OPAL-RT TECHNOLOGIES

# DynaGrid Control Center: Power Grid Control Center of the Future

SIEMENS

OTTO VON GUERICKE UNIVERSITÄT MAGDEBURG

TECHNISCHE UNIVERSITÄT ILMENAU

Fraunhofer IOSB

RUHR UNIVERSITÄT BOCHUM RUB

Fraunhofer IFF

## Application

- High-Voltage, Direct Current (HVDC)

## Related Products

- HYPERSIM
- OP5707
- IEC 60870-5-104, C37.118 and IEC 61850.

## Type of Simulation

- Hardware-in-the-Loop (HIL)
- Country-wide, multi-lab co-simulation

SUCCESS STORY

# INTRODUCTION

OPAL-RT is proud to be the simulation platform provider for the DynaGrid Control Center (DGCC), the power grid control center of the future. The demonstrator for research on the next generation of control center technologies was co-developed by Siemens AG (SAG), Ilmenau University of Technology, Otto-von-Guericke University (OvGU), Fraunhofer IFF (IFF), Fraunhofer IOSB-AST (AST), and Ruhr-Universität Bochum (RUB).

"Of the future" is a science fiction cliché by this point—but in this case, very much true. As more (and more varied) types of resources are integrated in power grids, more dynamic, real-time, split-second re-allocation decisions must be made for a myriad of reasons.

Intelligent grid control involves—in total and perhaps more than anything else--the efficient management of system dynamics. With the massive integration of renewable energy sources and power electronics, the control and monitoring of our transmission grids is becoming increasingly complex.

And as with any extremely complex system, there is not just one variable at play. In many countries, large nuclear or coal-fired power plants are being taken off the grid, and as a result, electrical energy needs to be transported over increasingly longer distances. This, in turn, increases the potential for system instabilities in frequency and voltage.

To avoid or eliminate such congestion and protect the installed equipment, the generating units have to be actively managed and re-dispatched, leading to constantly increasing costs.

Keep in mind that this is all happening in real-time, so an accurate metaphor may be the performer spinning plates in the air, where all plates must remain spinning, and not one may fall to the ground.

A promising solution is to invest in intelligent control systems and digital substation control technology, which reacts effectively and with foresight to changing system states and dynamics.

*"In order to maintain the stability of our highly dynamic transmission grids, in the future we will require control centers with automated control functionality."*

*Prof. Dr.-Ing. Rainer Krebs, Principal Expert and Head of Protection, Operation and Control System Studies Dept., Digital Grid, Siemens AG*

# OBJECTIVE

The DGCC research project was planned as nothing less ambitious than “the control center of the future”. Research and scientific partners in Germany cooperated in this three-year research project. The goal was to develop an assistant system for automated grid control and outage prevention. Such an innovative and future-oriented project required the ongoing and coordinated support of many players.

The German government supports the innovative spirit of German-based companies by offering innovation-friendly conditions and market-oriented R&D and innovation activities. The project DGCC (03ET7541) was funded by the German federal ministries of Economic Affairs and Energy (BMWi) as part of the funding initiative *"Future-proof Power Grids"* with roughly €5 million.

## Innovative Solutions for Grid Control

Building a sustainable global energy system is considered one of the central challenges of the 21st century. Many countries are working on the transition from nuclear and fossil fuels to renewable energies--the so-called energy transition. Leading this transformation process is Europe, and above all Germany, which is transforming its energy supply fundamentally step by step. But the transformation of the energy system also involves enormous technological challenges. The Federal Government is therefore funding numerous research and development projects without which a sustainable, secure, and cost-effective energy supply for tomorrow would not be possible.

One of these projects is the joint project DynaGrid Control Center, in which a research consortium, coordinated by Siemens AG, was dedicated to ensuring grid stability and security of supply of energy through intelligent dynamic control centers. The innovative and future-oriented project required the coordinated support of several research institutes and universities. The Ilmenau University of Technology, where the heart of the project--an innovative, globally unique dynamic grid control center--has now been put into operation, represents a key partner of the research consortium.

