



PROFOTECH
professional
fiber optic
technologies

Innovative metering solutions



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COMPANY INTRODUCTION

PROFOTECH JSC is a Russian integrated company – developer and manufacturer of special optical fiber, fiber instrument current transformers and complex intelligent solutions for digital substations.

- Since: December, 2010
- Shareholder: RUSNANO JSC
- HQ and Production line: Technopolis “Moscow”, Moscow, Russia
- R&D: “Skolkovo” Innovation Center, Moscow, Russia
- Personnel: high-professional specialists, engineers and scientists of Institute of Radio-engineering, Electronics Institute of Russian Academy of Science and Moscow Power Engineering Institute
- Products: Fiber-optic instrument current transformers and electronic voltage transformers (all voltage levels)
- Purpose: high-precision measurements in digital format according to IEC 61850-9-2 for digital substation equipment (commercial metering, relay protection, automation, etc.).



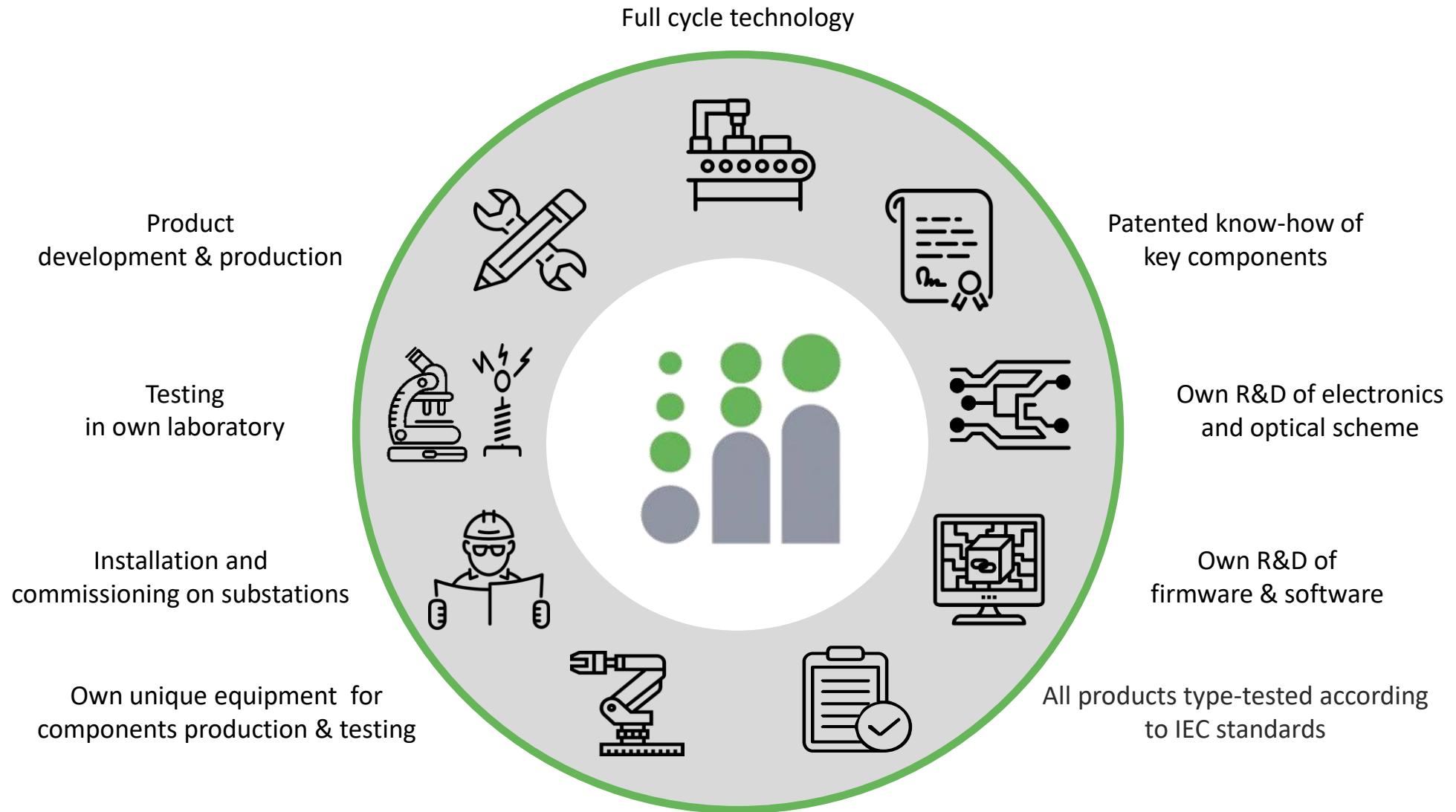
Technopolis “Moscow”



“Skolkovo” Innovation Center



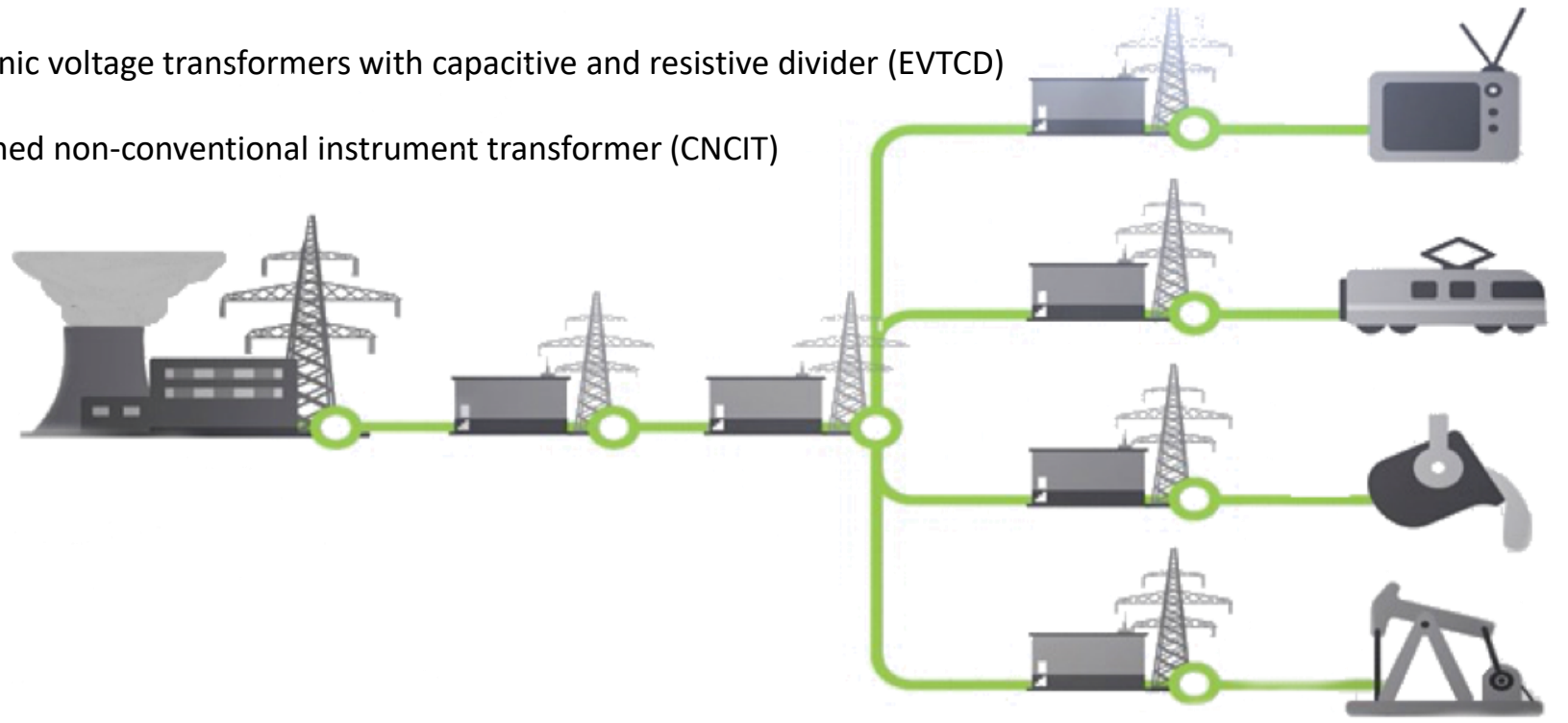
PROFOTECH VALUES



PRODUCTS

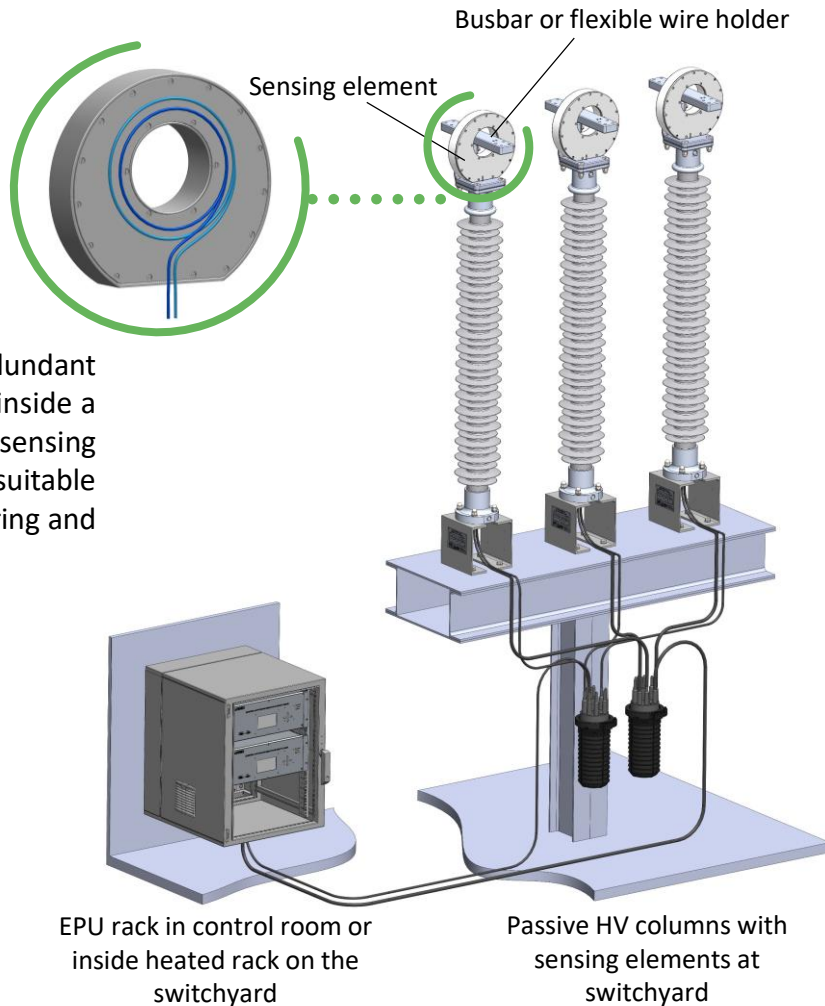
PROFOTECH provides various solutions for digital current measuring for protection, automation, revenue metering, quality control.

