European Research Infrastructure supporting Smart Grid Systems Technology Development, Validation and Roll Out

TRANSNATIONAL ACCESS PROVISION

RESEARCH INFRASTRUCTURE DESCRIPTION AND
TRANSNATIONAL ACCESS CONDITIONS

Technical University of Denmark

Danmarks Tekniske Universitet

DTU

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Research Infrastructure

Name of Infrastructure/Installation	**SYSLAB and ICL**
Location	Technical University of Denmark, Kgs. Lyngby, Denmark
Web Site	*www.dtu.dk* *http://www.powerlab.dk/*

Description of the Research Infrastructure

2.1 SYSLAB

SYSLAB is an experimental facility at DTU Risø campus, designed as a testbed for advanced control and communication concepts for power grids. The facility has been extended several times since its inception in 2005; the current setup extends across multiple sites on Risø campus within an area of about one square kilometer. A 400V, 3-phase grid with a total of 16 busbars and 119 automated coupling points serves as the electrical backbone of the facility and allows a large variety of different grid topologies to be set up by means of a central crossbar switch. When all cables are in use, a maximum feeder length of up to 3km can be achieved. The grid can be connected to the campus distribution grid through one of several interconnection points, operated in island mode or be split up into multiple independent subgrids.

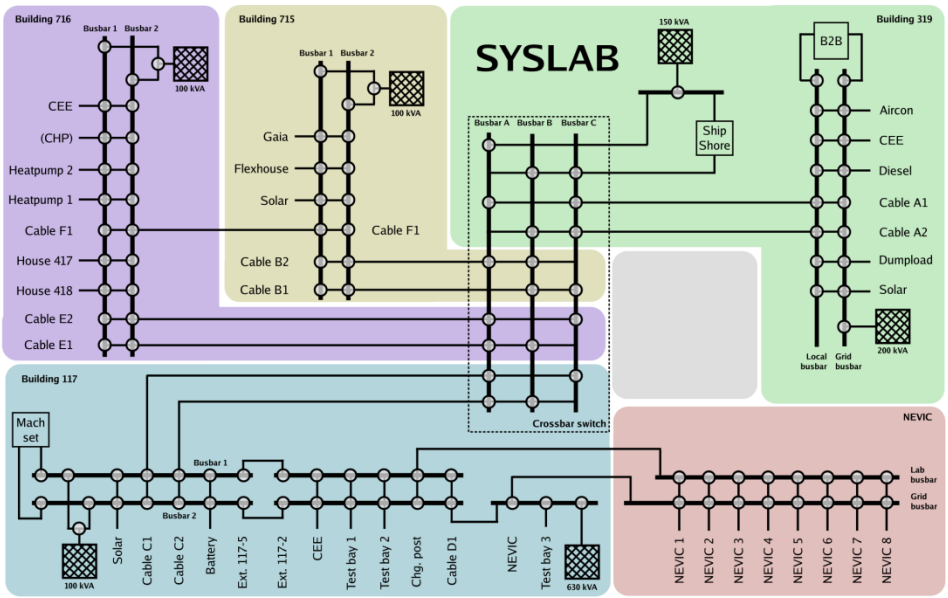

Figure 1: Layout of the electrical grid in SYSLAB

Figure 2: Overview of the SYSLAB facility on Risø campus

A large variety of DER units can be connected at different points of the grid. These include two wind turbines, three PV installations, a conventional (combustion engine) generator, three buildings with controllable heating, vanadium redox-flow and lithium-ion batteries for storage, electric vehicle charging posts and various other types of controllable loads. Unit sizes range between 10 and 100 kVA. A back-to-back converter allows controlled power exchange between SYSLAB and the campus grid and can be used for equipment simulation or PHIL tests.