*"Control rooms are the brain of the entire system that controls and monitors all processes in the grid.*

*With the decarbonization of the entire energy system, the electricity infrastructure will change the way the grid operates. The visualization of periodic snapshots of the system status, which is state of the art today, will no longer suffice for future grid operation. We must move from "photos" to " movies". In this respect, the "pictures have learned to move" in this project."*

*Prof. Dr.-Ing. Dirk Westermann, principal researcher and project manager of the Dynagrid project at Ilmenau University of Technology*

# SOLUTIONS & DEVELOPMENT

The development of such a complex interconnected distributed demonstrator system required multiple types of expertise. All project partners added valuable input into the system at various points during development. While SAG took part in setting up and maintaining the energy management system in the control room, OvGU built the real-time simulation environment to deliver process data over ICT interconnections maintained by AST. The real-time simulation of the substation was done by IFF. The HVDC software model has been developed and benchmarked by RUB. TUIL developed and implemented new methodologies for grid control (preventive measures and curative actions utilizing VSC-HVDC)

### Scenario 1: Hardware-in-the-Loop

High-voltage direct current (HVDC) transmission lines will play an important role in future power transmission networks. These HVDC transmission lines transmit large amounts of energy over long distances within the existing alternating current (AC) network and, with the aid of power electronics, behave quite differently from conventional equipment.

In order to be able to study this behavior, an HVDC line was built on a laboratory scale and integrated into a simulation of the AC grid (hardware-in-the-loop).

### Scenario 2: Preventive HVDC measures

An HVDC line in the transmission network can be used as additional equipment to achieve an optimized operating point in terms of stability after equipment failures while avoiding expensive re-dispatch measures of power plants. The necessary changes to the HVDC operating point are regularly determined using new algorithms and verified using dynamic stability analysis before they are sent to the plant.

This ensures that not only the thermal limits but also the stability limits are always observed.

### Scenario 3: Corrective HVDC measures

With quickly controllable operating resources such as HVDCs or renewable feeders, bottlenecks can be eliminated when they occur. This presupposes that the necessary measures, i.e. changes in working points, are coordinated holistically, and initiated and implemented with sufficient speed. Such behavior is called curative n-1. In the DGCC project, systems have been developed that use optimization algorithms, dynamic security assessment (DSA) and highly dynamic local measurements to determine suitable corrective measures, which are then automatically executed in the field by the respective control unit.

Like the preventive measures in scenario 2, the designed workflow ensures that neither the stability limits nor the thermal limits are exceeded at any time.

### Scenario 4: Detection of defects (short circuits) in the grid

As with scenario 3, corrective measures should only be taken in case bottlenecks are expected to occur due to network failures or outages. The measures are verified beforehand by means of dynamic simulation (DSA). Impending bottlenecks are recognized by highly sophisticated machine learning algorithms which can compare real-time phasor measurements with simulated PMU measurements delivered by DSA.

A reaction time of less than one second drastically reduces the current reaction time of manual central interventions.

### Scenario 5: Simultaneous adaptation of parameters

The dynamic behavior of our electrical networks is significantly influenced by local control units. The controller parameters in a power plant, for example, are optimized in such a way that, from the grid's point of view, they behave system compliant at all possible operating points. Generally, they are set once and are not adapted after that. If the parameters could be changed depending on the network situation, the system stability could be increased in many situations. In the DynaGrid Control Center project, optimization algorithms have been developed to optimize all the controller parameters with respect to the current network status at regular intervals. These optimized parameters are then also verified using DSA.

The dynamic control room can continuously communicate the optimized parameters to the relevant units via a customized IEC 61850 communication link (external gateway to OPAL RT required).

# SOLUTIONS & DEVELOPMENT

**The distributed simulation system consists of two main components:**

### A real-time simulation system, located at OvGU in Magdeburg

- A real-time software-based power-system simulator was installed at the Otto-von-Guericke University in Magdeburg for a reduced model of the German transmission network.
- The simulator was coupled with the power-electronics lab with HVDC hardware, resulting in a hybrid simulation.
- Protection and measuring components like relays and PMUs form together, with substation automation and communication, so-called digital substations.

### A dynamic grid control center at TUIL in Ilmenau

- As the main part of the project, a dynamic grid control center, based on the Siemens Spectrum Power 7 and the SIGUARD suite, was installed at the TUIL of Ilmenau. The distance between the OPAL-RT simulator and the process simulation is around 200 km.
- Newly developed dynamic applications were integrated as operator assistant systems for e.g. Dynamic Security Assessment, Adaptive Protection Settings and PMU Data Streaming Analytics, assessing the actual and prospective future power system states and dynamic interactions.
- The main task of these systems was to propose validated preventive or reactive measures to the operator.

Additionally, intelligent substation models have been included in the transmission system simulation. Both simulations run on different OPAL RT systems in HYPERSIM. Measurement data and control signals were exchanged via a dedicated ICT link.

