SMART WIRES

SMART WIRES HARDWARE-IN-THE-LOOP CAPABILITIES: HOW THAT TRANSLATES INTO A HIGH TRUST IN OUR TECHNOLOGY AMONG THE BIGGEST UTILITIES IN THE WORLD

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SMART WIRES

THE ECONOMIST – TECHNOLOGY QUARTERLY

The ultimate supply chains

"The places best suited to the generation of renewable energy in very large amounts are not often the places where today's generation is concentrated. So new transmission lines will be needed. And because grids are complicated, some expansions will require compensation changes elsewhere as bits of the grid become congested."

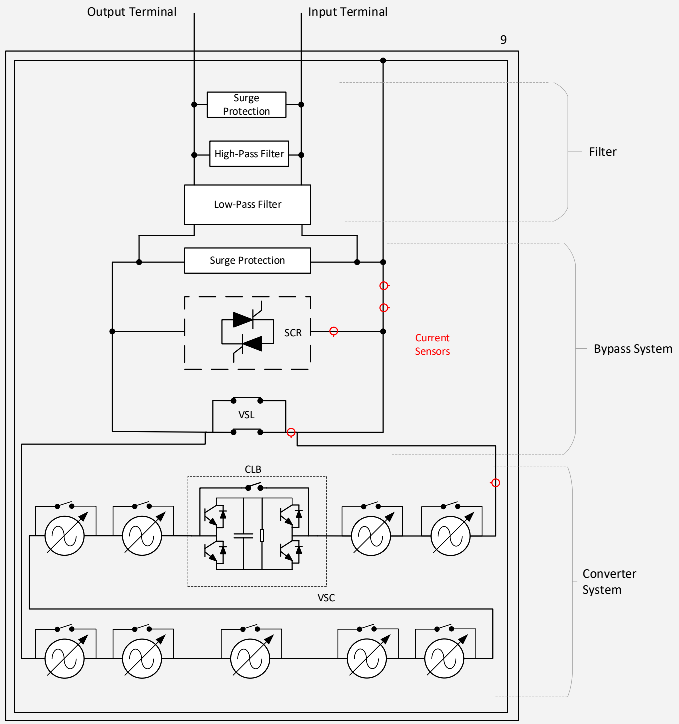
SMARTVALVE

OVERVIEW

- **Patented award-winning technology:** transformerless, modular Static Synchronous Series Compensator (m-SSSC) that employs VSC technology
- **Real-time control:** injects a controllable voltage that is independent of the line current, allowing the series reactance produced by the device to be varied (manually or automatically) in real-time
- **Modular design:** enables flexible, scalable and movable deployments that minimize use of substation space
- **Multiple network applications:** power flow control and dynamic services including improving voltage stability and transient stability
- **Fast deployment:** built for rapid delivery and deployment
- **High reliability:** no single point of failure ensures high reliability and redundancy
- **Proven at scale:** multiple large-scale deployments across the world, delivering GWs of extra capacity on the existing grid

SMARTVALVE

OVERVIEW



SmartValve 10-1800 Single-Line Diagram

SmartValve harvests all power from the line to operate the control and communication circuits and senses line current for control and fault-protection purposes.

Filter Capabilities

- The high-pass filter allows the passage of high-frequency transients.
- The low-pass filters allow the power line frequency to enter the SmartValve.

