Research Programmes
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Centre for Research
and Utilization
of Renewable Energy

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Research Programmes
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Brno University of Technology
Faculty of Electrical Engineering and Communication

Brno, April 2014

The main goal of the Centre is to concentrate significant research and development facilities for solution to issues of development, research and utilization in the areas of electrochemical sources of electric energy, hydrogen cells, electro-mechanic energy conversion, power and control electronics and sensors, and production of electric energy from renewable resources.

Centre for Research and Utilization of Renewable Energy (CVVOZE) is a research institute of the Faculty of Electrical Engineering and Communication at the Brno University of Technology. Implementation of the Centre is performed with the assistance of four faculty departments:

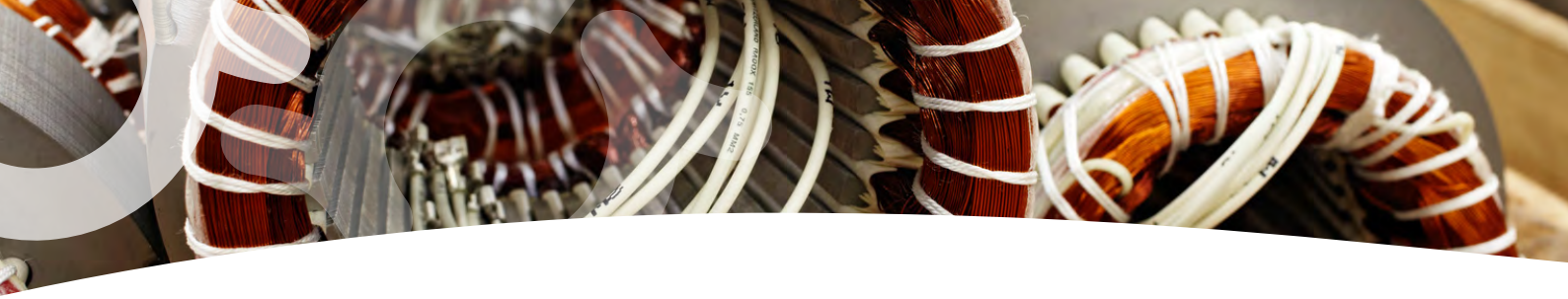
- Department of Power Electrical and Electronic Engineering
- Department of Control and Instrumentation,
- Department of Electrical and Electronic Technology
- Dept. of Electrical Power Engineering.

Scope of the Centre covers a broad spectrum of branches in the field of electrical engineering in connection with topical subject of renewable energy sources and their efficient utilization in manufacturing, transportation and the energy industry.
Research and development within the Centre is divided into three Research programmes:

- electromechanical energy conversion;
- chemical and photovoltaic energy;
- generation, transmission, distribution and use of electrical energy.

In the catalogue, each research programme is presented, including its main laboratories and equipment.

Contents



Research programme 1

→ Electromechanical energy conversion

Head of the research programme: **Prof. Frantisek Zezulka**
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This research programme is focused on optimization of current and development and optimization of new drive systems for electrical machines, electrical devices, power and control electronics, control systems and autonomous electric energy sources. Development of electrical machines for ecological transport is focused on increased efficiency of existing machines and development of novel conception machines, mainly machines with permanent magnets with radial or axial magnetic flow. Research on electrical drives is focused on utilization of modern types of signal processors. Other issues are development of sensors for electrical/nonelectrical characteristics and research in control and communication technologies for stability, reliability and safety of distributed sources of renewable energy.

Research topics:

- New technology trends in power electronics
- High-efficiency and reliability electrical drives
- Research and optimization of electrical drives with a minimal content of environmentally harmful materials
- Experimental energy network (E.E.S.) and Smart Metering
- Energy harvesting
- Safety and reliability of energy systems.