# SOLUTIONS & DEVELOPMENT

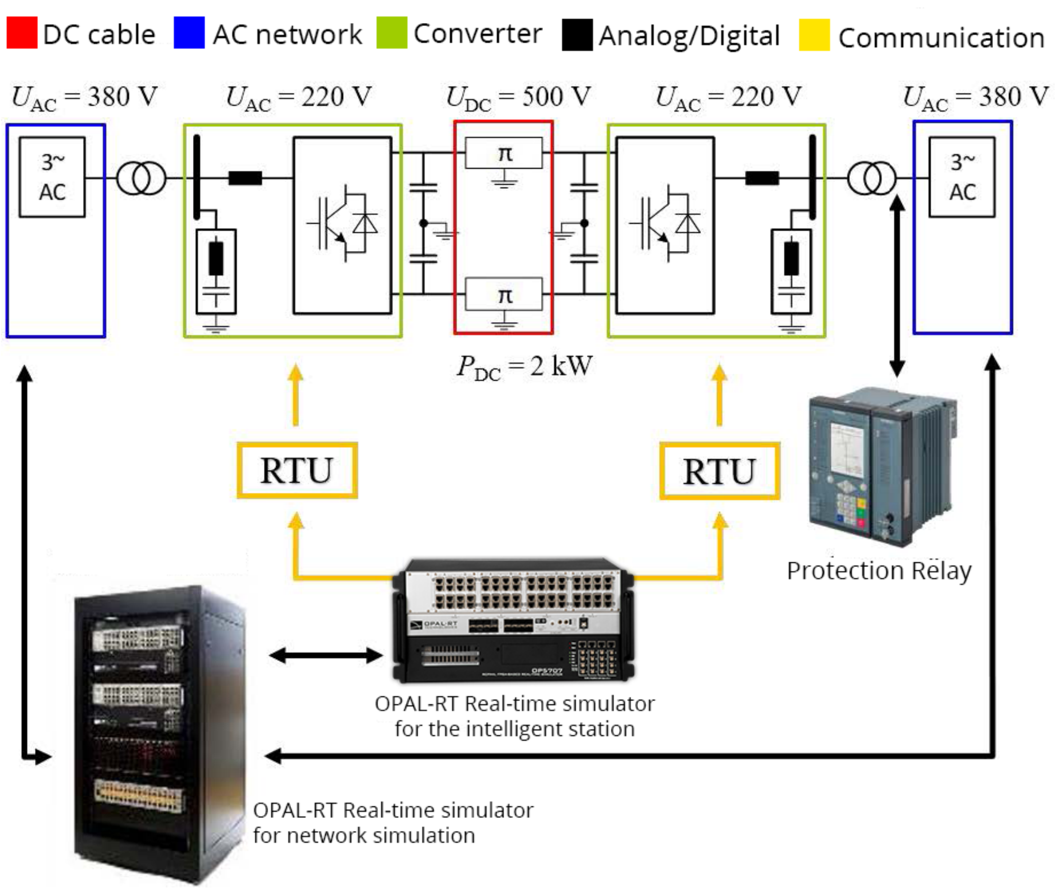
**The hybrid network model**

In this project, a hybrid AC-DC grid model was created, simulated in real time and can also integrate hardware components. With this hybrid network model, it is possible to examine the real operating behavior of a real VSC-HVDC transmission link. The intelligent station can also be tested and verified as a real-time simulation. Innovative algorithms are tested, and the latest measurement technology is used, which is also part of the entire hybrid network model.

The overall model is shown schematically in the image below. The coupling of the systems is differentiated into an analog and communication technology connection of the individual systems.

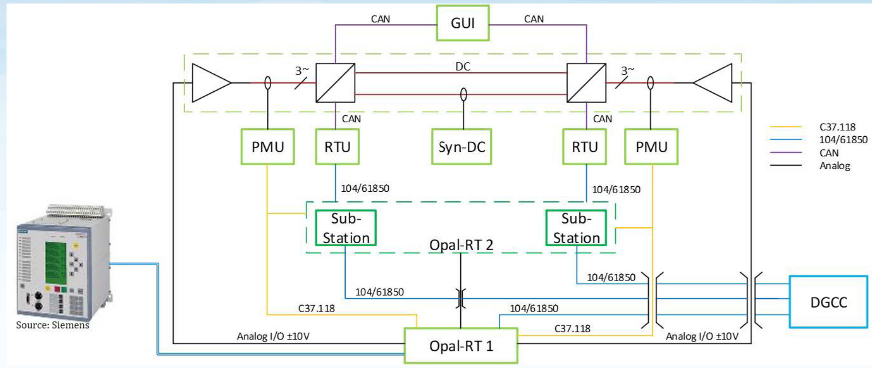
**The following components are interconnected using various coupling systems to form an overall model:**