Bypass Capabilities

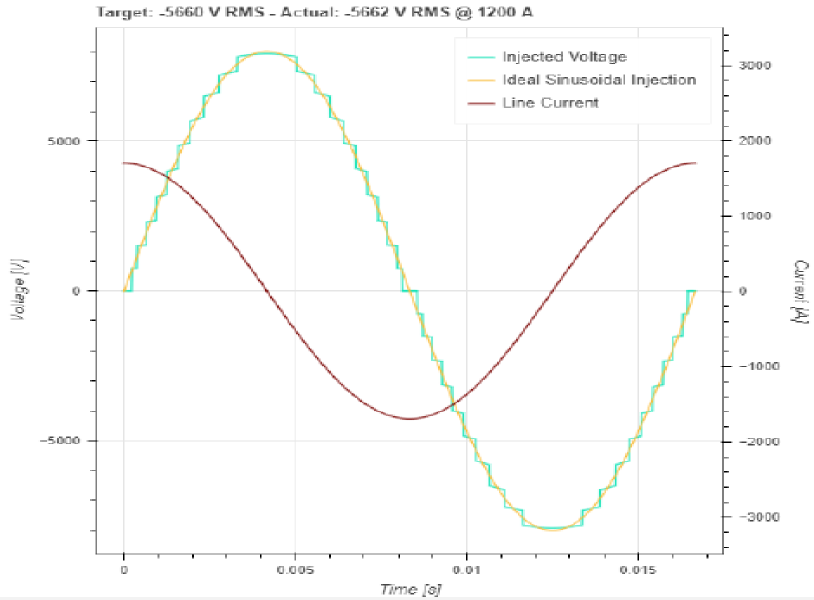
- The vacuum switch links (VSLs) primarily conduct current during steady-state conditions.
- The silicon-controlled rectifiers (SCRs) primarily conduct current during grid faults (e.g. a fault on the line connected to the SmartValve).

Converter Capabilities

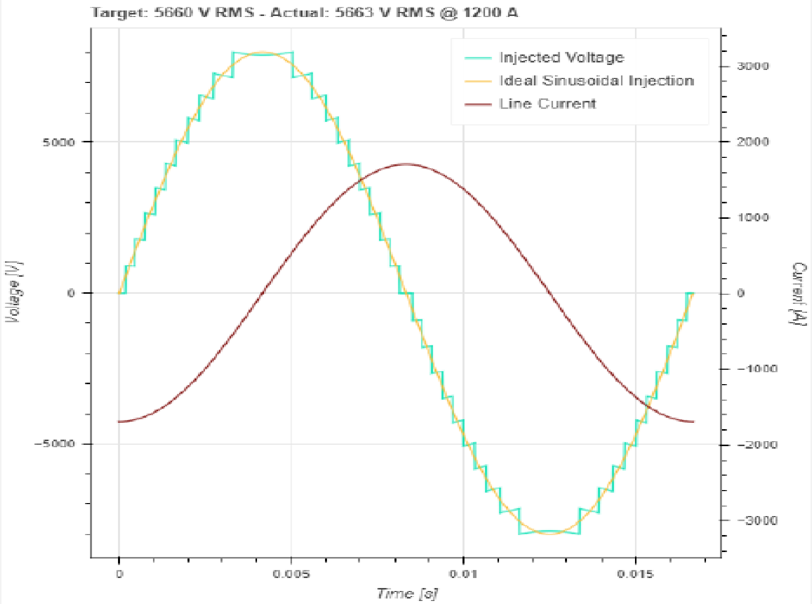
- The core components of each Voltage-Sourced Converter (VSC) are four semiconductor switches and the DC Link capacitor. Converter Level Bypass (CLB) protects the line converters in case of any failure.