All equipment on the grid is automated and remote-controllable. Each unit is supervised locally by a dedicated computing node which acts as a communication gateway. The node computers run a custom, Java-based software platform on top of a standard Linux installation which provides communication between nodes, facilitates the deployment of local controllers and logs unit data. The nodes are almost identical, and the layout of the communication network does not put any of them at the center of the network. This results in great flexibility with respect to control architectures; standard master-slave control concepts can be tested as well as less traditional approaches such as controllers based on peer-to-peer communication or multi-layered hybrid control systems.

Various software interfaces exist for the interaction with the laboratory infrastructure; besides the native Java API many SCADA functions can be accessed through Matlab. Integration with most other programming languages such as C or Python is possible via the web services and XMLRPC APIs.

SYSLAB is currently being expanded with a small **district heating network** in order to study the interaction between energy carriers. A custom-built “heat substation” allows the flexible interconnection and transfer of energy between a number of heat sources, heat consumers and a storage tank. In the current setup, a heat pump and an electrical booster heater allow energy to be transferred from the electrical network of SYSLAB to the heat network.

The **Flexhouses** are three highly automated buildings which are integrated into SYSLAB. Flexhouse I is a former office pavilion, while Flexhouses II and III were originally built as single-family homes before being retrofitted for research use. Their primary purpose is to facilitate research on the integration of buildings into the control of energy systems. Flexhouse I is electrically heated and cooled, with individual electrical radiators and split airconditioning systems in each room. The other two buildings have water-borne central heating systems which are fed from the SYSLAB district heating switchboard.

All buildings are equipped with a multitude of sensors, including room temperature, light intensity, presence/motion, window and door contacts. Each building has a variety of controllable energy consumers - appliances, space heating and cooling and hot tap water.
A custom-made building automation platform allows the deployment of building controllers written in Java or Python which are able to interact with the building as well as process remote-control signals from SYSLAB, e.g. for demand response applications.

2.2 ICL

The **Intelligent Control Lab (ICL)** is a laboratory for research, development and test of new advanced principles for intelligent supervision and control of smart grids. It consists of

- a full-scale ABB Network Manager SCADA system which is linked to the SCADA system operated by the local DSO on the island of Bornholm and allows monitoring of the entire Bornholm grid on a large monitor wall in a realistic control room setup
- a 10-rack real-time digital simulator (RTDS) able to simulate power systems of up to 480 buses. The RTDS can be used for Hardware-in-the-Loop (HIL) tests and can be connected to a linear high power amplifier in order to conduct Power Hardware-in-the-loop (PHIL) experiments.
- A PMU extension to the RTDS with GTNET PMU cards (46 channels) for research and development on wide area monitoring and control.
- a PMU lab with a PMU test platform, consisting of a Doble amplifier and PMUs from several manufacturers.
- an IBM Blade Center for hosting and executing optimization and control software.

Potential applications of the ICL include proof-of-concept tests of intelligent control and operator training, HIL and PHIL testing, wide area monitoring and control topics, relay testing and protection coordination using IEC 61850 and PMU testing according to IEEE C37.118.1.

Services offered by the Research Infrastructure

SYSLAB has been used in the past for a variety of applications, including:

- Development and proof-of-concept testing of novel control concepts for smart grids
- Component characterization and testing
- Validation of simulation tools
- Electrical vehicle interoperability testing
- Testing of real-time prediction algorithms
- Development of demand response algorithms
- Testing of communication performance at the protocol level
- Proof-of-concept testing of data models for smart grid communication
- Island grid and microgrid studies

Potential applications of the **ICL** include:

- Proof-of-concept tests of intelligent control algorithms
- Operator training
- HIL and PHIL testing against the RTDS
- Wide area monitoring and control related research
- Relay testing and protection coordination using IEC 61850
- PMU testing according to IEEE C37.118.1.

Brief description of the organization managing the Research Infrastructure

The Center for Electric Power and Energy (CEE) is a center for research, innovation and education at the Technical University of Denmark (DTU), department of Electrical Engineering. CEE covers a broad range of electric technologies including production, transmission, distribution and consumption of electricity as well the interactions with other energy carrier systems such as district heating. CEE aims at enabling a more intelligent, flexible and automated electric power system that can accommodate the future expansion of renewable energy production and the long term vision of a fossil-free society. CEE holds competences within electric components, electric power systems, automation of complex power systems, electricity markets, end-user interaction and intelligent energy systems.

