Distribution Network and Protection (D-NAP) Laboratory – A Dynamic Power Systems Laboratory

Dynamic Power Systems Laboratory

1 Description of the Research Infrastructure

Housed in a £90 M state of the art research and knowledge exchange environment, the laboratory contains a reconfigurable 400 V three-phase AC power network with multiple controllable voltage supplies and loads with flexible control systems and interfaces. The laboratory has power hardware-in-the-loop (PHIL) and controller hardware-in-the-loop (CHIL) capabilities. The network and devices are used to test and demonstrate smart grid technologies within a controlled environment, and under steady-state and abnormal conditions. Typical areas of research include: distributed control, future power systems with high penetrations of converters, control and communications integration, islanded (and auto-islanding) power systems, and dynamic power systems (e.g. marine/emergency).

There are four modes of operation of this facility: power hardware in the loop simulation; pre-set scenario playback; direct grid connection; and islanded system operation. The laboratory network is designed such that it can be split into three separate power islands under independent control, or connected together as an interconnected system. This provides a high degree of flexibility enabling many different land-based or marine scenarios to be demonstrated.

The power network facilities are complemented with extensive real-time power system simulation capabilities enabling augmentation of the hardware network with simulated systems, which thereby representing large power networks. Simulated systems can be linked with real substation equipment – such as measurement devices, protection relays, and communications routers – to authentically and systematically validate prototype smart grid solutions. Specific technologies underpinning the infrastructure include: real-time communications emulation, precision time-synchronisation, phasor measurement units (PMUs), and state-of-the-art protocols for data communications.

The laboratory infrastructure has been mapped into the Smart Grid Architecture Model (SGAM) for facilitating the integration of devices and use cases under test. This allows for fast prototype development and minimises possible incompatibilities or integration issues.
In order to achieve accelerated testing, the RI is underpinned by the following main systems:

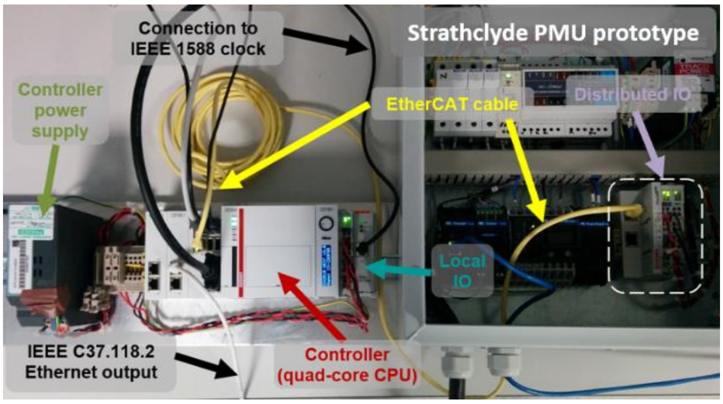
Power converters and controllable loads

A 90 kVA back-to-back, fully-controllable converter is one of the main assets of the laboratory. It allows the performance of experiments grid-connected or islanded from the grid thereby creating an island of >90 kVA. Two other power converter units of 15 kVA and 10 kVA are available that can be controlled as emulated loads or as different types of generators; these devices could also be used to form smaller islanded systems. A 50 kVA and 2 x 12.5 kVA controllable loads are also available. Induction machines, which can be operated as motors or generators, provide inertia and controllable torque. This provides a controllable and repeatable environment for systems tests, to deploy and validate new microgrid control algorithms.

Two-rack RTDS system

The Real-Time Digital Simulator (RTDS) allows large power networks to be simulated at a resolution of 50 μs or smaller. The laboratory has an up to date two-rack RTDS with a range of I/O capabilities including hard-wired analogue and digital I/O, DNP3, PMU, and IEC 61850 Sampled Values and GOOSE communications. A number of grid and marine system models have been created for validating on- and off-shore networks, renewable generation, and network automation. Such infrastructure has been used to test protection and control schemes under a large number of scenarios and to inform standard settings.