1. Fiber-optical current transformers for AC and DC applications (EFOCT)
2. Fiber-optical current transformers with flexible sensing element (EFOCT-F)
3. Fiber-optical current reference transformers (Ref. EFOCT)
4. Electronic voltage transformers with capacitive and resistive divider (EVTCD)
5. Combined non-conventional instrument transformer (CNCIT)



FIBER-OPTICAL CURRENT TRANSFORMERS for AC and DC applications (EFOCT)

EFOCT is designed for measurement of AC / DC / AC+DC current with highest precision at transients.



Independent redundant optical fiber coils inside a cover of sensing element: both suitable for revenue metering and protection

EFOCT consists of sensing elements, installed on variable design high-voltage insulator and Electronic Processing Units (EPU) connected by passive optical cable. For redundancy can be installed independent optical coil inside the cover and independent EPU connected by its own fiber cable.

Each phase acts as single-phase CT, no influence between phases.

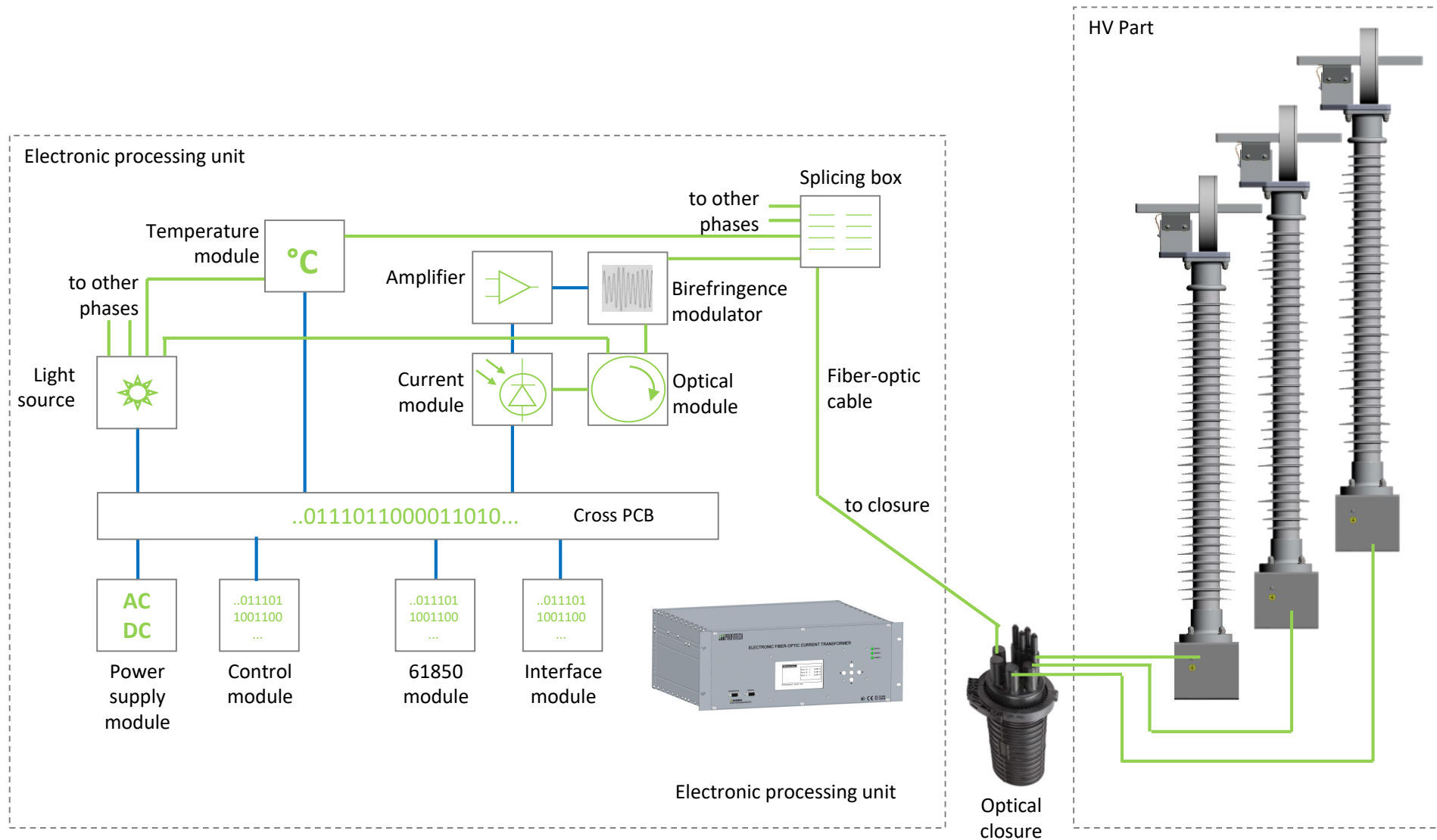
EFOCT generates digital stream according to IEC 61850-9-2 and/or IEC 61850-9-2LE standard.

| Parameter | Value |
|--|---|
| Rated voltage | 0 – 750 kV |
| Rated primary current | 50 – 190 000 AAC 100 – 460 000 ADC |
| Accuracy class | 0.2S (for measurements) 5TPE (for protection) 0.1, 0.05 (for precise measuring) 0.05% (opt. VT digitizing board) |
| Temperature range | +5..+40 EPU -60 .. + 60 Sensing element |
| Bandwidth (0dB) | DC – 5000Hz, Switchable 0dB filters at 70, 150, 500, 2500, 3000Hz |
| Dynamic short-cut current (measurable) | 200 kA |
| Time synchronization | 1PPS optical / TTL, PTP |
| Digital interface | 2 output pairs IEC 61850-9-2 1 output pair for MMS diagnostics |
| Digital interface redundancy | PRP on all ports |



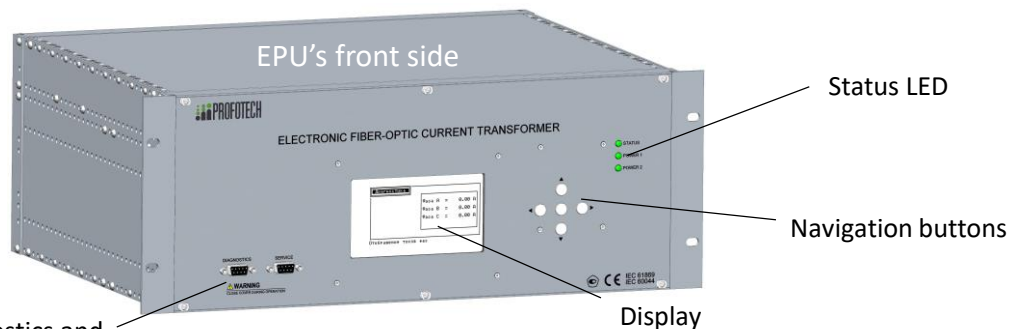
Transmission & distribution of electricity

EFOCT GENERAL SCHEMATIC

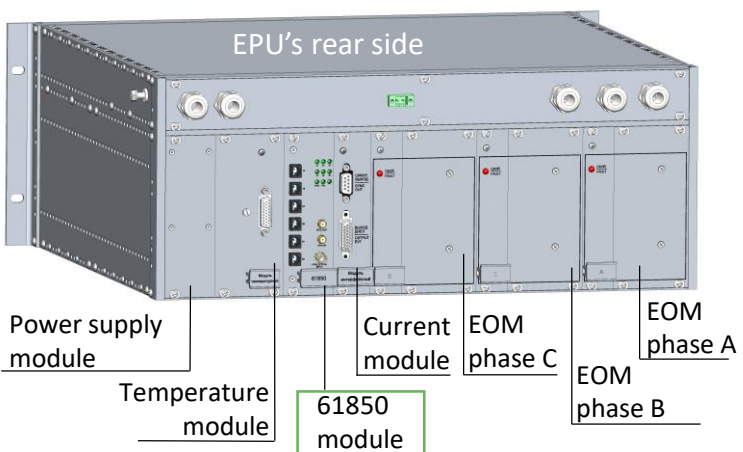


ELECTRONIC PROCESSING UNIT (EPU)

EPU contains all optical and electronic components required for full measurement function. Independently of type of optical sensor, voltage level and rated current all EPUs are unified. Each EPU fits revenue metering and relay protection classes at the same time.



Local diagnostics and service connection ports



EFOCT EPU has a modular structure. Usually it includes current measurement modules (one per each phase), temperature module, interface module and 61850 module. Optionally can be installed conventional VT digitizing board to provide full IEC61850-9-2LE stream without extra MU.

