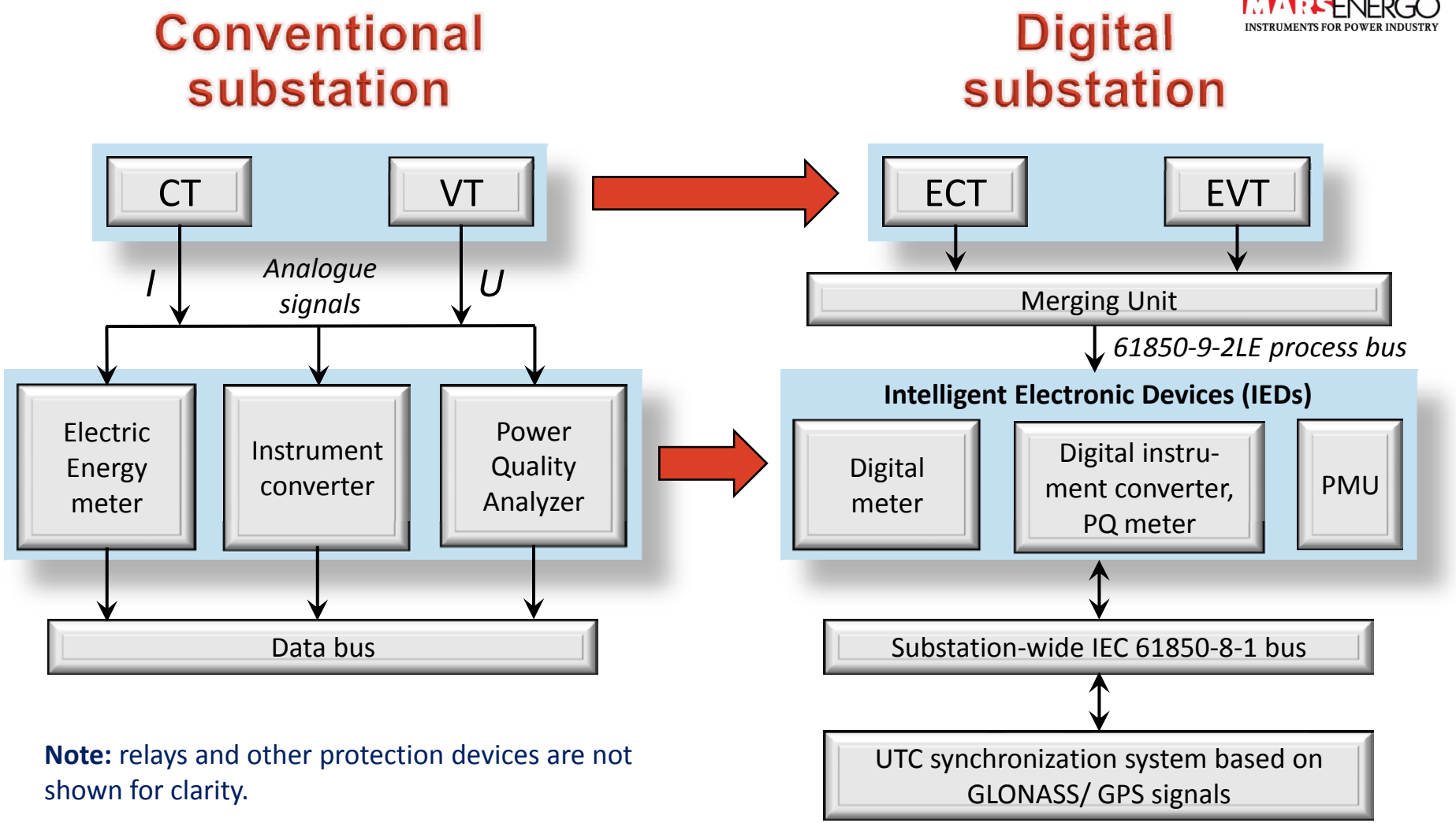
- **Power energy sector: generation, distribution and grid companies**:

Growth of IEC-61850-based equipment and deployment of digital substations brings up the subsequent task - to develop a set of reference measuring instruments that support data exchange with digitized high-end devices via corresponding communications protocols.