Laboratory of specific electrical machines

Head of the laboratory: **Assoc. Prof. Cestmir Ondrusek**
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Phone: +420 541 146 717

- Research and development of permanent magnet electrical machines
- Research of high efficient electrical machines
- Research of high-speed engines
- Research of electrical motors for hybrid vehicles
- Simulations of electrical machines dynamics
- FEM analysis of magnetic fields using ANSYS Maxwell
- Design and optimization of electrical machines using artificial intelligence
- Modelling of electrical machines using the method of equivalent circuits

Laboratory of automation and embedded systems

Head of the laboratory: **Prof. Frantisek Zezulka**
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Email: zezulka@feec.vutbr.cz
Phone: +420 541 146 440

- Research of Smart grid and Smart metering technologies
- Physical models of a Smart grid-based on experimental electrical network (EEN)
- Investigation of methods for EEN stabilization
- Research on methods for the optimization of EEN control
- Design and testing of EEN control algorithms
- Application of Internet weather forecast sources to predict power balance in EEN
- Consultancy in development of smart metering and smart grid systems
- Consultancy in development of island grid systems (transfer energy, storage energy in accumulators and hydrogen)
- Research and development of embedded systems for smart metering
- Development of embedded software for ARM, AVR, AVR32 microcontroller cores
- Development of software and hardware for wireless applications (Bluetooth, ZigBee, WiFi)
- Development of software and hardware for energy harvesting application and for power wireless transmission of electrical energy
- Developing applications for Windows and Windows Phone by .NET Framework
- Development of dynamic web applications (ASP and .NET), including design of small database system
- Development, technical assistance and testing of Safety application with PLC systems interconnected by Ethernet/IP industrial fieldbus
- Research and development of M2M communication for smart grids management
- Development of means and methods of monitoring the degree of environmental pollution and aerosol particles

Laboratory of measurements

Head of the laboratory: **Assoc. Prof. Petr Benes**
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- Calibration Laboratory
  - — Primary and secondary calibration of the acceleration sensors
  - — Calibration of the angular rate sensors (gyroscopes)
  - — Inertial MEMS sensors modeling
  - — Calibration of the temperature sensors
  - — Calibration of the Acoustic Emission sensors
- Testing Laboratory – testing of weather and mechanical resistance of mechanical and electronic products (vibration, temperature, humidity)
- Data acquisition, sensor design and sensor research, SW development, design of measurement systems, virtual instrumentation, HIL (Hardware-in-the-Loop) testing
- Vibro-diagnostic methods, machine health monitoring systems, noise measurement,
- 3D mapping, 3D scanning, inertial navigation

Examples of R&D projects solved within the Research programme 1

- **Application of VUT 001 Marabu for hydrogen fuel cells propulsion**

  Identification code: FR-TI1/061
  Principal Investigator: Assoc. Prof. Bohumil Klima
  Project start: Sep 1, 2009
  Project end: Aug 30, 2013

  Objective is to create environment for design and development of aircraft powered by fuel cells. Major project result will be verification of fuel cells propulsion of aircraft. Development of standalone fuel cells propulsion system is expected, with its further verification testing and integration into the small airplane. Existing VUT 001 Marabu airplane will be modified for integration of newly developed propulsion system. Practical verification of fuel cells propulsion onboard the aircraft will be done.

- **New series of pumps with lower energy intensity**

  Identification code: FR-TI3/011
  Principal Investigator: Prof. Vitezslav Hajek
  Project start: Feb 1, 2011
  Project end: Dec 31, 2014

  Main idea leading to the project solving was based on marketing investigation. Result of this marketing investigation is reduction of energy intensity of CNC machine. Main goal of the project is an industrial research and development of series of pumps for CNC machine with lower energy intensity. Consideration will be especially dedicated to research within the meaning of electromotors magnetic circuit optimisation in magnetic losses point of view and increasing hydraulic efficiency. The result of the project solution will be a modern pump on high technical level, which meets the customers' requirements at maximum rate.

- **Research and development of lightweight vehicles compact power axes series with an integrated electric-drive**

  Identification code: TA01011060
  Principal Investigator: Assoc. Prof. Pavel Vorel
  Project start: Jan 1, 2011
  Project end: Dec 31, 2013

  Project objective is research and development of compact, unsuspended power axes series with an integrated electric-drive. In project will be solved power axes with series of different power requirements, divided in categories according to max. speed: up to max speed 10 km per hr (typically used in lawn tractors) up to max speed 15 km per hr (typically used in handicapped persons vehicles) up to max speed 40 km per hr (typically used in municipal service vehicles or free time vehicles) During the development will be paid attention especially to costs price which is an important success factor on the market. Prototypes will be built to each of developed power axle version. Prototypes components will be supplied by subcontractors and assembled by EVEKTOR and FEKT VUT. According to time schedule will be produced 5 power axes prototypes which will be subjects of set of tests, such as functional test, driving cycle or durability test. Test results will be evaluated to verify required parameters.