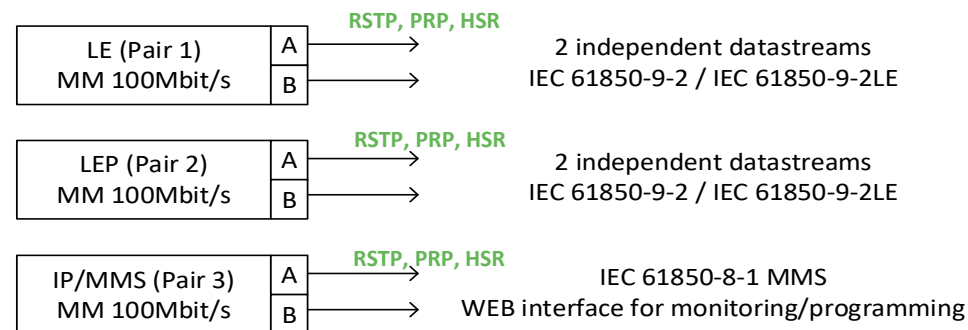
IEC 61850 module

61850 module is designed to operation as a part of EFOCT. This module provides precise timescale synchronized to master clock of the substation and converts digital signals received by internal bus from current measuring boards to the data streams in IEC 61850-9-2 standard.

Time synchronization provided either by IEC 61588 (PTP) or using 1PPS-signal.

| Type of time synchronization (<math><1\mu S</math> accuracy) | Recommended usage |
|--|---|
| 1PPS electrical (TTL) front/edge | Metrological (calibration) |
| 1PPS optical MM front (ST connector) + NTP on port pair 3 | Field applications |
| PTP v.2 ports pair can be selected: 1, 2 or 3 | Field applications with time server redundancy |
| Local | Setting up during installation on substation or simple projects |

IEC 61850 interfaces are MM 100 Mbit with MTRJ-F plug

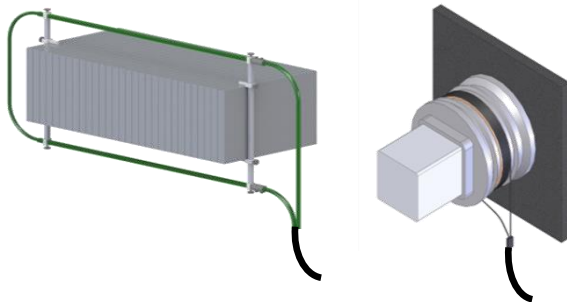


CURRENT SENSING ELEMENT

HV part is fully passive. Sensing element could be performed in 3 variations according to customer demands

FLEXIBLE for DC and AC applications

Flexible sensing element is wound around AC or DC busbar, HV cables, transformer bushings etc.



Mounted under potential $\leq 5\text{kV}$

BUSBAR

Sensing element is mounted on busbar. For voltages above 20kV fiber cables goes down through insulator. Design can contain optional holding insulator or can be mounted directly to the pole of the HV-switch.

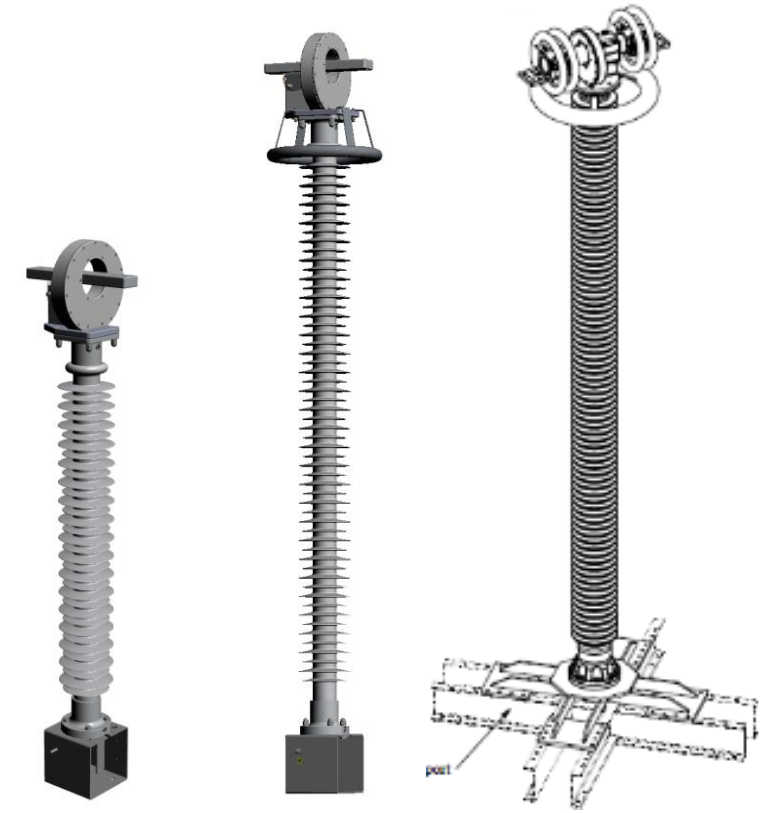


$\leq 20\text{ kV}$

35-750 kV

STAND-ALONE

Sensing element is installed on insulator filled with gel. Insulator is mounted on the pedestal for protection of cable coming out from bottom flange and secure mounting of HV column

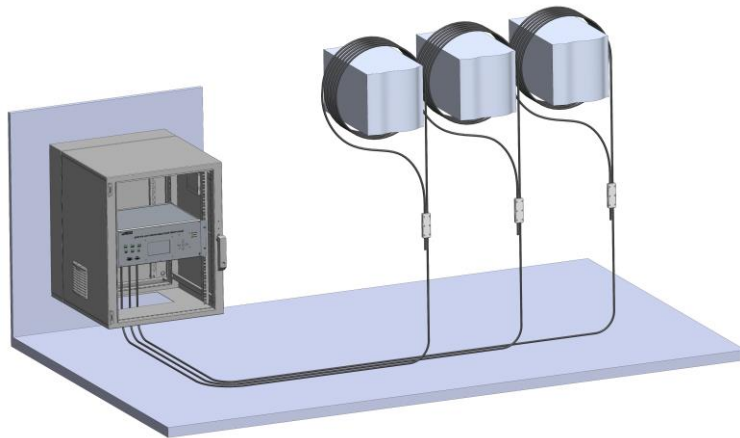


20-750 kV

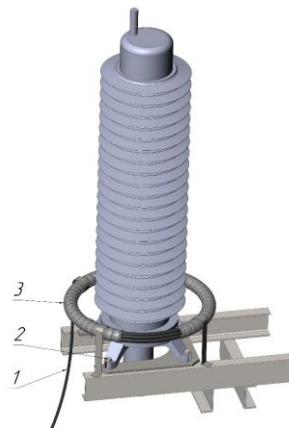
FLEXIBLE SENSING ELEMENT for AC and DC MEASUREMENTS (EFOCT-F)

Flexible sensing element (loop) is a compact sensor, that can be mounted around the primary conductor of any shape, without disconnection during installation

Flexible SE is based on an armored cable with PVC isolation with sensitive optical fiber inside. For installation on the busbar a special protective housing is used.



Example of EFOCT-F installation around the cable joint for complex protection of overhead power line



- 1 – EFOCT-F cable
- 2 – Assembly of cable fixture to the pedestal (located inside EFOCT circuit and can freely pass through the sensor if necessary)
- 3 – Dielectric cover for sensitive optical cable

- Versatility in the installation allows to implement a range of current protection cases
- Lack of saturation effect allows for the higher efficiency protection algorithms.
- Absence of oil in the structure and maintenance-free sensitive element lead to increased safety of personnel and infrastructure
- The consistently high accuracy of the optical CTs makes it possible to detect a number of phenomena inaccessible to electromagnetic CTs.
- Possibility of high sampling frequency for transients recording

| Parameter | Value |
|----------------------------------|---|
| Working principle | Faraday effect in special optical fiber, sensing element is a flexible cable |
| Rated Primary Current (AC or DC) | 1 000 – 400 000 A |
| Interface | IEC 61850-9-2LE (with PRP support), For DC: Modbus, 0-5mA, 0-20mA, etc. |
| Accuracy class | 0.05, 0.1 (ref. instrument) 0.2s (metering) 5TPE (protection) |



HVDC lines



Transmission and distribution of electricity



Generation



Industry, energy-intensive production

REFERENCE EFOCT-F

Ref. EFOCT-F is a mobile expert system for verification and calibration of CTs used for revenue metering of power with digital (61850-9-LE) outputs



- Uniquely high measurement accuracy, the ability to measure harmonic components up to 50th order
- Easy and flexible system scaling
- Automated workplace that allows you to track the results immediately in the test process
- Wide temperature range of the sensing element
- Significantly smaller weight and size parameters, ease of installation and operation
- Does not depend on external interactions (large magnetic fields, dustiness, gas pollution)
- Any geometry of the fiber-optic loop (sensing element) does not require precise positioning relative to the conductor
- Simplicity of installation, does not demand rupture of the busbar
- Convenient and easy to transport
- Can contain from 1 to 3 phases

| Parameter | Value |
|-----------------------|--|
| Rated voltage | Any existing models from 0 to 500 kV |
| Rated primary current | 1000 – 190000A Flexible 250 – 4000A Solid |
| Accuracy class | 0.1; 0.05 |
| Temperature range | -40 .. +60 (0.1%) 0 .. +60 (0.05%) |
| Interface | IEC 61850-9-2 |
| Options | Transient registration software Comparison with digital or analog signals |



Transmission & distribution of electricity



*Reference measurements
'CT calibration*



Generation



Industry, energy-intensive production



HVDC lines

EFOCT ADVANTAGES



- Digital signal processing and modern interfaces (compliance with IEC 61850)
- Standardization of the interface, the ability to connect devices from different manufacturers
- High measurement accuracy and dynamic range
- Extended temperature range allowing operation on the territories with harsh climates
- Full galvanic isolation, compliance with EMC requirements
- Ability to measure AC and DC
- One device covers up to 600% or rated current at 0.2S class



- Increase of operational safety for maintenance personnel
- Increase of secondary equipment safety due to the absence of high potentials at opening of secondary circuits
- Ability to connect devices from different manufacturers
- Smaller weight and dimensions, convenience of installation and operation
- Fire and explosion safety