- **Designers and manufacturers of digital substation equipment:**

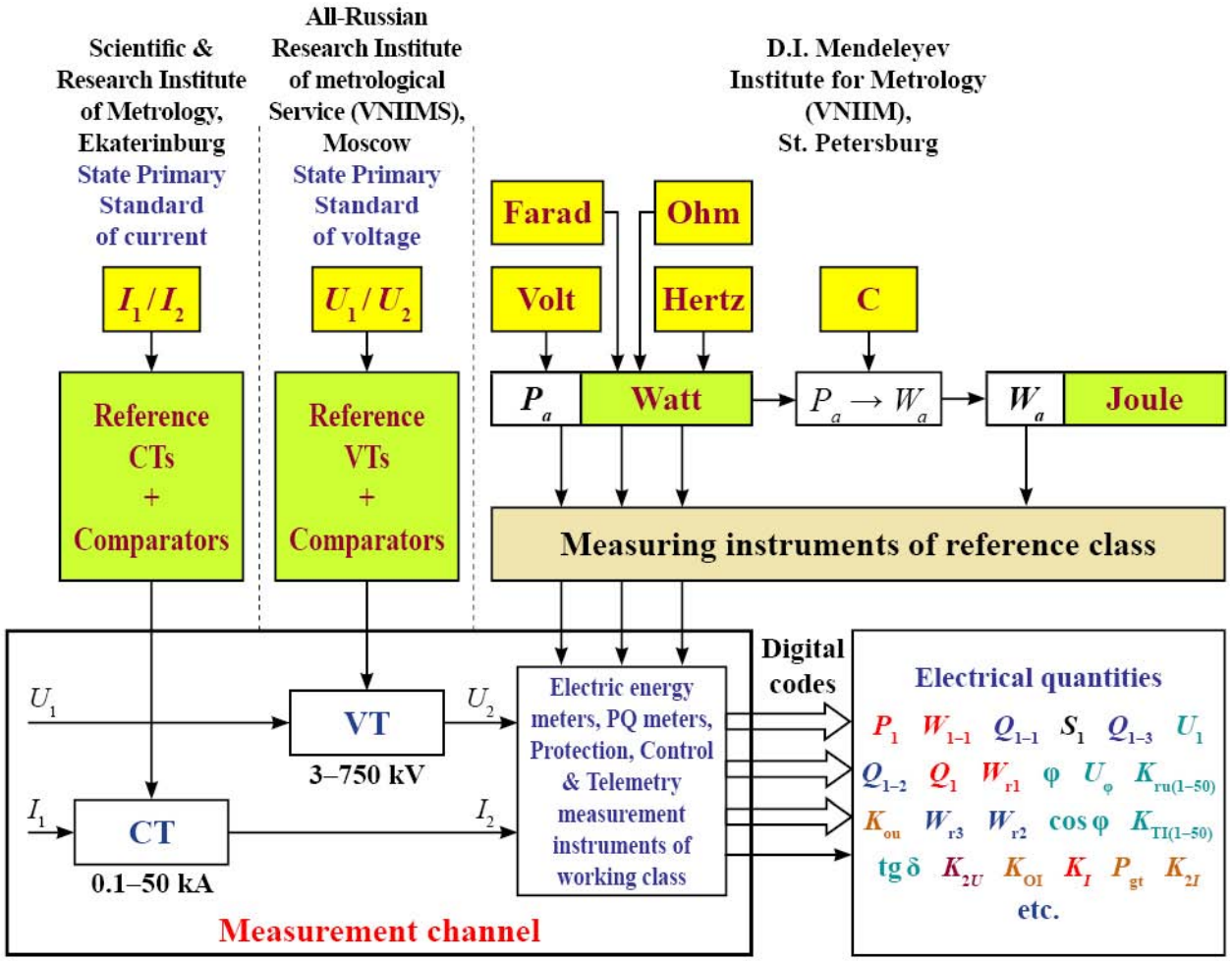
Research and Development laboratories and manufacturers of non-conventional (electronic) transformers, IEDs and other high-end devices need the means for product testing.