- **Small electric motors with integrated electronic unit**
  Identification code: TA02010309
  Principal Investigator: Prof. Vitezslav Hajek
  Project start: Jan 1, 2012
  Project end: Dec 31, 2015
  Industrial research and development of small electric motors with integrated electronic unit. Project purpose is to investigate, propose and check possibilities to create a system of small electric machines with integrated electronic unit. It is assumed solution of magnetic circuit, possibilities of use of new materials and parts, solution of integrated electronic components, construction, technical preparation and making of samples and prototypes, measurement.

- **Research and development of mass flow meter**
  Identification code: FR-TI3/522
  Principal Investigator: Assoc. Prof. Petr Benes
  Project start: Jan 1, 2011
  Project end: Jun 30, 2014
  Research and development in the field of application Coriolis effect to project of mass flow meter, development, design and optimization elements of flow meter - measure pipeline, sensing and exciting system ,control unit, communication module. The project will be practically verified.

- **Research and development of small asynchronous motors from the aspect of optimization their efficiency**
  Identification code: FR-TI3/073
  Principal Investigator: Prof. Vitezslav Hajek
  Project start: Jan 1, 2011
  Project end: Dec 31, 2014
  Basic idea that leads to research and development is a reduction of waste and an increasing of efficiency of small asynchronous motors. The aim of this project is a research and development of small asynchronous motors that should achieve better and more optimal parameters, above all in the field of waste and efficiency. We suppose optimization of magnetic circuits by using new or different materials and technology. We will create design and technology documentation and according to this documentation we will produce the first functional samples and prototypes. They will be verified by measuring and testing including of type tests and operational tests.

- **Redesign of high voltage, high power synchronous generators**
  Identification code: FR-TI3/457
  Principal Investigator: Assoc. Prof. Cestmir Ondrusek
  Project start: Jan 1, 2011
  Project end: Dec 31, 2013
  The aim of the project is to design innovative family of high voltage synchronous generators, which will be competitive from the point of view of production costs, time delivery and the products will be able to fulfil all the requirements of customers especially those from a ship industry.

Research programme 2

→ Chemical and photovoltaic energy

Head of the research programme: **Prof. Jiri Kazelle**
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Phone: +420 541 146 191

This research programme is focused on research and development of new materials and conceptions for electrochemical current sources and operational layers for solar elements. An integral part of the research is investigation and verification of theoretical parameters of systems containing new types of materials. Research is also focused on selective absorber and radiator for thermal photovoltaic systems using thin optical layers. Research focused on diagnostics of photovoltaic cells and panels extends utilization of luminescence diagnostic methods for their analysis. Further issue is development of mathematical-physical models of electrochemical processes, heat transport in solar systems and processes on boundaries of thin optical layers.

Research topics:

- Research and optimization of conventional electrochemical power sources.
- Modern electrochemical power sources.
- Solar cells and panels – technology and diagnostic methods.
- Mathematical-physical analyses.

Laboratory of lead acid accumulators

Head of the laboratory: **Assoc. Prof. Petr Baca**
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Phone: +420 541 146 188

- Electrochemical analyses
- Capacity tests, long time cycle life tests
- Modes of operation: EV, HEV, traction and stationary applications
- Voltage, current, potential measurements
- Measurement of the surface temperature of electrodes
- Measurement of gas pressure in batteries
- Pressure measurement in an electrode system
- Measurement of components of internal cell resistance
- Development of new additives in the active mass of lead acid batteries
- Simulation of the charge distribution during discharge
- Research and development of electrolytes, electrode materials, laboratory electrolysers and fuel cells

Laboratory of chemical power sources

Head of the laboratory: **Assoc. Prof. Marie Sedlarikova**
Technicka 3058/10, 616 00 Brno
Email: sedlara@feec.vutbr.cz
Phone: +420 541 146 143

- Research and development of modern materials for low-temperature fuel cells with alkaline or polymer electrolytes
- Development of modern catalysts without platinum for fuel cells
- Optimization of catalysts and structures of fuel cell electrodes
- Research and development of materials for positive and negative electrodes of Li-ion batteries and for supercapacitors
- Formation of thin electrochromic layers either by electrodeposition or by vacuum deposition
- Research and development of electrode materials for Ni-MH and Ni-Zn batteries. Development of gel polymer and liquid aprotic electrolytes for Li-ion batteries and electrolytes suitable for alkaline batteries
- Development of new polymer membranes and separators designed for application in Li-ion, Ni-Zn and Ni-MH batteries

Laboratory of electrode materials

Head of the laboratory: **Assoc. Prof. Marie Sedlarikova**
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Phone: +420 541 146 143

The main field of research in this laboratory is oriented on investigation of electrode materials, liquid and polymer materials for modern electrochemical power sources.