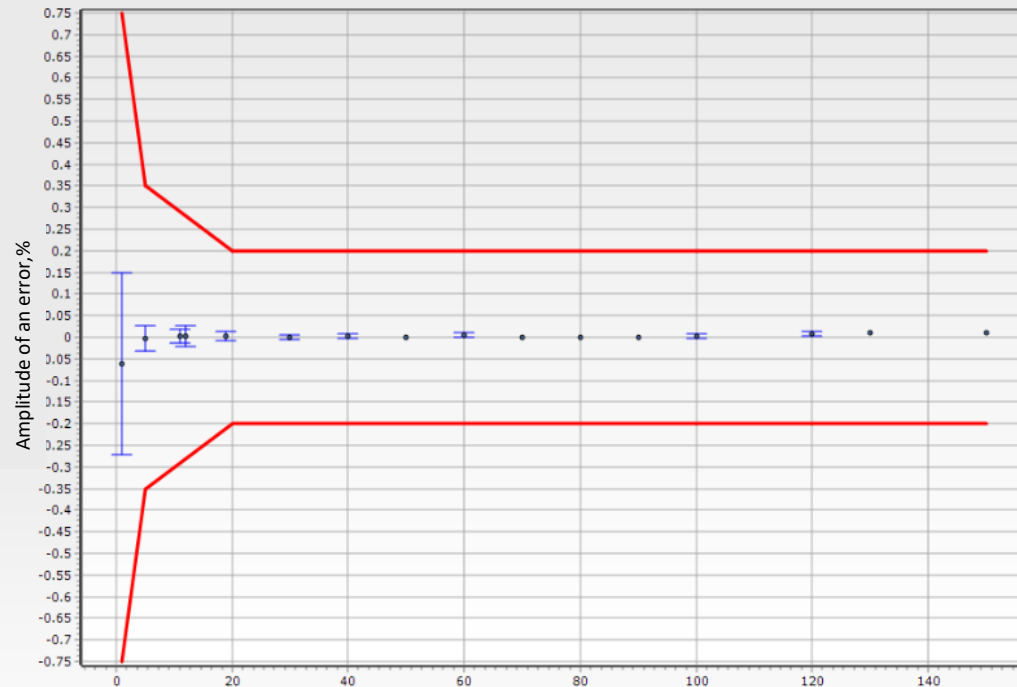





- Absence of copper secondary circuits, reducing the cost of materials and installation
- No risk of interruptions in power supply to consumers
- Reducing the costs of ongoing operation
- Price advantage comparing to world-known manufacturers
- High unification with spare parts reducing
- Service-on-demand diagnostics implemented

EFOCT ADVANTAGES




AMPLITUDE AND PHASE ACCURACY

High linearity characteristics



-  Border of amplitude error of optical CT
-  Border of admissible error accuracy class 0.2 as for GOST 7746-2001 and IEC 60044-8-
-  Amplitude of an error of optical CT



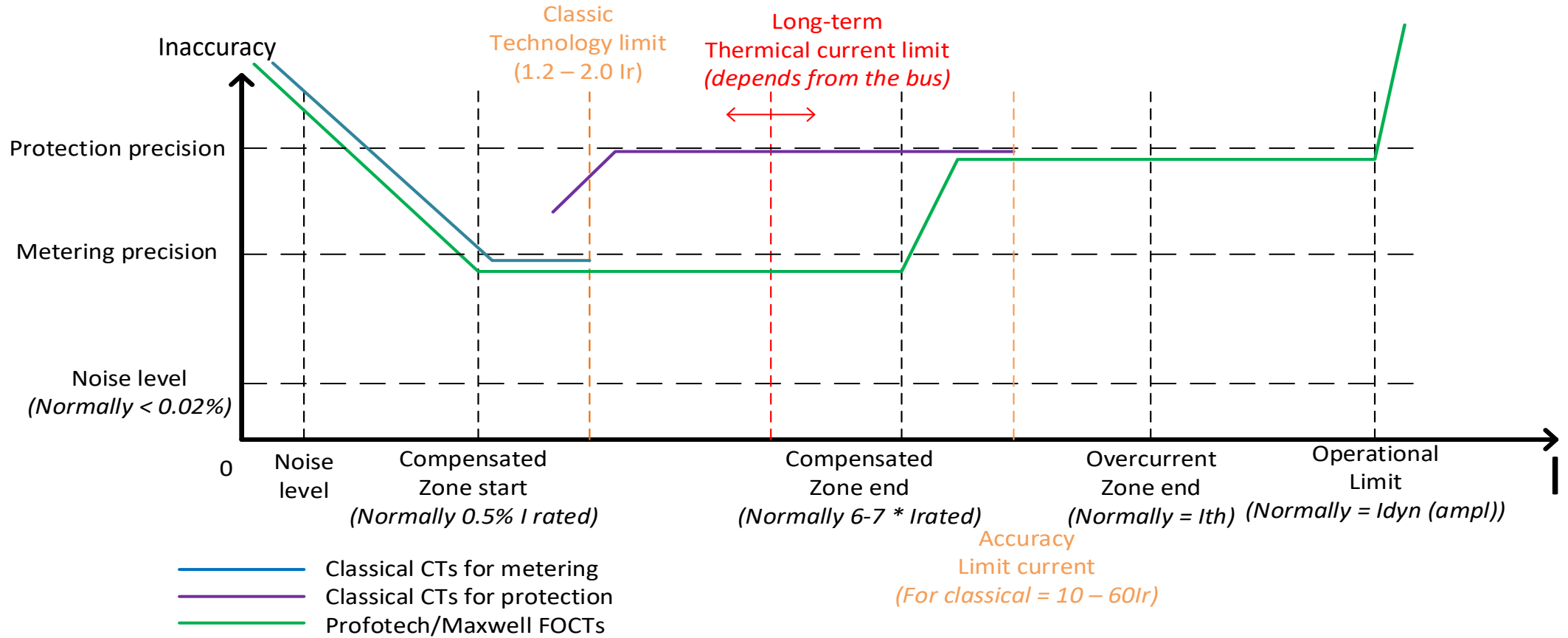
-  Border of amplitude error of optical CT
-  Border of admissible error accuracy class 0.2 as for GOST 7746-2001 and IEC 60044-8-
-  Amplitude of an error of optical CT



EFOCT ADVANTAGES

EXTENDING ACCURACY LIMITS

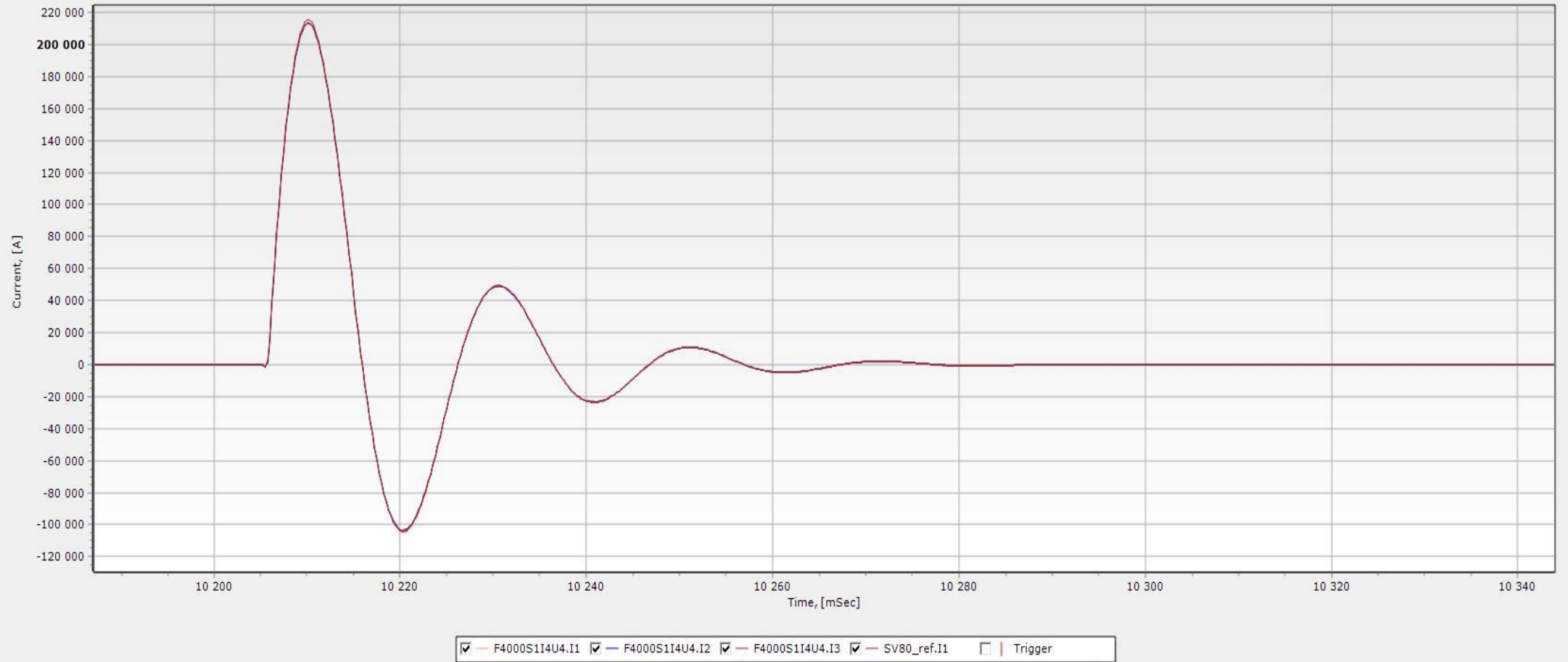
Dynamic range allows to use single measuring circuit