Basic differences between conventional and digital substations



Note: relays and other protection devices are not shown for clarity.

System of measurement standards existing in Russia up to now (solution for conventional substations)



The existing system of measurement standards supports the conventional solution created to ensure traceability of basic electric quantities (Volt, Ampere, Ohm, Watt) and scaling ratios from reference-class- instruments of analogue type to working standards, working-class devices etc. that are of analogue type too.

Mars-Energo reference equipment for conventional substations

MARS ENERGO
INSTRUMENTS FOR POWER INDUSTRY

Multipurpose Test Systems

MTS ME 3.3
MTS ME 3.1K
MTS ME 3.0

Multipurpose Reference Standards

Energomonitor 3.3T1
Energomonitor 3.1K
Energomonitor 3.0

CT/VT Test System ME Audit

6 to 330 kV; 5 kA; 30 kA

CT Test Set

VT Test Set

Set for testing electric energy meters and PQ analyzers

2014 Concept

Power Calibration System PCS ME 1.0

PCS ME 1.0 and EnergoEtalon™ software form a state-of-the-art reference setup that provides:

- Extremely high accuracy of measurements;
- Versatility required for testing/calibration of high-end measuring instruments for AC and DC determinations;
- Extended frequency range (16…3000 Hz).

Basic specifications:

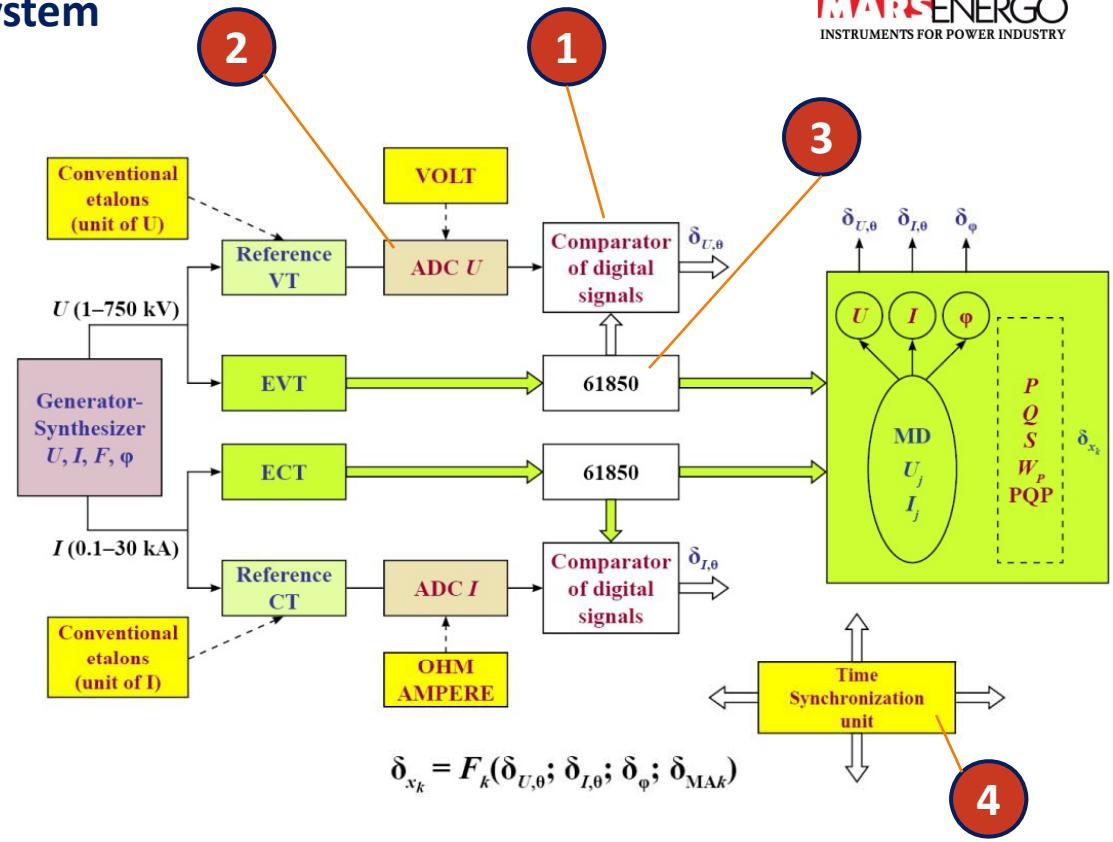
Parameter	Extended uncertainty of measurements
Current	
0.01–50 A	0.004 %
Voltage	
0.1–600 V	0.003 %