Main fields of development:

- New materials with enhanced lifetime, capacity and safety of Li-ion batteries.
- Electrode materials for positive electrodes (based on $LiCoO_2$ or $LiFePO_4$) and materials for negative electrodes (based on graphite or titanium oxide).
- Alkaline batteries based on Ni-Zn principle – research focused on negative electrode and/or electrolyte.
- Liquid and gel polymer aprotic electrolytes.
- Preparation of current collectors (supports) of active masses, their deposition, new membranes, separators and electrolytes.
- Development and testing of electrode materials and aprotic electrolytes for batteries and supercapacitors.

- Mainly used techniques follows:
  - — Cyclic voltammetry.
  - — Galvanostatic cycling.
  - — Impedance spectroscopy.
  - — Method EQCM for observation of mass changes occurring in electrode substance.

Laboratory of photovoltaics

Head of the laboratory: **Assoc. Prof. Jiri Vanek**
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Phone: +420 541 146 122

- Study of the photovoltaic effect and the development of solar cells and modules diagnostic metohods.
- Diagnostics of defects in solar cells using an advanced LBIC (Light Beam Induced Current) method.
- Electroluminescent method of detecting defects in solar cells and modules.
- Photoluminescent method of detecting defects in the solar cells.
- Thermovision diagnostic of the solar system and modules.
- Testing of photovoltaic system (autonomous photovoltaic systems).
- V-I characteristic of photovoltaic cells and modules by the STC (standard testing condition) and in real condition.

Laboratory of microscopy

Head of the laboratory: **MSc. Petr Cudek**
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Phone: +420 541 146 132

- Material properties by scanning electron microscopy, environmental scanning electron microscopy and atomic force microscopy techniques are diagnosed in the laboratory. Low-vacuum scanning electron microscope VEGA 3 XMU with LaB6 cathode from TESCAN Brno Company and atomic force microscope 5500 SPM from Agilent Company are installed the laboratory.
- All electrotechnical materials are diagnosed in laboratory focusing on materials for electrochemical power sources. Also the profilometric measurement of very thin layers are observed in the laboratory.

Examples of R&D projects solved within the Research programme 2

- **Improvement of security of lithium ion batteries**
  Identification code: GAP102/10/2091
  Principal Investigator: Assoc. Prof. Marie Sedlarikova
  Project start: Jan 1, 2010
  Project end: Dec 31, 2012
  Fire resistance of lithium ion batteries shall be improved by modification of the electrolyte. The organic solvents will be replaced by solvents with higher flash point and the polymers by polymers with lower rate of burning. Necessary properties of the final electrolytes will be investigated such as conductivity, potential window, compatibility with both positive and negative electrodes, formation of passivation films on negative electrode, freeze resistance and other electrochemical and technological properties. Sulfolane and polymers containing silylgroup in side chains will be the first choice. Flame retarders will be checked.

- **Research of new electrodes of alkalic accumulators**
  Identification code: FR-TI3/198
  Principal Investigator: MSc. Miroslav Zatloukal
  Project start: Jan 1, 2011
  Project end: Dec 31, 2012
  The project is oriented to a new generation of electrode materials designed for alkaline batteries. The objective is to produce a functional sample of a Ni-Zn electrode possessing high parameters which will bring low cost in relation to the energy accumulated in the battery and good competitiveness. The technology of manufacturing of Ni alkaline systems with lowest requirements on maintenance throughout the whole lifetime of the accumulator will be verified.

Research programme 3

→ Generation, transmission, distribution and use of electrical energy

Head of the research programme: **Assoc. Prof. Petr Toman**
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Phone: +420 541 146 200

The major targets are research and development of new facilities for electric energy distribution with enhanced energy-ecological parameters leading to increased reliability of electric energy supply, research and optimization of operation of electric energy sustainable sources in energy mix, safety of electrical networks and facilities, increased efficiency of generation and distribution of heat and cold including cogeneration and trigeneration, optimization of energy management of buildings, smart active networks including accumulation and new diagnostic and measuring power electrical methods.