EFOCT ADVANTAGES

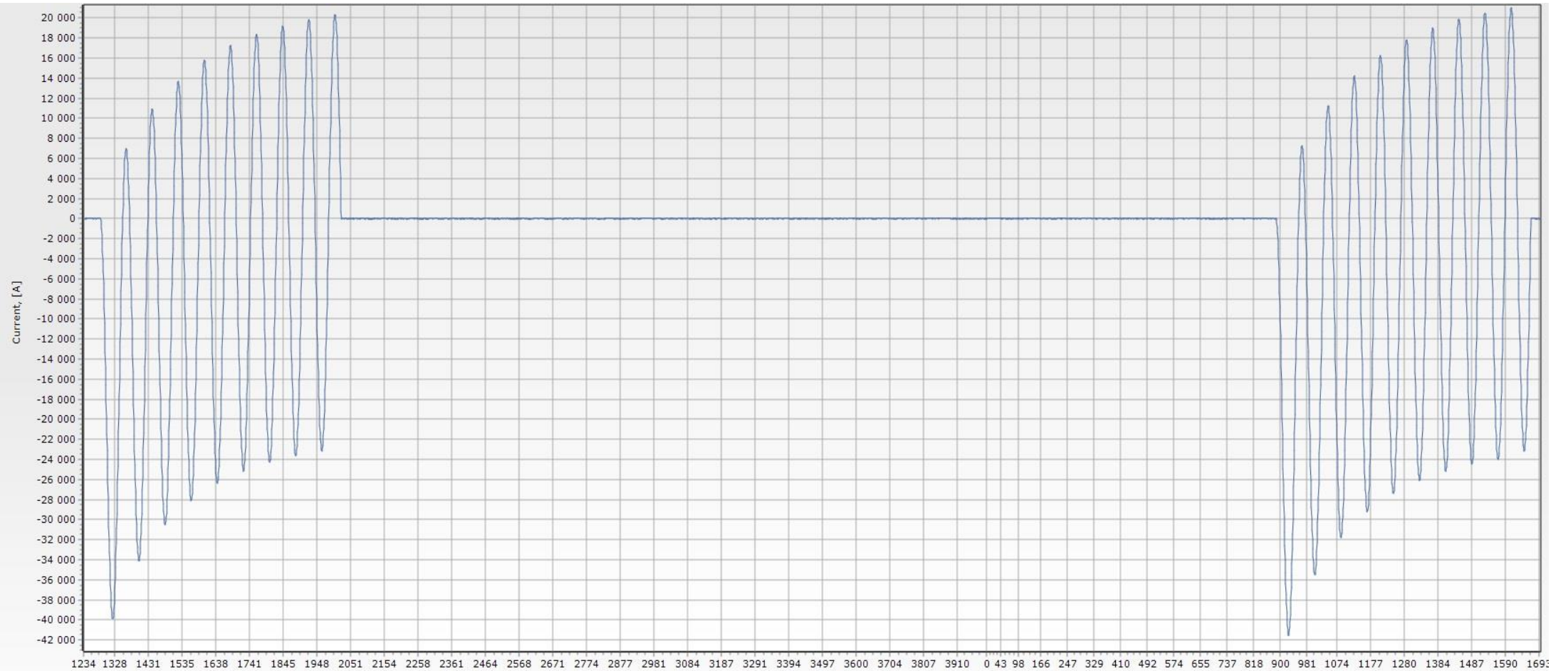
HIGH PRECISION AT TRANCIENTS
Full TPE-class compliance



EFOCT ADVANTAGES

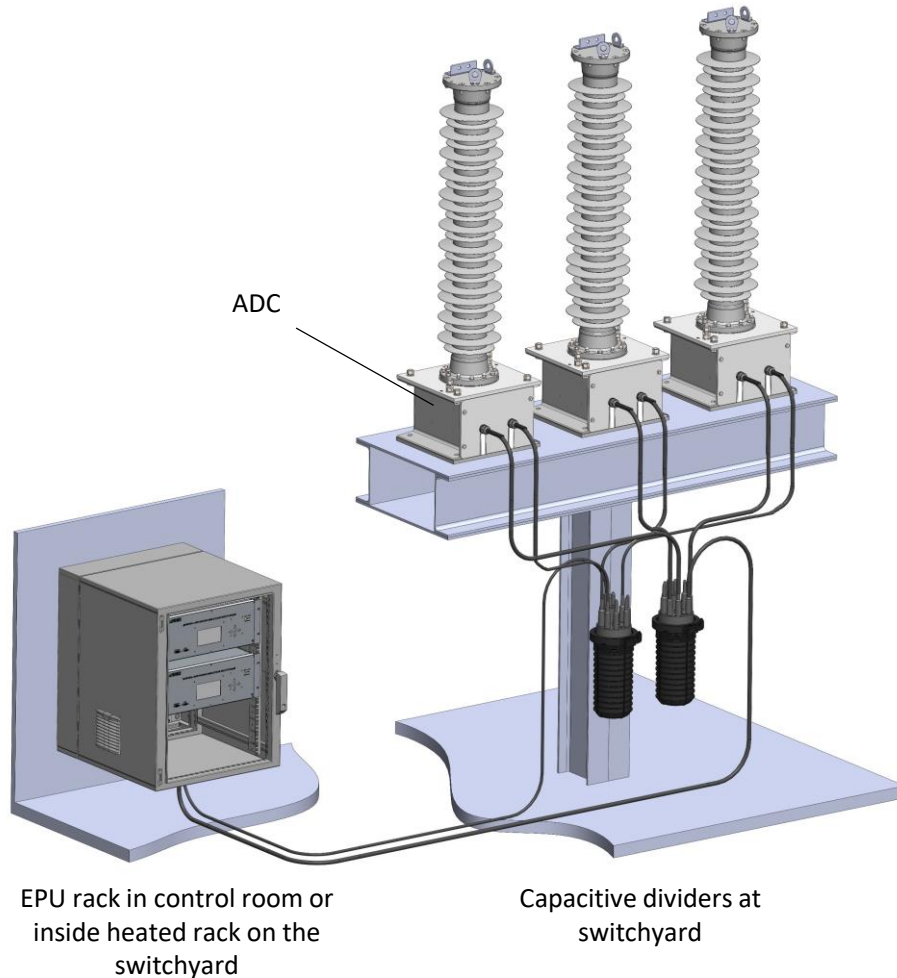
ABCEENCE OF FERRO-MAGNETIC CORE AND SHORT-CIRCUIT SATURATION

Correct work in C-O-C-O chains, no necessity for extra signal filtering via calculations



ELECTRONIC VOLTAGE TRANSFORMER WITH CAPACITIVE DIVIDER (EVTCD)

EVTCD is designed for scaling transformations of high voltage alternate current with grounded neutral to a low voltage AC.



EVTCD consists of capacitive dividers without inductive parts, installed on the pedestal with integrated ADC board and Electronic Processing Units (EPU) connected by optical cable.

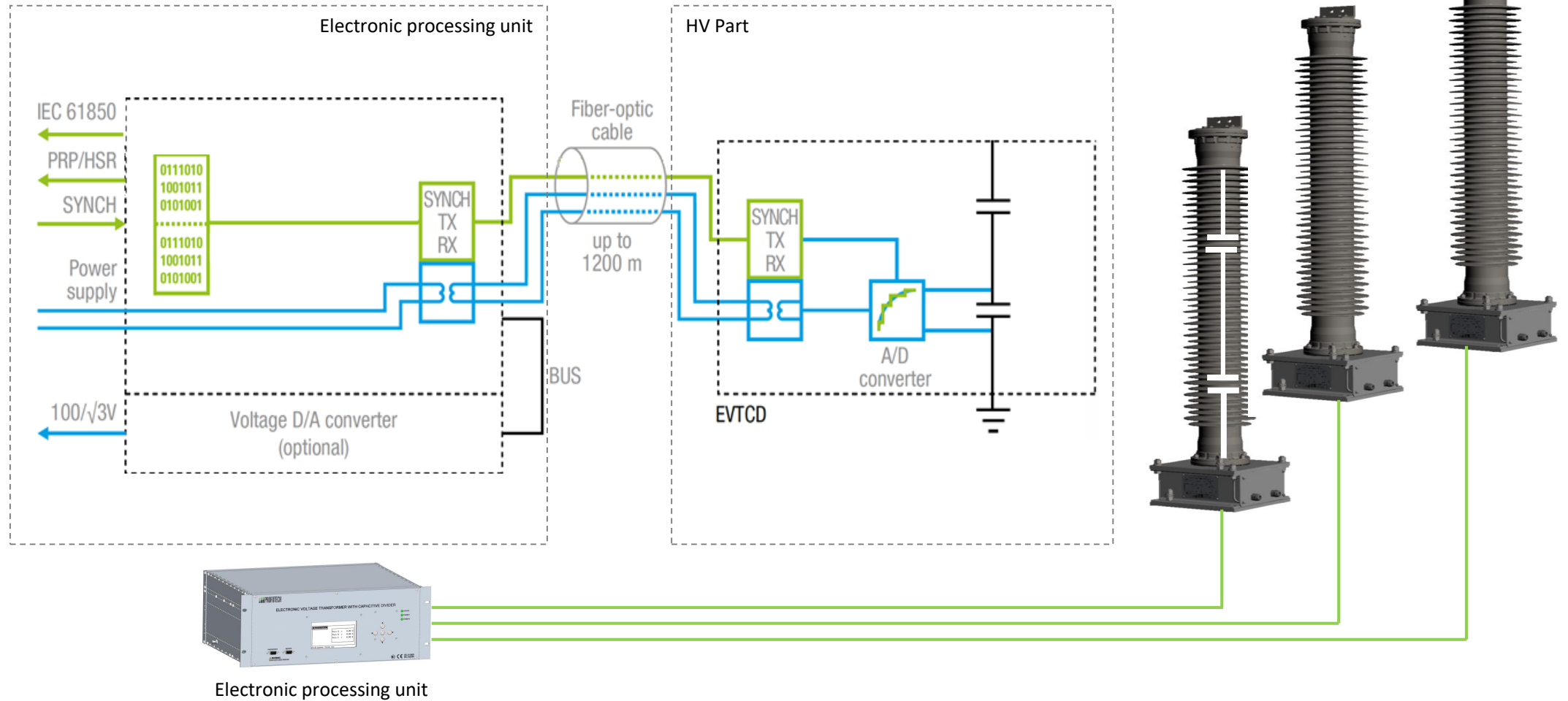
For redundancy can be installed independent ADC board inside the pedestal and independent EPU connected by its own fiber cable.