THE SMARTVALVE

Voltage Injection Wave Form



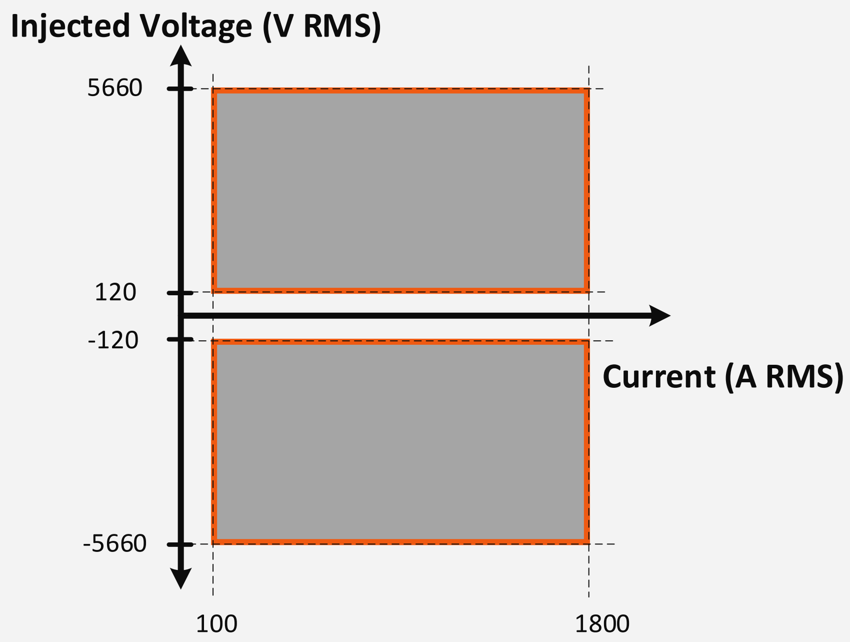
Voltage and current waveforms of a SmartValve 10-1800 injecting 5.66 kV RMS in **capacitive** injection

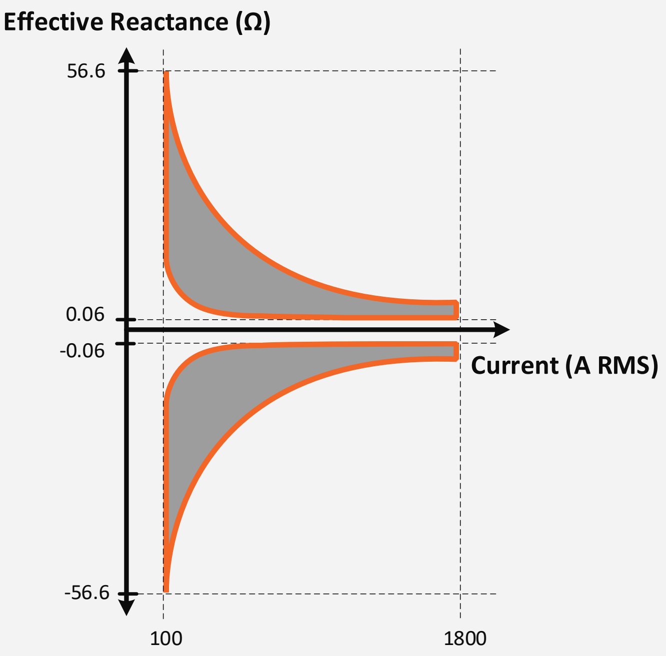


Voltage and current waveforms of a SmartValve 10-1800 injecting 5.66 kV RMS in **inductive** injection