Parameter	Extended uncertainty of measurements
Power Factor	
PF = 1	0.004 %
PF = 0.5	0.006 %
Phase angle U ^ I	
0°…360°	0.0011° at 50 Hz

System of measurement standards (solution for digital substations)

New components of reference system

1. **Comparator of digitized signals**
   Compares standard-compliant digital signals from the reference device and device under test.
2. **Reference ADC**
   Its own modular, angular and UTC synchronization errors are precisely investigated.
3. **Digital code converter**
   Provides communications via **61850-9-2** protocol with time delays coordinated across measurement channels.
4. **Synchronization unit**
   Provides synchronization of measurements with UTC.



EVT — Electronic VT
ECT — Electronic CT
61850 — Digital code converter (IEC 61850)

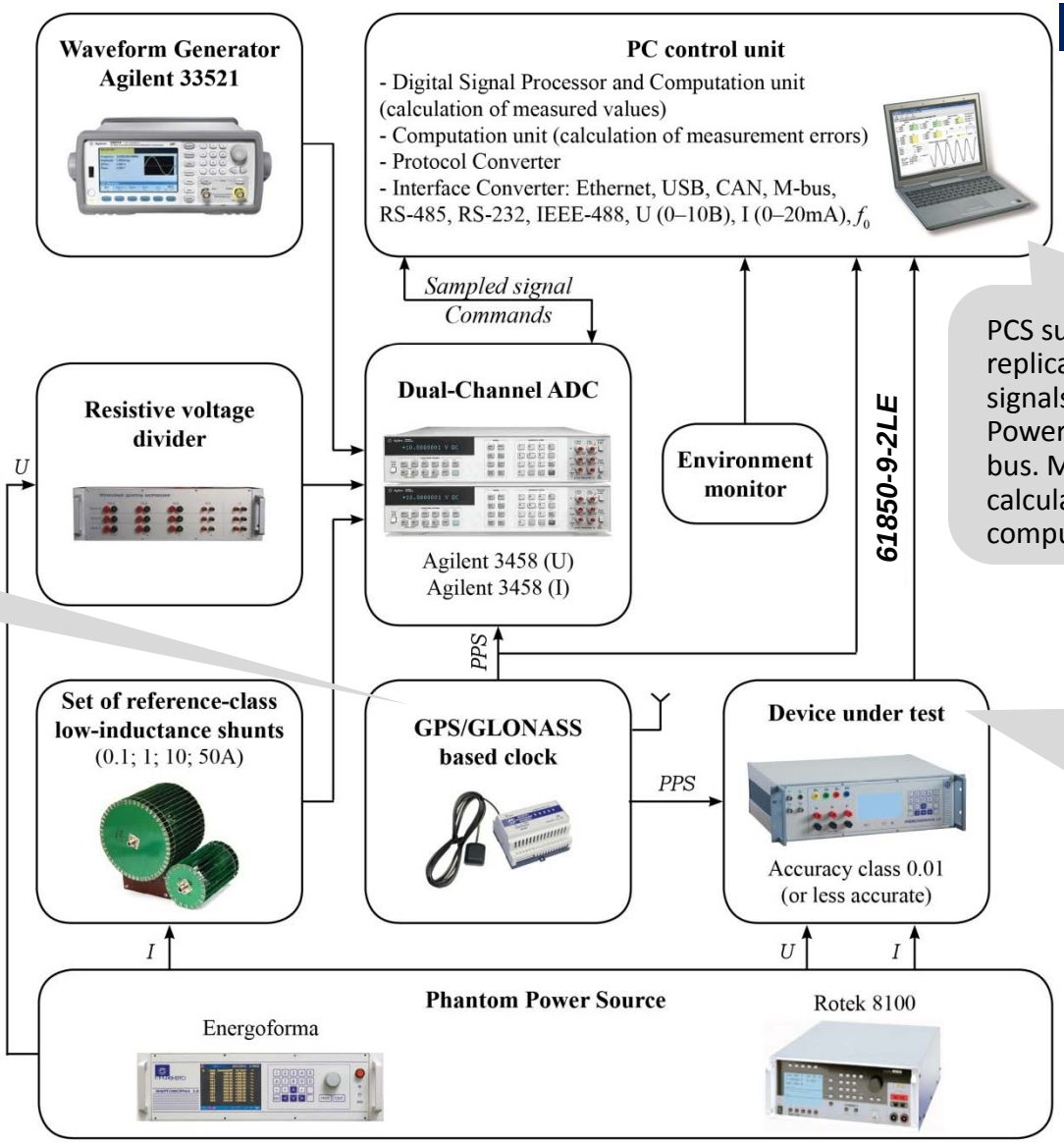
Block diagram of Power Calibration System PCS ME 1.0-61850 for digital substation applications