Each Phase acts as single-phase VT, no influence between phases.

| Parameter | Value |
|---|---|
| Rated voltage | 35 - 500 kV |
| Measured voltage range | 1 .. 190% U_r |
| Accuracy class | 0.2 (for measurements) 3P (for protection) 0.05% (VMU without column) |
| Temperature range | +5..+40 EPU -60 .. + 60 Sensing element |
| Bandwidth (0dB) with Capacitive Divider | 20 – 3000Hz, Switchable filters 70, 150, 500, 2500, 3000Hz |
| Time synchronization | 1PPS optical / TTL PTP |
| Digital interface | 2 output pairs IEC 61850-9-2 1 output pair for MMS diagnostics |
| Digital interface redundancy | PRP on all ports |



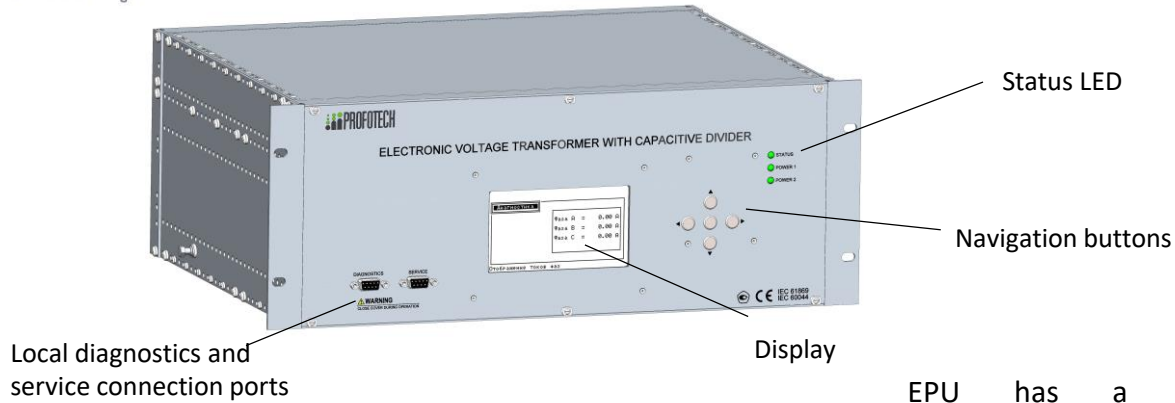
EVTCD GENERAL SCHEMATIC





EVTCD

EVTCD EPU measures and processes optical signals received from the three column ADC units



EPU has a module construction and includes a three-phase optical module, a voltage module, and a 61850 module.

Via the output ports of the 61850-9-2 module the digital packet of data on instantaneous voltage values and with quality flags is sent to secondary devices directly from the EPU.

Voltage dividers are intended for voltage step down to the safe level for the transformer's electronic components

RESISTIVE



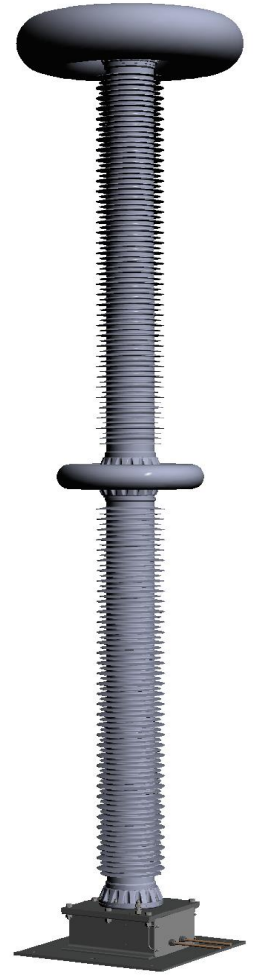
6-13 kV



100 - 145 kV



220 - 245 kV



550 kV

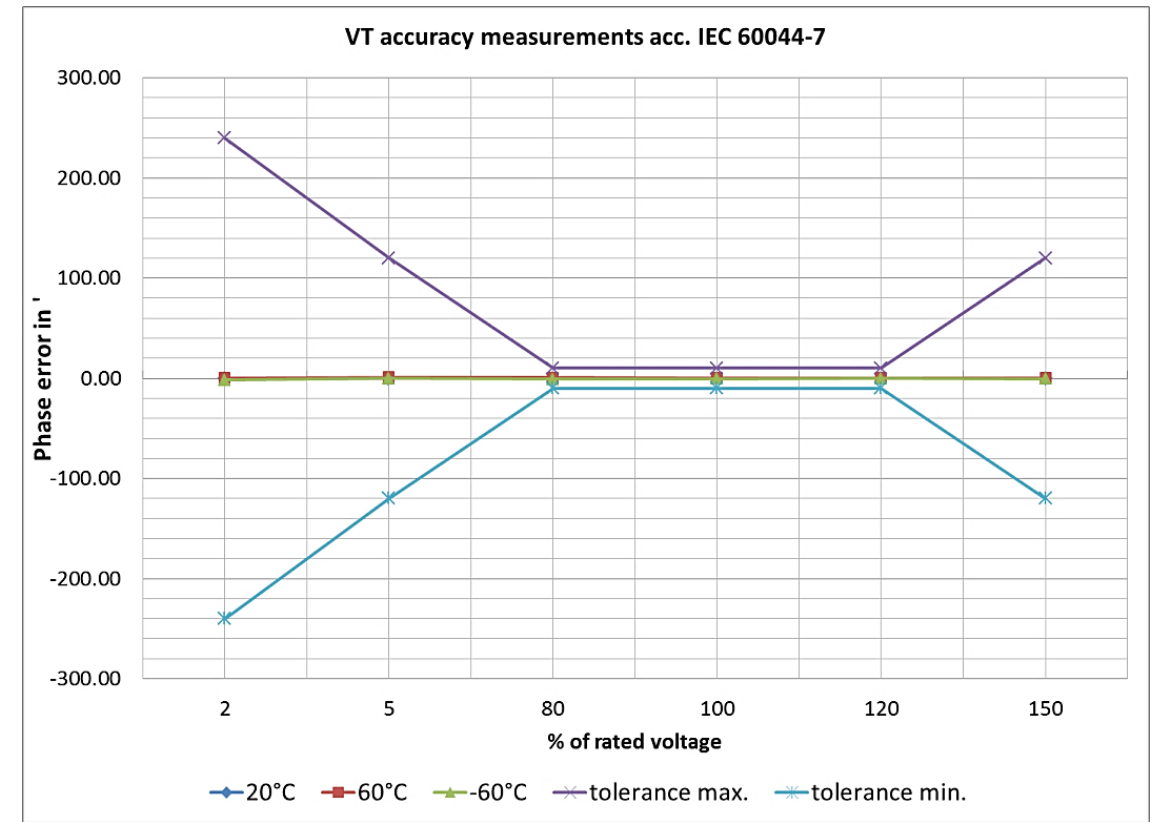
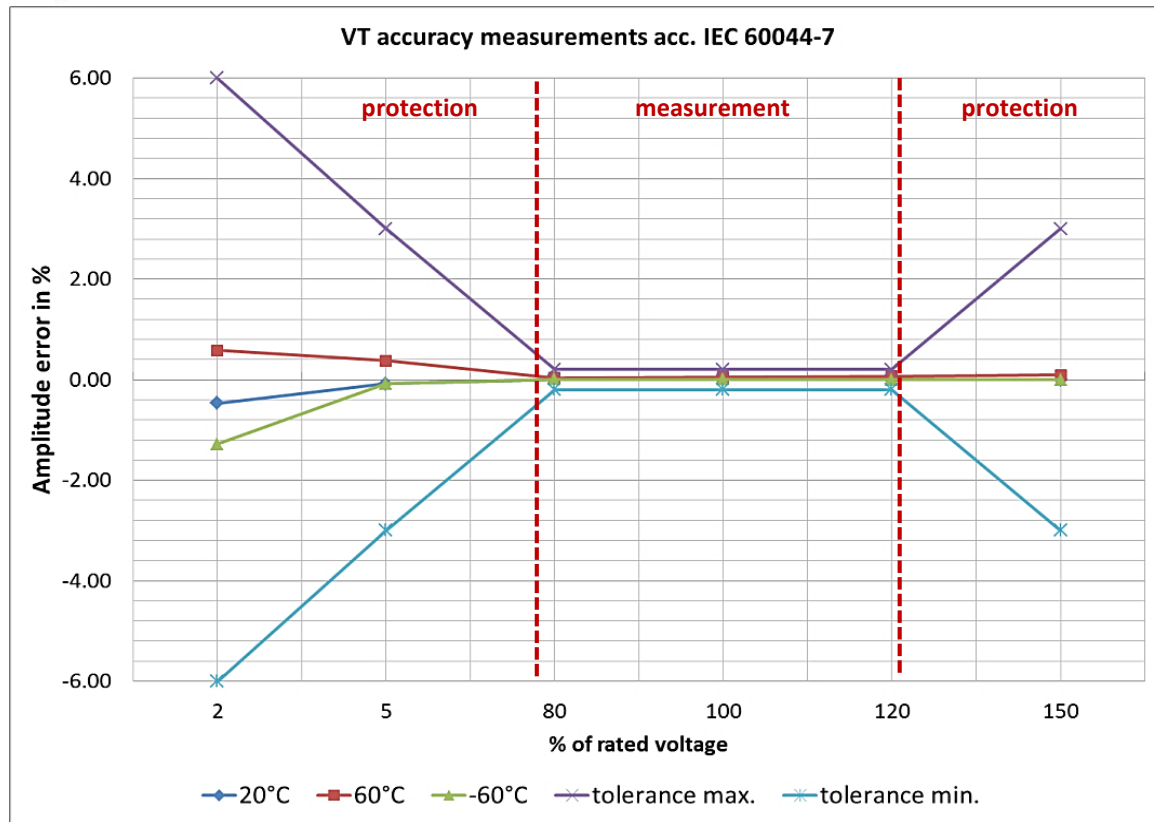
EVTCD ADVANTAGES

- Absence of inductive divider block, ferro-resonance free
- Avoidance of dangerous over voltages
- Absence of secondary networks of influence
- Wide voltage ranges 100-145kV, 200-245kV in the same dividers
- Temperature coefficient of the capacitance for amplitude and phase displacement are compensated
- Wide frequency range, can be used for power quality metering
- Wide temperature range -60..+60°C
- Each EPU suitable both for revenue metering and protection
- Can be combined by optical interconnection cable with any EFOCT and produce combined IEC 61850-9-2LE data stream
- Extra low oil weight (few kilo) – just inside capacitor packets
- Explosion and fire safe