SMARTVALVE

Voltage and Reactance Ranges

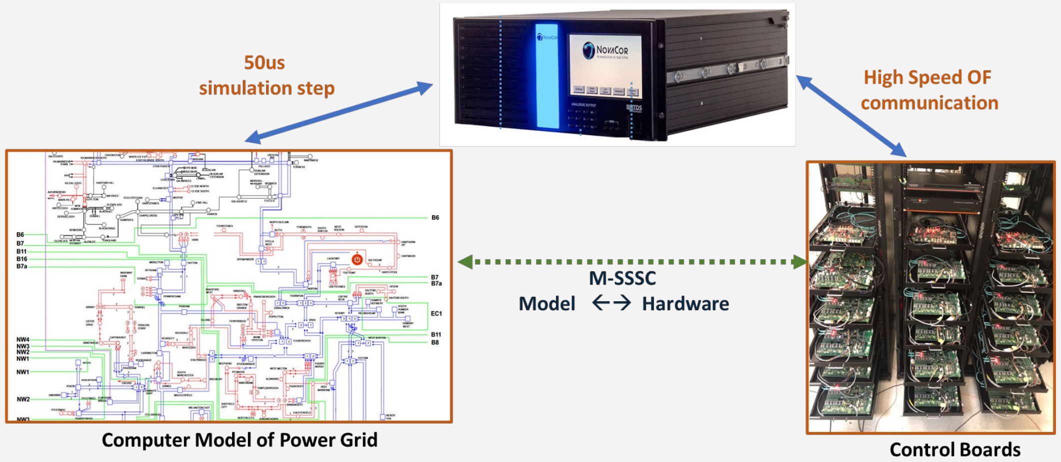




Unlike traditional solutions, M-SSSCs can inject voltage independently of line current.

HARDWARE-IN-THE-LOOP WITH RTDS

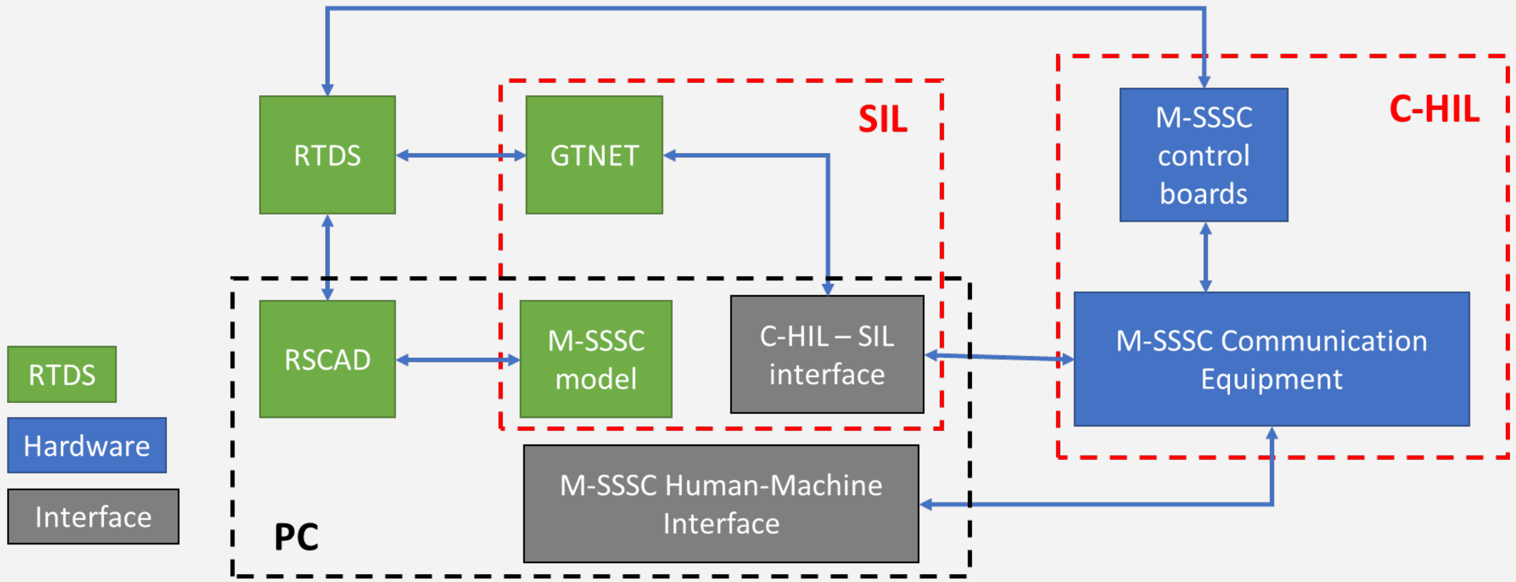
HIL SETUP



RTDS is an ideal tool for testing power electronic device control systems applied to power grids.
C-HIL aims to avoid bugs associated with Firmware and Hardware before installing the device in the field.