PCS ME 1.0-61850

PSC accepts IEC 61850-9-2 LE data

PCS has its own UTC synchronization module

Current and voltage measurement range s will be extended up to 5 kA and 220 kV (Mars-Energo is working on High Voltage block of the system)



PCS supports transfer of digital replicas of current and voltage signals (generated by Phantom Power Source) over the process bus. Measurement errors are calculated in the built-in error computation unit

PCS supports testing and calibration of the instruments that measure vectorized quantities of:

- current,
- voltage,
- current and voltage

Versatility of PCS ME 1.0-61850

Application notes

- PCS ME 1.0-61850 can be used as a system for calibration of instruments making up digital substation infrastructure: electronic CTs and VTs with digital outputs and merging units with analogue inputs and outputs (per IEC 61850-9-2LE).

- Who needs PCS?
  - National metrological institutes or standard laboratories may use it as a multifunctional calibration system for electrical energy and power quality applications;
  - Metrological service departments of power industry enterprises;
  - Research and design departments and laboratories that conduct products testing.

Versatility of PCS ME 1.0-61850

Extra functionality

- *With EnergoEtalon-61850 software*
  Operates with devices supporting digital communication interface (IEC 61850-9-2 LE), e.g. non-conventional instrument current/voltage transformers or digital power quality analyzers.
- *With EnergoEtalon-PMU software*
  Provides for calibration of the most precision Phasor Measurement Units.
- *Great opportunity*
  We offer an outstanding opportunity to get either the entire calibration setup or any part of it (that can be easily integrated in the equipment already installed in your lab). Considering that most of its blocks are typical “on-the-shelf” equipment you may purchase just EnegoEtalon software as a key component of the system.

ECT/EVT Test Set KSP-61850

Purpose

KSP-61850 is meant for testing and calibration of transformers designed in conformity with IEC 60044-7-2010 and IEC 60044-8-2010 standards.

The purpose of KSP-61850 is to convert (considering scaling factors), measure and compare signals (including IEC 61850-9-2LE signals) from analogue or digital outputs of electronic current (up to 5 kA) and voltage (up to 220, 330 kV) transformers.