EVTCD ADVANTAGES

LOW AMPLITUDE AND PHASE ERROR

Remains in the same accuracy class in a wide temperature range

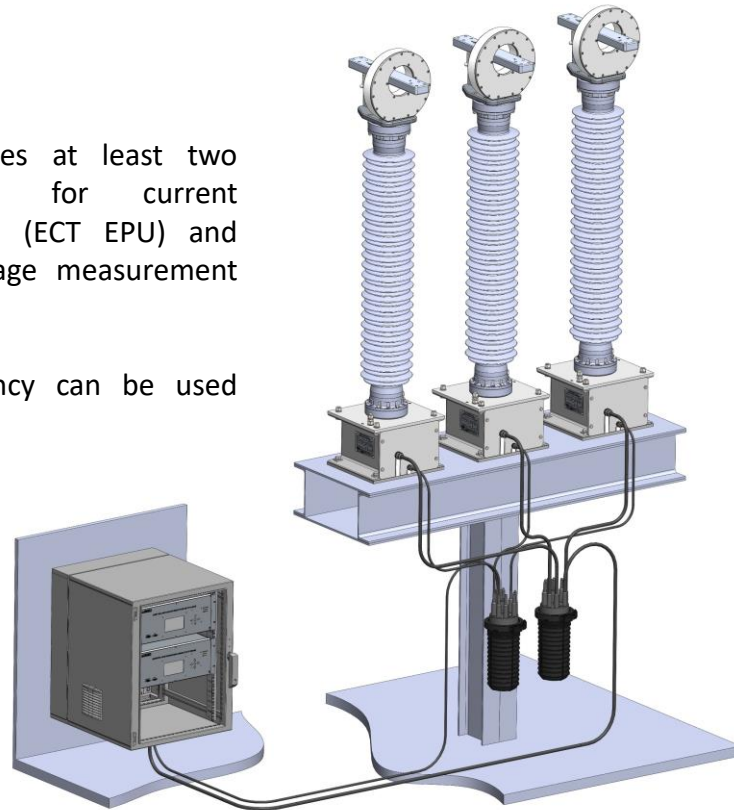


COMBINED NON-CONVENTIONAL INSTRUMENT TRANSFORMER (CNCIT)

CNCIT is a high-accuracy combined current and voltage transformer, which generates output signal according to IEC 61850-9-2 standard.

CNCIT includes at least two EPUs: one for current measurement (ECT EPU) and one for voltage measurement (EVT EPU).

For redundancy can be used extra EPU set.



EPU rack in control room or inside heated rack on the switchyard

Passive HV columns with sensing elements at switchyard

Joint Product with **CONDIS**

CNCIT consists of a combination of an optical current sensor (EFOCT), voltage sensor (EVTCD), fiber-optic cable, EPUs. There can be up to two sensitive loops inside SE case that are able to cover the full accuracy range required by the Customer's needs.

Optionally can contain built-in power and quality meter.

| Parameter | Value |
|-----------------------|--|
| Working principle | Current - Faraday effect in special optical fiber, Voltage - capacitive divider with ADC module |
| Insulation | silicon ribbons, mineral oil |
| Rated Voltage | 100-145 kV 200-245kV |
| Rated Primary Current | 200 – 4 000 A |
| Digital interface | IEC 61850-9-2 / IEC 61850-9-2LE (with PRP and PTP support) |
| Accuracy class | current - 0.2s (metering), 5TPE (protection) voltage – 0.2 (metering), 3P (protection) |



Transmission & distribution of electricity

COMBINED NON-CONVENTIONAL INSTRUMENT TRANSFORMER (CNCIT)

CNCIT EPU consists of two parts: ECT EPU and EVT EPU



ECT EPU

EVT EPU



ECT EPU measures and processes optical signals coming from sensing elements. Based on DSP of the EPU calculates the effective current value. ECT EPU has measured optical signal and modular structure. Usually it includes optical modules (one per each phase), temperature module and interface module.

EVT EPU carries out measurement and processing of signals coming from the measuring unit. The unit is of modular design and includes analog terminals unit, interface unit for communication with ECT EPU, and 61850 module for measurement data generation according to IEC 61850 standard.

In case of relay protection functions for current measurements, CNCIT can be completed with one or two ECT EPUs connected to the separate sensing coils located at the same SE housing.

In case of redundancy demand for voltage measuring could be installed the second EVT EPU with separate measuring modules for each phase.

HV column consists of a fiber-optical sensing element mounted on top of HV capacitive divider column

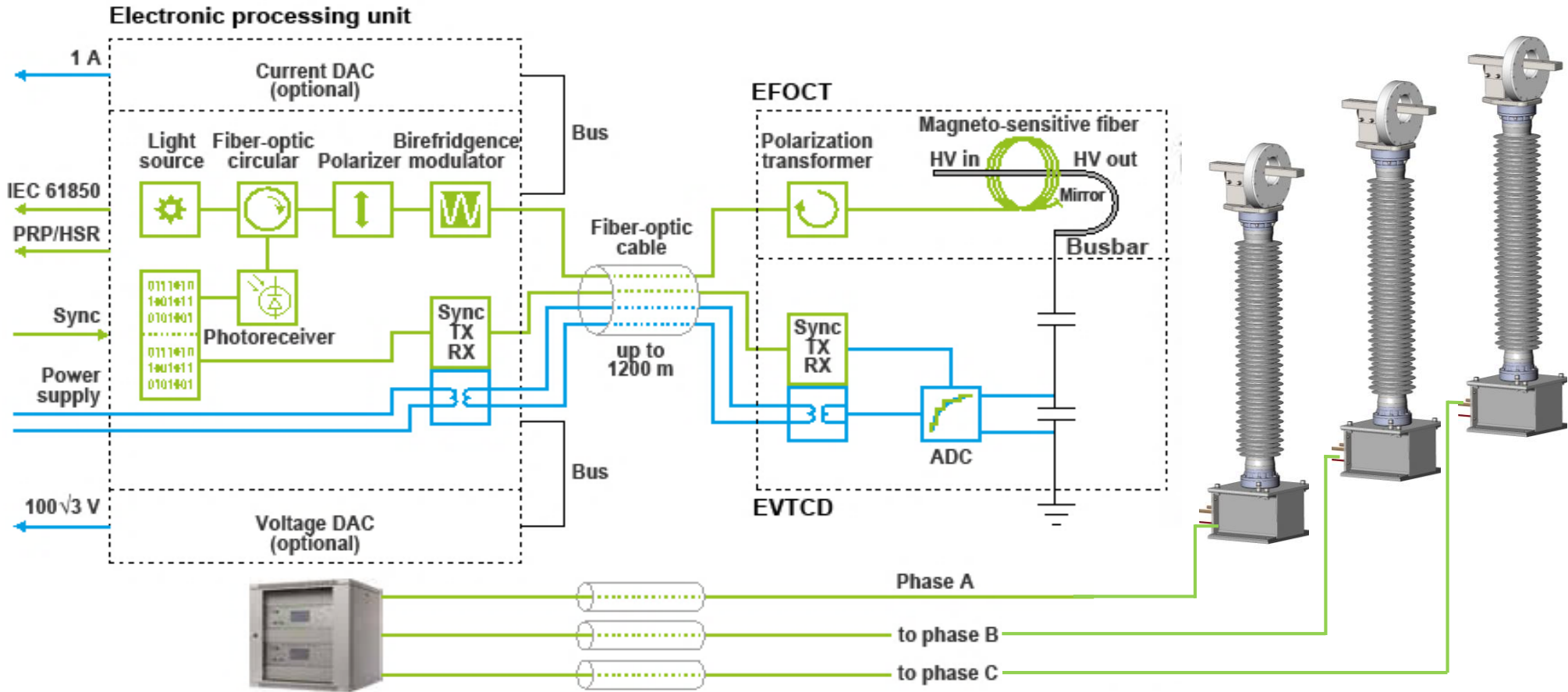


100 - 145 kV

200 - 245 kV

Capacitive divider column is installed on a basement, where measuring units are located

CNCIT GENERAL SCHEMATIC



CNCIT ADVANTAGES

- High measurement precision:
 - Voltage accuracy class 0.2 (meas.) / 3P (prot.)
 - Current accuracy class 0.2S (meas.) / 5TPE (prot.)
- Rated Voltage: 100-145, 200-245 kV (other upon request)
- Rated current: 250 – 4000 A (other upon request)
- Sensors with active temperature compensation
- “Arctic” design: applicable for wide service temperature range
- Reduced footprint and weight: only 1 column for both voltage & current measurement
- Ferro-resonance free because inductive part is replaced by optic sensor and electronic primary converter
- Ideal for revenue metering (is installed at the border of objects, voltage and current are measured in single point)
- Optional power and quality metering inside EPU

ITEROPERABILITY

Official tests for compatibility successfully passed with Secondary device vendors:

