Success Story

eMEGASIM Real-Time Digital Simulator:

A Unique Smart Grid Lab and Energy Storage Bed at Newcastle University

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Newcastle University's Smart Grid Lab and Energy Storage Test Bed are unique facilities that enable research into future energy systems. They are funded through a combined grant from the Engineering and Physical Sciences Research Council (EPSRC), Newcastle University and industrial partners Northern Powergrid and Siemens. These key facilities, part of Newcastle's flagship project Science Central, bring together academia, the public sector, communities, business and industry to create a global centre for urban innovation and sustainability.

1. Challenge

The aim of the facilities is to develop an exemplar of a smart, sustainable, resilient eco-system that links energy, transport and digital infrastructure in an urban context. The focus of **Newcastle University's Smart Grid Lab** is the simulation of distribution networks under futuristic scenarios, including the integration of large-scale proliferation of electric vehicles and large numbers of renewable energy generators.

1.1 Linking Hardware and Power Systems in the Loop

Upon the set-up of the laboratory, there was a need to be able to emulate power systems. "*We needed to link the real-time simulation of power systems with actual hardware, like power converters, electric vehicles, battery systems, smart appliances, and other physical kits currently in our lab. We wanted to bridge the gap between simulation and experimentation by bringing hardware and power systems in the loop in a smart grid context*" said Dr. Charalampos Patsios, Senior Research Associate at the School of Electrical and Electronic Engineering at Newcastle University.

2.2 Simulation Based On Real Streamed and Stored Data

At Newcastle University's Smart Grid Lab, researchers have access to real data from local network operators. They wanted to stream that data in their lab to be able simulate the operation of power systems under different scenarios in real-time.

"*We have live data streamed in our labs originating from our local distribution network operator here in the UK. We wanted to use this data as input to scalable and re-configurable network models and other physical or emulated systems. For example, we can use live data of power flows in an actual substation here in Newcastle, and trial the operation of an actual battery system to perform a peak-shaving operation or other services. Another example would be to study the impacts of increased renewable penetration in networks, using values like real-time voltages, currents and ratings.*"

It was not only about live data but also stored data. The researchers at Newcastle University have a huge amount of stored data from smart meters and trials around smart grids in the UK. They wanted to be able to run this data for a range of scenarios, perform power systems hardware-in-the-loop experiments and test the impact on actual hardware and vice-versa.

2. Solution

OPAL-RT's real-time simulation solutions enabled Newcastle University's researchers to **accurately model the operations of various systems and capture interesting quantities, such as voltage, currents and power flows**. By using the simulator, there were able to study **the interactions and interdependencies** of different subsystems and components in real-time.

OPAL-RT has also enabled researchers to increase the scalability of the case-studies, allowing the modelling of networks of increased complexity. Safety was also a major concern as the lab is operating in voltages not exceeding 400V. Higher voltages can now be emulated allowing for a safe study but also accurate representation of associated phenomena. Using OPAL-RT's real-time

platform, it is now possible to simulate higher voltages and power flows and scale it down to a voltage level or power level that would be easily manageable inside the lab.

"*We wanted to reduce the risks of experimenting with high power, high voltage networks," commented Martin Feeney, Smart Grid lab Supervisor. "Therefore we wanted the ability to simulate these in real-time and scale them down to the size of voltage that is manageable inside the lab. Now we have the ability to perform real-time simulation of power systems, including physical hardware, and to capture respective quantities, such as currents, voltages and power flows*."

2.1 Smart Grid Lab

In the Smart Grid Lab, the real-time network simulator (RTNS) allows for detailed real-time simulation of networks using sophisticated models that can interact with the physical laboratory environment. In addition to the **OP5600 OPAL-RT real-time simulator**, the laboratory is equipped **with a Triphase power amplifier** in order to conduct Power-Hardware-In-the-Loop testing. Real-time network simulation models can interact with the laboratory via a digital link to a three-phase, four quadrant inverter drive capable of delivering fully controllable voltage waveforms and events. This arrangement provides the power-hardware-in-the-loop (PHIL) platform, which facilitates the real experimental LV network to interact with the large-scale network model simulated by RTNS in real-time. It enables sophisticated investigation of the capabilities of next generation smart grid technologies.

2.2 Energy Storage Bed

The facility can also interface with any other electrical energy storage technology across a wide range of technical specifications, or even emulate technologies through dedicated battery emulators. In addition to the actual grid, the facility can "virtually" connect to simulated networks using the sophisticated Real-Time Network Simulator.

3. Conclusion

As concluded by Dr. Charalampos Patsios, the OPAL-RT team and its real-time simulation solution managed to meet the technical criteria but also some more practical constraints like:

- "**Timelines** – *We had tight deadlines to meet to set up the lab facilities*.
- **Budget**. *We had a limited budget for these and this also played out for our decision.*
- *Another challenge was that we wanted had to have **a flexible and open system that would be able to interface seamlessly with different software and hardware solutions by third parties**. So we needed flexibility as well*."

The Smart Grid Lab represents the future of smart electrical networks with low carbon technology emulation, load emulation, EVs, energy storage and a flexible LV network with Power Hardware in the Loop technology.

The researchers will be able to evaluate new network technologies in the more challenging scenarios of the future, where electrical systems are even more

critical to the function of our energy systems. This will help them understand how smart grids will help meet future energy challenges.

"*The need for accurate, fast, flexible and reliable modelling of physical systems and their operation is growing in the power systems domain. This is due to the increases in scale and complexity of these systems and the constantly evolving technologies around them. Bridging the gap between computer simulation and physical systems is imperative in order to design, prototype and test different solutions in a way that builds confidence around them and ensures they are innovative, long lasting and sustainable*"

Dr Haris Patsios, School of Electrical & Electronic Engineering, Newcastle University

OPAL-RT TECHNOLOGIES

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About OPAL-RT TECHNOLOGIES

OPAL-RT is the world leader in the development of PC/FPGA Based Real-Time Digital Simulator, Hardware-In-the-Loop (HIL) testing equipment and Rapid Control Prototyping (RCP) systems to design, test and optimize control and protection systems used in power grids, power electronics, motor drives, automotive industry, trains, aircraft and various industries, as well as R&D centers and universities

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