Modules:

- ***Low Voltage module***
  - Digital Calibration System DCS ME 61850 (vectorized quantities; comparison principle);
- ***High Voltage module***
  - Reference device - Capacitive HV Transducer (designed as a capacitive HV divider of active type);
  - Variable High-Voltage Source TGI-230;
  - Reference Current Transformer PCTI;
  - Adjustable Current Source IT5000.

ECT/EVT Test Set KSP-61850

DCS ME 61850
Digital Calibration system,
single phase,
stationary design
(Utilizes comparison method)

Concept
Energomonitor-61850
Multifunctional
reference instrument
(8-channel, portable design)

Low-Voltage module

1. Source of test voltage 2. Reference Voltage Transducer	
2.1 HV Transducer CHVT-220 (accuracy 0.05)	2.2 Reference VT (EPRO) (accuracy 0.01)

1. Source of test current 2. Reference Current Transformer	
2.1 Reference CT PCTI (accuracy 0.05)	2.2 Reference CT (EPRO) (accuracy 0.01)

High-Voltage module

Description of KSP-61850 modules

Digital Calibration System DCS ME 61850

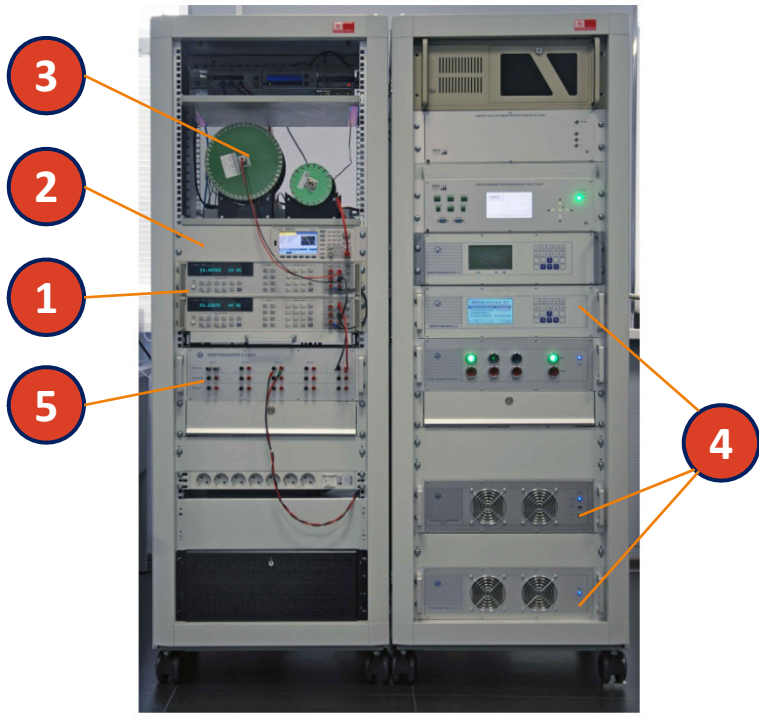
- **Purpose**

DCS ME 61850 Calibration System is meant for testing and calibration of the following devices: electronic current and voltage instrument transformers designed per IEC 60044-7-2010 and IEC 60044-8-2010 standards with output signals compliant to IEC 61850-9-2LE.

The purpose of DCS ME 61850 Calibration System is to measure and compare analogue signals taken from secondary outputs of reference AC current and voltage transducers/transformers with digitized signals taken from outputs of AC current and voltage transducers/transformers under test.

- **Scope of supply (basic):**

1. Reference ADC-device: multimeter Agilent 3458A,
2. Generator of synch pulses: Agilent 33521A,
3. Reference Current shunts (reactance-free, RS series),
4. Phantom Power Source: Rotek8100 or Energoforma 3.0,
5. Resistive Voltage divider.