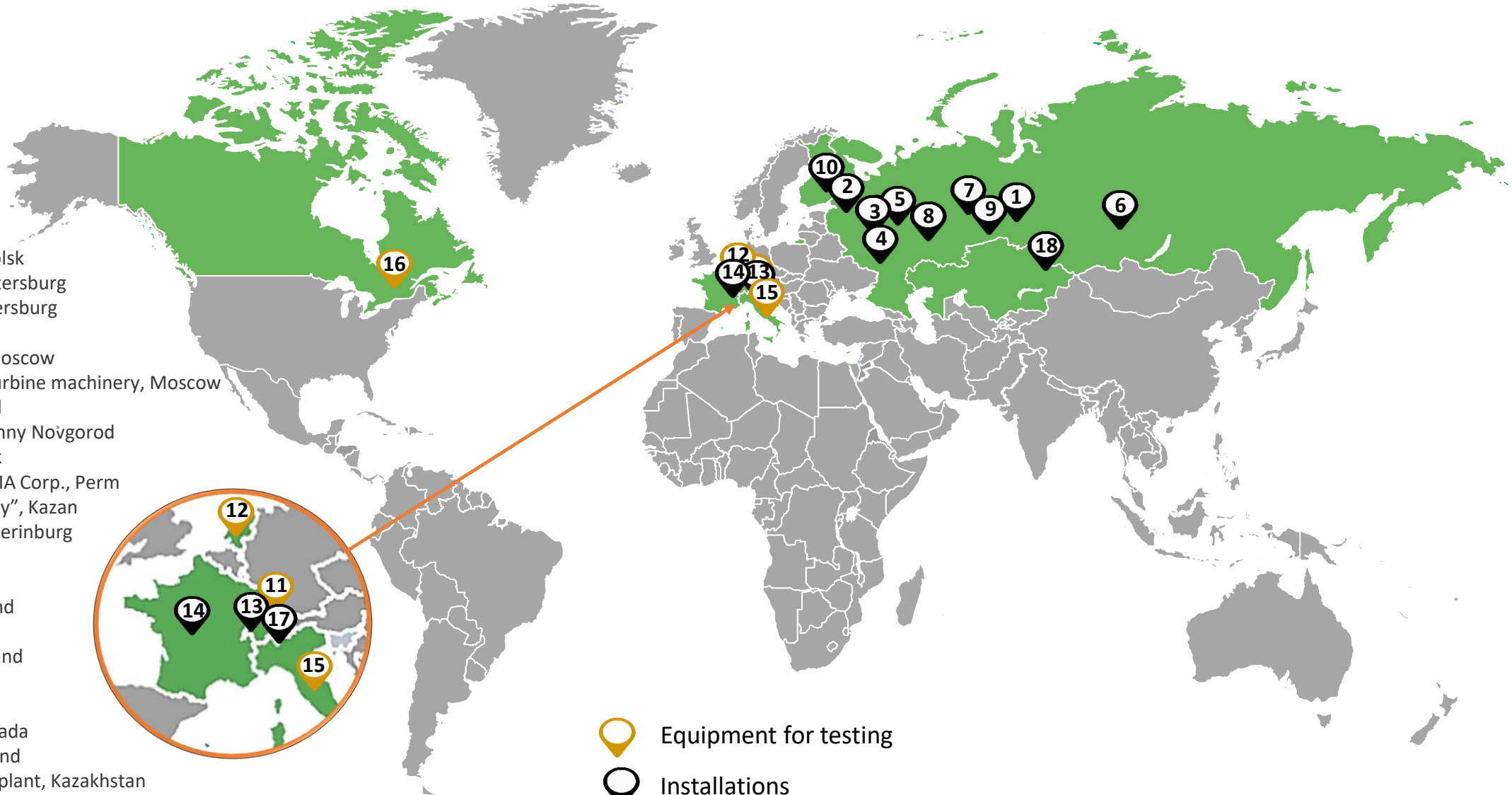
| VENDOR | DEVICE |
|-------------------------------------|---|
| Siemens | SIPROTEC 5 Protection terminal 7SL87 SIPROTEC 5 Fault recorder 7KE85 |
| ABB | 670LE2, REG 670, REG 650 Protection terminals |
| EFACEC | TPU L500 Protection terminal |
| Schweitzer Engineering Laboratories | SEL-421 Protection terminal |
| Nari Relays | NR PCS 902 |
| Landys&Gyr | ZMQ802C – Energy meter |
| EKRA | EKRA2704 Protection terminal |
| RELEMATICA | TOR-300 |
| PROSOFT | ARIS-EM Energy meter |
| Unitel Engineering | MP3-3 Protection terminal |
| General Electric | Alstom Grid MiCOM Agile P645 Protection terminal Installed on the pilot project, not tested officially |





REFERENCE PROJECTS

- 1 PJSC FGC UES, Tobolsk
- 2 PJSC Rosseti, St. Petersburg
PJSC TGK-1, St. Petersburg
- 3 JSC OEK, Moscow
PJSC Mosenergo, Moscow
JSC NPT Salut gas turbine machinery, Moscow
- 4 Transneft, Belgorod
- 5 PJSC RusHydro, Nizhny Novgorod
- 6 RUSAL, Krasnoyarsk
- 7 PJSC VSMPO-AVISMA Corp., Perm
- 8 OJSC "Grid Company", Kazan
- 9 FSUE "UNIIM", Ekaterinburg

- 10 Fingrid, Finland
- 11 Maxwell, Switzerland
- 12 DNV-GL, Holland
- 13 Groupe-E, Switzerland
- 14 EDF, France
- 15 Terna, Italy
- 16 Hydro Quebec, Canada
- 17 Swissgrid, Switzerland
- 18 Kazakh electrolysis plant, Kazakhstan












-  Equipment for testing
-  Installations

REFERENCE PROJECTS

Projects in Russia

| | |
|---|--|
|  | PJSK FGC UES , 2017-2018 - implementation of the Tobol-500kV project (its part). Supply of optical transformers (OT), performance of supervision works. |
|  | PJSC Rosseti, Lenenergo , 2017-2018 - implementation of a pilot project on the organization of a digital protection system using OT (as an element of the DSP). |
|  | JSC OEK , 2017-2018 - creation of an automatic reclosing system on a turnkey basis. |
|  | Transneft , 2017-2018 - implementation of DSP (its part) projects at Uvat (110 kV) and Desna (110 kV) s / s. Supply of optical transformers, carrying out chef-up operations. |
|  | PJSC TGK-1 , 2016-2018 - project implementation: "Modernization of the ASCUE system using optical transformers". |
|  | PJSC RusHydro , 2015-2017 - Implementation of the project CPS (its part) at the Nizhny Novgorod hydroelectric station. |
|  | PJSC VSMPO-AVISMA Corporation , 2017 - project implementation: "Creation of a direct current measurement system using optical transformers" (titanium production). |
|  | JSC NPT Salut gas turbine machinery , 2016 - project implementation: "Creating a system for measuring and protecting a generator using optical transformers". |
|  | OJSC "Grid Company", Kazan , 2015 - project implementation: "Creation of digital AISCs using optical transformers". |
|  | FSUE "UNIIM" , 2015 - project implementation: "Development and supply of reference flexible optical current transformer". |
|  | Mosenergo PJSC , 2012 - project implementation: "Creation of measurement points on generator leads using optical transformers". |
|  | RUSAL , 2011 - project implementation: "Modernization of a direct current measurement system using optical transformers" (aluminum production). |

Projects worldwide

| | |
|---|---|
|  | Maxwell (Switzerland) , 2018 - supply of current two-phase transformer for demonstration purposes in Europe. Status: equipment shipped; the first stage of the demonstration is completed. |
|  | DNV-GL (Holland) , supply of EFOCT-220 - 2 sets FOCT (500kV for outdoor test bay and Flexible for indoor test bay). Status: In operation since 2018. |
|  | Groupe-E (Switzerland) , installation of a set of combined current transformer and voltage transformer at substation open switchgear in Switzerland. Status: Equipment delivered; installation completed. In operation since 2017. |
|  | EDF (France) , test installation of one-phase set of combined current transformer and voltage transformer at substation open switchgear in France. Status: In operation since 2018. |
|  | Terna (Italy) , study on the compatibility of Profotech's current transformer at CESI for Terna's tender specifications for the future. Status: The terms of cooperation with Terna are agreed. Equipment shipped. Tests began at Q1 2019. |
|  | Hydro Québec (Canada) , comparative tests of Profotech's current transformer at IREQ during 2017-2018-2019 for the Hydro Québec tender specifications of Poste Saguenay pilot project. Status: 2 sets of equipment shipped in 2017 and 2019, qualification tests of first set successfully completed, the second set tests began at Q2 2019. |
|  | Swissgrid (Switzerland) , installation of 3 sets of 3-phase flexible optical current transformers at Chatelard substation in Switzerland. Status: Equipment delivered; installation completed. In operation since Q2 2019. |
|  | Kazakh electrolysis plant (Kazakhstan) , installation of XXX sets of flexible optical current transformers for DC measurement on refinery plant. Status: Equipment delivered; installation completed. In operation since Q2 2019. |
|  | Fingrid (Finland) , supply of a set 3-phase suspended OCT to Pernoonski "Digital Substation" 110kV project. Status: contract signed; delivery planned on Q3 2019. |



PARTNERS

CONDIS

- Partnership since 2016 (Joint Sales and Marketing Agreement signed)
- Development and production of bundled product - Combined current and voltage transformer (CNCIT)
- World-wide distribution of NCITs manufactured by Profotech labeled as Condis-Profotech
- Provision of commissioning and warranty services for Profotech's products outside Russia and CIS countries



- Partnership since 2018 (NDA and MOU signed)
- Key ability to deliver own plant HV technologies and equipment
- Proved interoperability of Profotech's OCT's with Efacec protection relays
- Cooperation in joint development and implementation of projects and compatible solutions for smart grid and digital substations based on IEC-61850

SIEMENS

- Partnership since 2016 (NDA and MOU signed)
- Research and testing of IEC-61850, IEC-61850-9-2LE compatibility with Siprotec5 family relays
- Cooperation on delivery of complex solutions for smart grids and digital substations with Profotech OCT's

SERVICES AND TESTING



Research & Development



Calibration and Testing



Repairs





Advisory


PROFOTECH has the only testing center in Russia that conducts:

- Calibration and testing of the current and voltage transformers, MUs, digital power and quality meters with the analog and digital (IEC 61850-9-2) outputs with the accuracy classes of up to 0,05;
- Calibration and testing of the voltage transformers of the levels of up to 220kV with the accuracy class of up to 0.1;
- Calibration and testing of the current transformers with the accuracy class of up to 0.05, rated current up to 190kA AC and 1380kA DC (for flexible current transformers);
- Calibration and testing of the current and voltage transformers, and other devices by the continuous cycle. Reproduced conditions: Temperature range -70 to +90 degC / Humidity 98% at 35-55 degC. Dimensions of operation capacity of a chamber 0.7x0.7x3.2m
- Compatibility tests of VT, CT, MUs and relay protection devices



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