HARDWARE-IN-THE-LOOP WITH RTDS

SETUP C-HIL + SIL

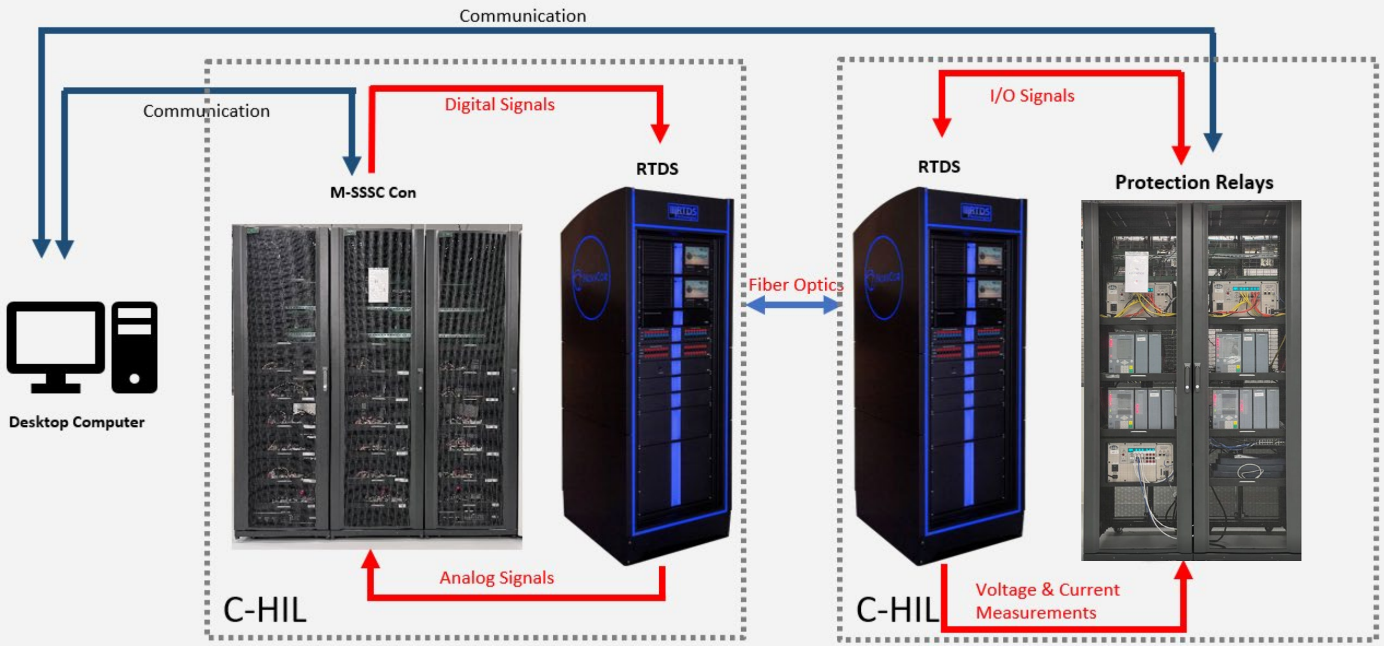


To represent an M-SSSC system with multiple devices connected in series, one M-SSSC is studied with C-HIL, and the remaining M-SSSCs are represented as RSCAD models in a Software-In-Loop (SIL) array.