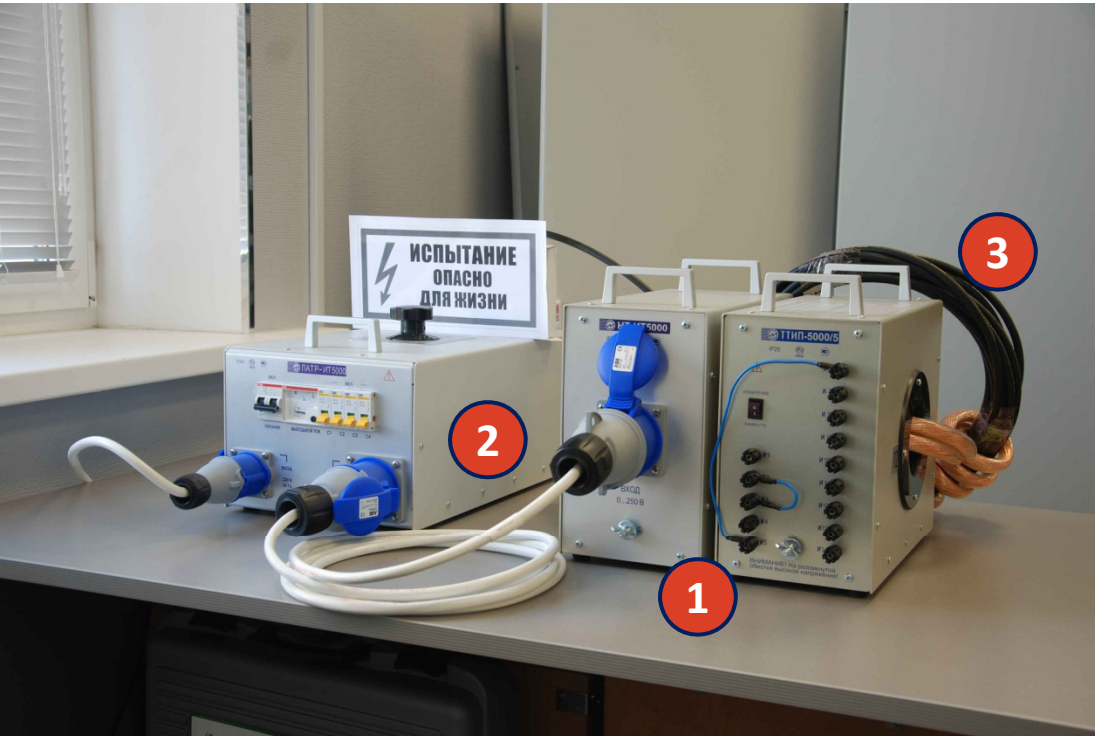
Low-Voltage module of KSP-61850 Test Set

Description of KSP-61850 modules

VT test module consists of:

1. Reference Voltage Transducer CHVT-220, 330 kV (class 0.05) or Reference VT (EPRO, class 0.01)
2. Variable High-Voltage Source TGI-230
3. VT under test

Description of KSP-61850 modules



CT test module consists of:

1. Reference Current Transformer PCTI
2. Adjustable Current Source IT5000
3. CT under test (an optical transformer with IEC 61850 output is shown in the figure)