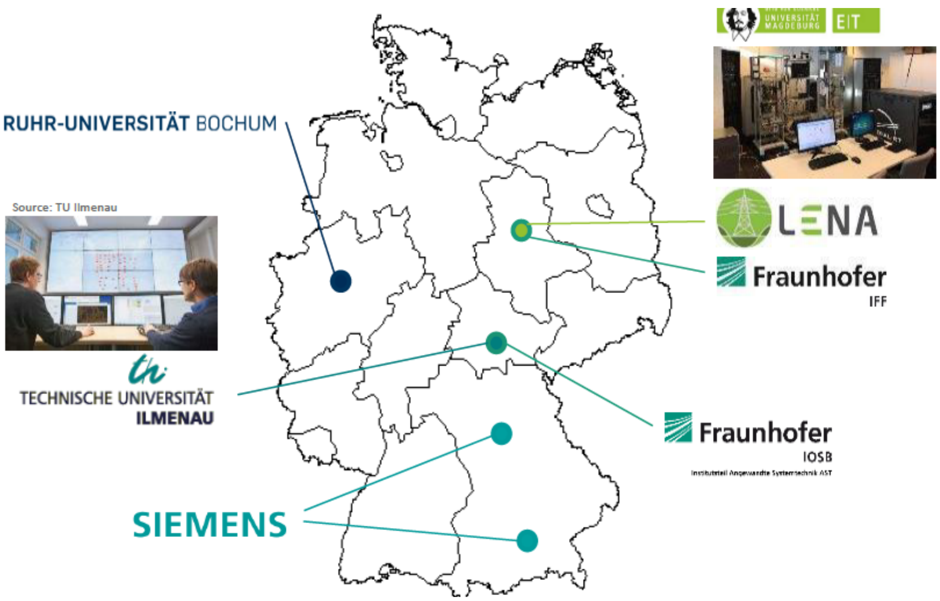
- OPAL-RT real-time simulator for network simulation
- OPAL-RT real-time simulator for the intelligent station
- Power amplifiers for AC grid simulation
- VSC converter with a transmission line of 1 GW
- VSC converter with a transmission line of 2 GW
- DC cable model
- Remote terminal units for controlling the converter
- PMU for AC-side measurements of the HVDC sections
- Syn-DCs for DC-side measurements of the HVDC
- Protective relay



# SOLUTIONS & DEVELOPMENT

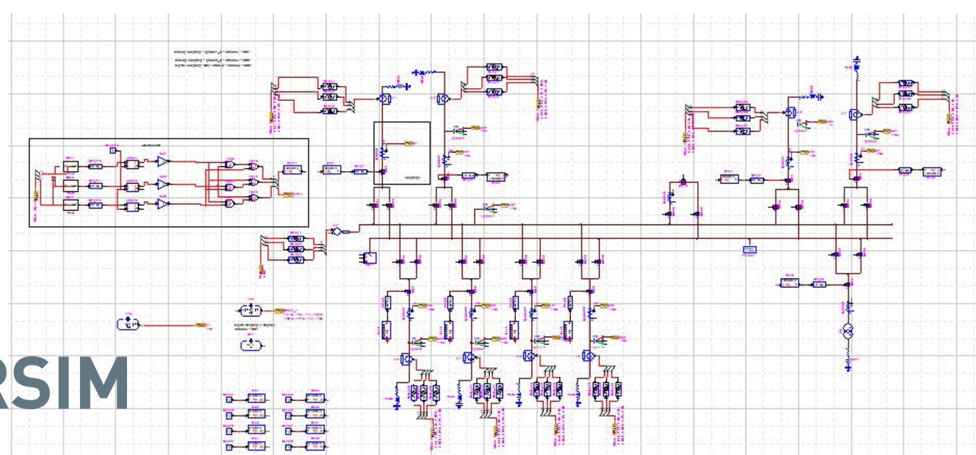
Coupling between the devices of the hybrid network model: information is exchanged between many devices using a wide variety of communication standards.




Schematic representation of the distributed ICT infrastructure of the DGCC demonstration system

An example of a station in the core area of the transmission system model running in HYPERSIM



HYPERSIM

# RESULTS

**Project results at a glance**

The key idea of the project was to develop an innovative system control methodology on the high and ultra-high voltage levels based on the structure of existing control rooms. This methodology allows for an adaptive integration of new, complex technologies into existing grid structures and enable grid operators to maintain high supply reliability in the future.

*"In the project DynaGrid Control Center (DGCC) we used an OPAL-RT simulator for a HVDC HIL simulation and different communication protocols. It was a key functionality in this project.*

*A simulation of a large AC 400 kV transmission system was realized including two hardware HVDC lines as a HIL application and we connected the complete system to a real control center in another city via IEC 60870-5-104, C37.118 and IEC 61850.*

*We set up a system on a pilot-plant scale. It was possible to simulate and manage inter area oscillation, HVDC management concepts and other topics of common interest."*

*Eric Glende, Otto-von-Guericke University*

# FURTHER READING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