The Energy Systems Operation and Management (ESOM) group is a research group within CEE and performs research covering the development and analysis of new solutions for the management and operation of future distributed power systems with a high share of renewable energy and distributed energy resources. The investigation of future system architectures, centralized as well as decentralized, is part of the research area, with the goal to provide optimal and seamless interaction of all system elements and subsystems. This includes e.g. agent-based solutions and aggregation. The solutions cover novel ICT implementations combined with innovative market-based designs and new grid management methods and important aspect is interoperability of communication and services. ESOM research efforts also cover innovative monitoring, operation and control which enable for example management of grid bottleneck, islanding solutions and microgrids. The research has important interfaces with many of the other groups including research within markets and energy resources, services and control.

PowerLabDK is an experimental platform for electric power and energy laboratory administered by CEE. PowerLabDK supports development, test, training and demonstration of technologies that will

contribute to the development of a reliable, cost efficient and sustainable energy system based on renewable energy sources. PowerLabDK is a national GreenLab under the Danish Energy Agency.

The facilities contain flexible test laboratories, large-scale experimental facilities and a complete full-scale power distribution system on the Island of Bornholm which serves as a data source and platform for full-scale and real-life experiments. The PowerLabDK facilities welcome engineers and researchers from industry and academia as well as innovative students. The two PowerLabDK facilities available for the Transnational Access programme in ERIGrid are SYSLAB and the Intelligent Control Lab.

Transnational Access conditions offered by DTU

The offered experimental facilities are located in Denmark, SYSLAB in Roskilde, DTU Risø Campus and Intelligent Control Lab in Kgs. Lyngby, DTU Lyngby Campus.

For **safety reasons**, for **critical applications**, the users are not expected to operate the systems by themselves; even when safety instructions will be provided, tests will be carried out by staff of DTU. For **the rest of applications** and after ad-hoc training, the user group will have full access to the related facilities for the duration of the stay (with the support of DTU's researchers and laboratory technicians when necessary). The **scheduling of the experiments** will be agreed and booked prior to the stay according to the availability of the involved staff and equipment. Administrative documentation for the access (contract, non-disclosure agreement, etc.) will comply with ERIGrid common indications.

In addition to the general corporate services (Internet connection, canteen, etc.) and the support and advice on accommodation and transportation to DTU's infrastructure, the access being offered includes supervision and help of DTU's staff:

- As a complement to the pre-access contacts between the user group and DTU, the stay will start with an introductory meeting with a senior researcher for confirming the stay conditions (confidentiality, safety indications), scheduling the activities, explaining the on-site procedures, clarifying the logistics and technical details.
- Preparatory work: a laboratory technician install the devices, electrical connections, use of the specific instrumentation, preparation of a test procedure (if necessary) on the basis of the users requests, and configuration of the experimental conditions.
- DTU's researchers will support the realisation and follow-up of the experiments.
- DTU's researchers will support the results interpretation, data processing and analysis, and test report preparation

In principle, a typical stay of 2 weeks is foreseen for a single user group but this period could be extended depending on the concrete user project. The user group (usually 2 persons) can use the infrastructure for the defined time.

Reimbursement of expenses:

User expenses for the Transnational Access are paid by ERIGrid (EU H2020 Programme). This includes travels to DTU by plane, accommodation, daily subsistence, and daily transportation during the stay.

For the user projects taking place at SYSLAB and ICL (DTU) will refund the stay expenses when the stay is finished: the user must declare the incurred expenses and present the invoices/receipts to DTU in order to get the refund.

Logical expenses must be made by the user: travels will be made in economy class and conventional hotels (not luxury) or equivalent accommodation will be used.

Contact details for Research Infrastructure

<table>
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