Multifunctional reference meter Energomonitor 61850

Purpose

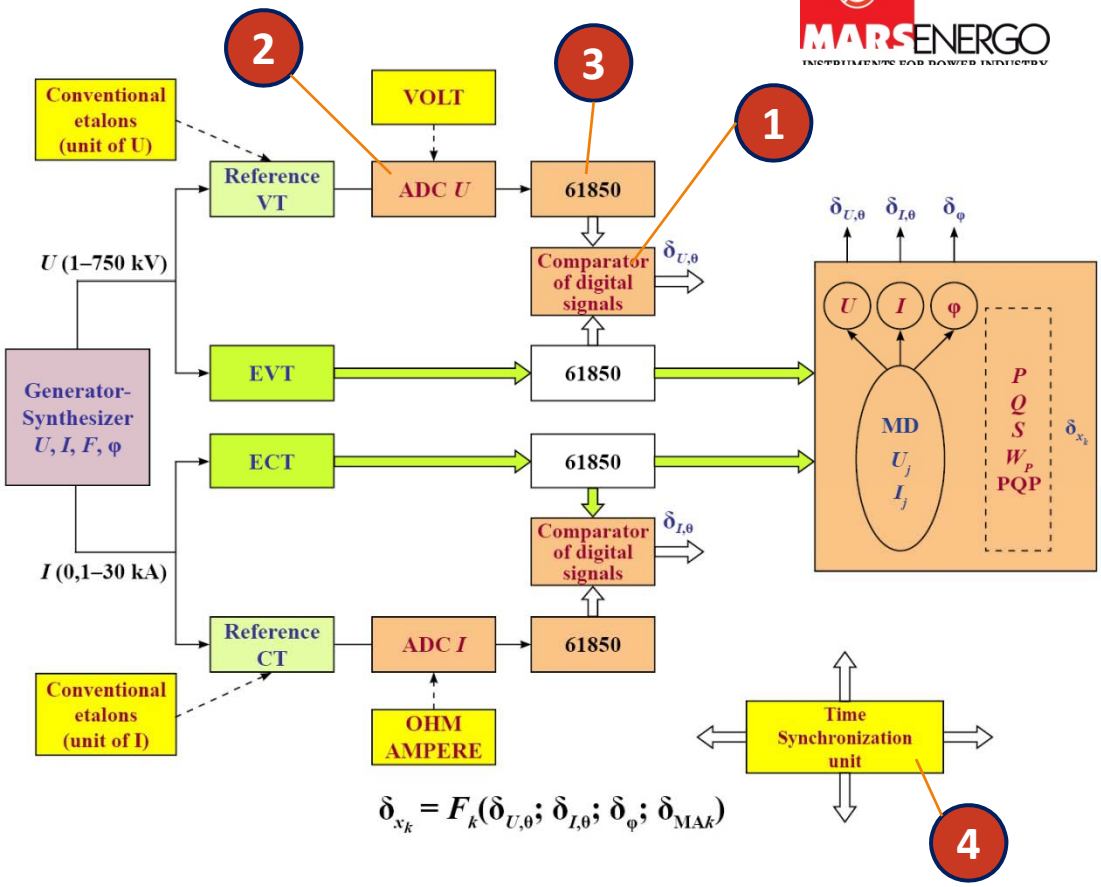
The purpose of Energomonitor 61850 is to:

- Measure voltage- and current-related quantities and convert measured values into digital streams determined by IEC 61850-9-2LE;
- Measure active and reactive power in single- and three-phase networks;
- Measure power quality parameters;
- Measure parameters of Phasor Measurement Units (PMUs);
- Measure ratio and angular errors of current and voltage scaling converters (transformers) either with analogue outputs or digital outputs per IEC 61850-9-2LE;
- Determine metrological parameters of SAMU (SAMU – Stand-Alone Merging Unit, IEC 61869-13) with analogue inputs of voltage and current.

Block diagram of a reference mobile system meant for testing/calibration of digital substation equipment based on Energomonitor -61850

Key components

1. **Comparator of digitized signals**
   Compares standard-compliant digital signals from the reference device and device under test.
2. **Reference ADC**
   Its own modular, angular and UTC synchronization error are precisely investigated.
3. **Digital code converter**
   Provides communications via **61850-9-2** protocol with time delays coordinated across measurement channels.
4. **Synchronization unit**
   Provides synchronization of measurements with UTC.



$$\delta_{x_k} = F_k(\delta_{U,\theta};\ \delta_{I,\theta};\ \delta_{\varphi};\ \delta_{MAk})$$

EVT — Electronic VT
ECT — Electronic CT
61850 — Digital code converter (IEC 61850)

Materials were prepared by VNIIM
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