Distributed high accuracy, fast data acquisition system



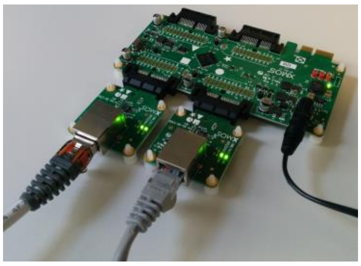
High accuracy instantaneous LV voltage and current measurements can be collected at a rate of up to 10 kHz using a distributed data acquisition system. The sampling uses an absolute time reference with resolution of <100 ns. The system is modular, so additional measurement points and processing nodes can be added where required. Furthermore, the platform can also be used to deploy control functions where control functionality can be distributed at the measurement nodes. For example, multiple PMUs or IEC 61850 IEDs – supporting standardised communications protocols – can be readily deployed for monitoring and control.

RTS and RTX units

Two real-time simulators from Applied Dynamics International allow smart grid scenarios to be enacted within the laboratory, with capability for real-time data monitoring and control. The two real-time units can be used in conjunction with RTDS for high fidelity multi-rate co-simulations.

Communications validation and emulation

The laboratory has the capability to mimic modern utility communications network infrastructure using four Nokia (formally Alcatel-Lucent) 7705 IP/MPLS routers, including tele-protection and Ethernet interface cards. The use of custom embedded platforms and ns3 servers allows extended communications networks to be emulated in real-time.

The RI is supported by a number of neighbouring facilities including a DC Power System Laboratory, a Demand-Side Management Laboratory, HV Test Cells, and an Electrical and Mechanical Workshop.

2 Services offered by the Research Infrastructure

The dynamic power system laboratory offers a flexible environment to test new components or algorithms on an LV network with a variable frequency and voltage supply. Devices can be attached to the network at a number of points and with voltage and current measurements taken back to a central real-time control platform. Some example services include:

Demonstration and proof of concept of new solutions for distributed power system control
The laboratory is well equipped to not only demonstrate novel distributed solutions for power system (for example, demand side aggregator with highly distributed portfolio providing frequency balancing ancillary service) but to rigorously test and evaluate these novel solutions. Therefore, novel prototypes can be de-risked before their adoption and deployment in industry. The various modes of operation of the laboratory provide the flexibility to represent a wide variety of smart grid configurations and scenarios.

Hardware in the loop testing of control, protection, and automation equipment
Using hardware in the loop testing, all primary power system equipment and assets are simulated, in real-time. It is possible to simulate arbitrary electrical networks and all the extremes of operation, including stable conditions and many different fault scenarios, such as systematically testing a range of different fault locations. However, the simulation is linked to the real commercial hardware devices under test, such as protection relays, PMUs, and communications equipment. The response of the hardware can be monitored and thereby validated. In this way, new schemes can be validated, adaptive features thoroughly tested, and new settings or operating guides resolved.

Novel inverter control testing
The three-phase programmable back-to-back converters allow novel inverter controls to be tested and validated in realistic conditions. For example, a 10 kW programmable DC power supply can be used to emulate a solar PV array as the input to an inverter. The inverter under test can then be subjected to different load and fault conditions while measuring its outputs, including harmonics.

As part of a technological university and a strong research centre, the RI benefits from the close proximity to a large number of expert researchers in electrical technologies, modelling, simulation, and experimental validation.

3 Brief description of the organization managing the Research Infrastructure

The Institute for Energy and Environment (InstEE) represents one of Europe's largest power systems and energy technology university research groups. Comprising 32 members of academic staff, over 200 research staff and students, and 18 technical and administrative colleagues, the Institute has four main research groups: Advanced Electrical Systems, High Voltage Technology, Power Electronics Drives and Energy Conversion, Wind Energy and Control. This is complemented by the Power Networks Demonstration Centre (PNDC) which hosts a fully operational HV and LV demonstration network and dedicated team of research, technical and support staff. PNDC accelerates grid-ready validation at a larger scale and higher voltage level than is possible than at the D-NAP facility.

The D-NAP Dynamic Power Systems Laboratory is based in the state-of-the-art Technology and Innovation Centre (TIC) within the University of Strathclyde. This facility, opened in July 2015, houses much of Strathclyde's industry-facing research work. There are 45 bespoke, state of the art laboratories across key research themes of energy, health, manufacturing, and future cities – which support innovation and research demonstration. The TIC also has extensive conferencing and meeting facilities.

4 Contact details for Research Infrastructure

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