Research topics:

- Novel concepts and strategies of power systems management.
- Smart active distribution networks.
- Safety of electrical networks.
- Electronuclear transmutation technologies.
- Cogeneration, trigeneration and energy management of buildings.
- New technologies for lighting installations.
- Diagnostics of the switching process in real-state network and results implementation in mathematical model.
- Calculation of electric arc plasma composition and basic thermodynamic and transport properties.
- Mathematical-physical modelling of the energy radiation iprocess in electric arc plasma and its utilization in numerical models of arc behaviour during the switching process.

High Voltage Laboratory

Head of the laboratory: **Assoc. Prof. Jaroslava Orsagova**
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Phone: +420 541 146 224

- Dielectric tests in accordance to IEC 60060-1
- AC withstands voltage tests
- Lightning and switching impulse tests
- Disruptive-discharge voltage tests of insulators
- Cable insulation breakdown tests
- Partial discharge diagnostic in accordance to IEC 60270
- Insulation diagnostic on transformers and cables
- Measurement of residual voltage of surge arresters

Laboratory of switchgear

Head of the laboratory: **Assoc. Prof. Jiri Valenta**
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Phone: +420 541 146 733

Laboratory is designed for AC and DC heavy current tests of low voltage switchgear.

- Standard short-circuit tests of low voltage devices up to 150 kA
- Short time current withstand tests up to 40 kA / 3 s
- Switching arc research and disagnostics

Parameters of AC tests:

AC 50 / 60 Hz - 200 ms:

- 150 kA / 250 V
- 100 kA / 500 V
- 60 kA / 750 V
- 40 kA / 1000 V

AC 50 / 60 Hz - 3 s:

- 40 kA / 100 V

AC 16 2/3 Hz - 200 ms:

- 50 kA / 1000 V

Parameters of DC tests:

- 50 kA / 1000 V - 200 ms ($\tau \leq 30$ ms).

Tests comply with appropriate IEC, GOST and UL standards, e.g.

- IEC 60947 Low voltage switchgear and controlgear
- IEC 60269 Low voltage fuses
- IEC 61439 Controlgear and switchgear
- UL 489 Molded case circuit breakers
- GOST-R 50030 Low voltage switchgear

Laboratory of unconventional energy sources and solar laboratory

Head of the laboratory: **Assoc. Prof. Petr Mastny**
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Email: mastny@feec.vutbr.cz
Phone: +420 541 146 213

Key activities:

- Non-destructive diagnostics of Peltier cells.
- Development of thermoelectric generator design.
- Cooperation of power sources in the combined systems (PV, VTE).
- Usage of thermoelectric converters for measuring temperature dependences of measuring devices.
- Optimization of RES.
- Research in the accumulation of large amount of electrical energy (hydrogen).
- Study of the properties of oxidation-reduction cycles to accumulate power in the electrolyte (VRB - flow batteries).
- Development of a comprehensive diagnostic -monitoring system for renewable energy sources (PV and VTE - Savonius, Darvius).
- Research in application of modern control systems for the management of RES.
- Research in possible implementation and operation of RES within system technology of buildings and family houses.
- Research in accumulation of thermal energy (PCM substances applications).
- Diagnostics of the operating characteristics of photovoltaic panels.
- Testing of photovoltaic generators in real operating conditions.
- Testing the usability of different types of mirror concentrators.
- Study the influence of spectral compound of solar radiation, depending on meteorological conditions.
- Research and development of hybrid systems with photovoltaic electricity accumulation.

Laboratory of lighting technology

Head of the laboratory: **Assoc. Prof. Petr Baxant**
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Phone: +420 541 146 212

Key research activities:

- Conventional and special analysis of light and technical parameters of light sources and luminaires.
- Precise radiometry and spectrophotometry.
- Calibration of digital cameras for luminance analysis purposes (selected types of devices).
- Development and production of special difference filters for digital camera lenses for correction of photometric quantities.
- Alternative measuring methods in photometry with emphasis on use of digital photography.
- Progress in development of own software applications for measuring and data processing.
- Low consumption light sources (LED, discharge lamps, induction light sources, using of lightpipes, optical fibres).
- Development of phytotron chambers with low energy consumption.
- Development of software and applications for measuring and data processing (Luminance analysers, UGR measurement).
- Development of software for evaluation of large data files from measurements.
- Measurement of photometric parameters of luminaires, luminous intensity curves, efficiency, evaluation of luminance characteristics.
- Measurement and evaluation of lighting systems with emphasis on use of luminance analysis and digital photography.

Electrical protection laboratory

Head of the laboratory: **Assoc. Prof. Jaroslava Orsagova**
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Key research activities:

- Method for earth faults localization and elimination.
- Method of additional earthig of faulted phase and evaluations its influence on distribution network safety.
- Research of earth fault localization method based on the real network experiment data analysis.
- Earth fault location using present control and monitoring systems via novel protection algorithms implemented in compliance with Smart Grids philosophy.
- Improvement of distribution network protections algorithms using IEC61850 communication. Testing and commissioning of digital protection with IEC61850 communication.
- CTs and VTs testing.
- IED protection function tests: overcurrent, differential, distance, directional and nondirectional earth fault, autoreclosing, synchro-check.
- Testing of energy meters, PMU (Phasor Measurement Unit) and MU (Merging Unit). Development of Merging Unit and software for Sampled Value analysis in accordance to IEC61850-9-2.
- Measuring of overhead line parameters.

Examples of R&D projects solved within the Research programme 3

- **Dynamic model of distribution network**
  Identification code: TA03020523
  Principal Investigator: Assoc. Prof. Petr Toman
  Project start: Jan 1, 2013
  Project end: Oct 31, 2015
  Questions of distribution network operation in grids with high penetration of renewable sources especially photovoltaic cells and wind turbines are very actual problem. There are very stochastic curves of supplied power for both types of sources which lead to necessity of dynamic solution of these systems. In the first part of project the dynamic model of distribution network and dynamic models of single sources will be solved. At the last step of the first block the control unit of experimental source which will represent distribution network and which can be used for testing of dynamic behaviour of especially smaller power plants will be created. At the second block the interaction between renewable sources and signal of remote control signal which is used in The Czech Republic for control of consumption will be solved and the measuring equipment for measuring of impedances of electrical network on frequencies of remote control signal will be developed.

- **Medium voltage networks protection system by using of current and voltage sensors with standardised digital interface based on IEC 61850-9-2**
  Identification code: TA03010444
  Principal Investigator: Assoc. Prof. Jaroslava Orsagova
  Project start: Jan 1, 2013
  Project end: Sep 30, 2016
  This project focuses on the digitizing of measurement according to IEC 61850-9-2, which brings new possibilities to the protection and control of switchgears under significant material savings in comparison with conventional solutions. The aims of the project is to develop a unique device for digitizing the output signal current and voltage sensors in the form of parameterized functional merging unit and by its joining together with industrially manufactured sensors create a sensory system for measuring voltage and current with a digital interface according to IEC 61850. An important part of the result of the project is a software tool for processing the output data sensors with digital interface used for testing, verification and display of measured signals. This software tool will enable to solve protection and control systems in MV networks with IEC 61850 communications as open systems with the possibility of different vendors devices interoperability that support the above standard.an integrated electric-drive. In project will be solved power axes with series of different power requirements, divided in categories according to max. speed: up to max speed 10 km per hr (typically used in lawtests, such as functional test, driving cycle or durability test. Test results will be evaluated to verify required parameters.

- **Centre for Advanced Nuclear Technologies**
  Identification code: TE01020455
  Principal Investigator: Assoc. Prof. Karel Katovsky
  Project start: Mar 1, 2012
  Project end: Dec 31, 2019
  CANUT defines the system for long term cooperation in RaDaI among research organizations and significant industrial companies participating in the project through partnership. The reason for CANUT project is building a strategic partnership among the members of the nuclear technologies consortium, where participants are internationally respected research institutes and industrial companies with a long term tradition. These technologies belong to the key and prestigious RaD topics in the world.

- **Research and development of modular system of growth chambers with low energy demand**
  Identification code: FR-TI3/383
  Principal Investigator: Assoc. Prof. Petr Baxant
  Project start: Apr 1, 2011
  Project end: Dec 31, 2014
  Growth chamber sphere has a long-lasting problem with a high energy consumption which is necessary for chambers inner atmosphere maintenance, especially as for temperature, humidity and illumination level. This project is oriented on a research and development of a new suitable technology for growth chambers lighting, temperature and humidity. Growth chamber which meets common users requested parameters of inner atmosphere by means of standard control programs will be developed. The development will be further focused on the whole process optimization with a view to the total energy demand decrease. The suitable modular system of growth chambers with low energy demand and utilization of modern light sources and light pipeline will be design on base of the research and development.

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