HARDWARE-IN-THE-LOOP WITH RTDS

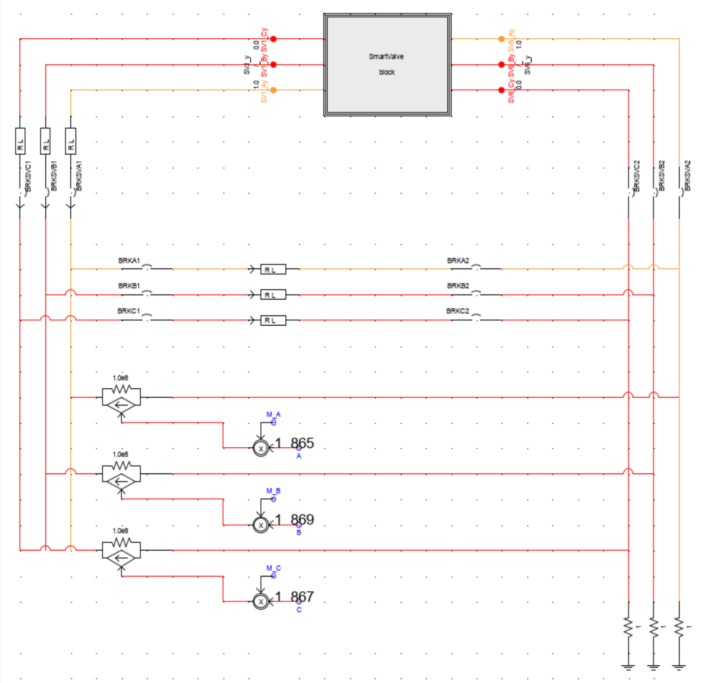
SETUP C-HIL + SIL

The RTDS on the right connects to the relays and amplifiers that interact with the RSCAD simulation.
RTDS on the left connects to the C-HIL configuration and transmits the analog signals from the ongoing simulation to the M-SSSC control boards, which feed the device's digital outputs back to the simulation in the RSCAD.



RTDS/HIL TESTS

Functional Performance Test (FPT)



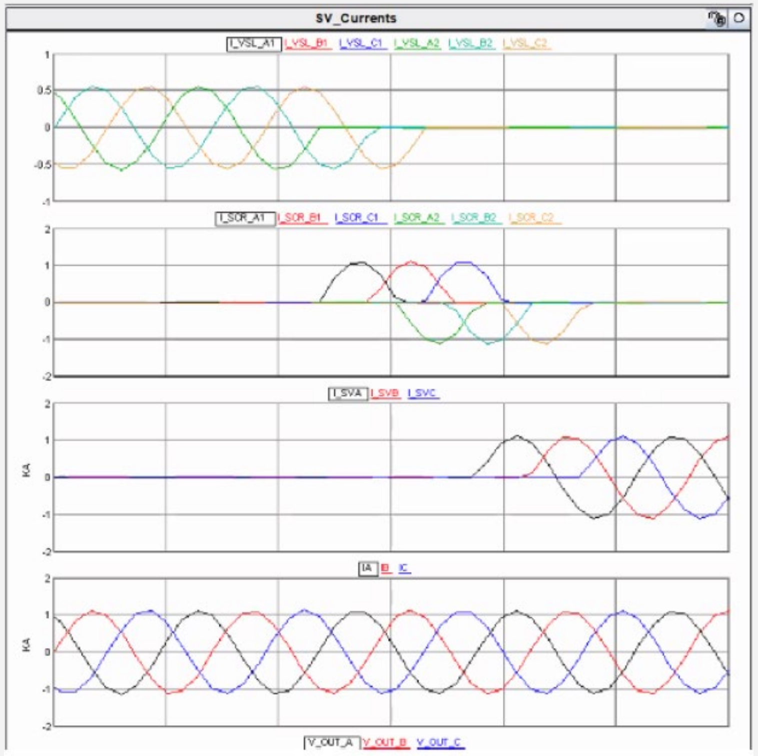
- **Configuration:** C-HIL

- **Description:** The FPT system uses the C-HIL configuration, consisting of a three-phase model comprising a controllable current source and an M-SSSC system.

- **Goal:** The FPT tests demonstrate the basic functional behavior of the M-SSSC system. These tests include steady-state operation, changes in operating setpoints, and transient conditions.

RTDS/HIL TESTS

Functional Performance Test (FPT) - Results



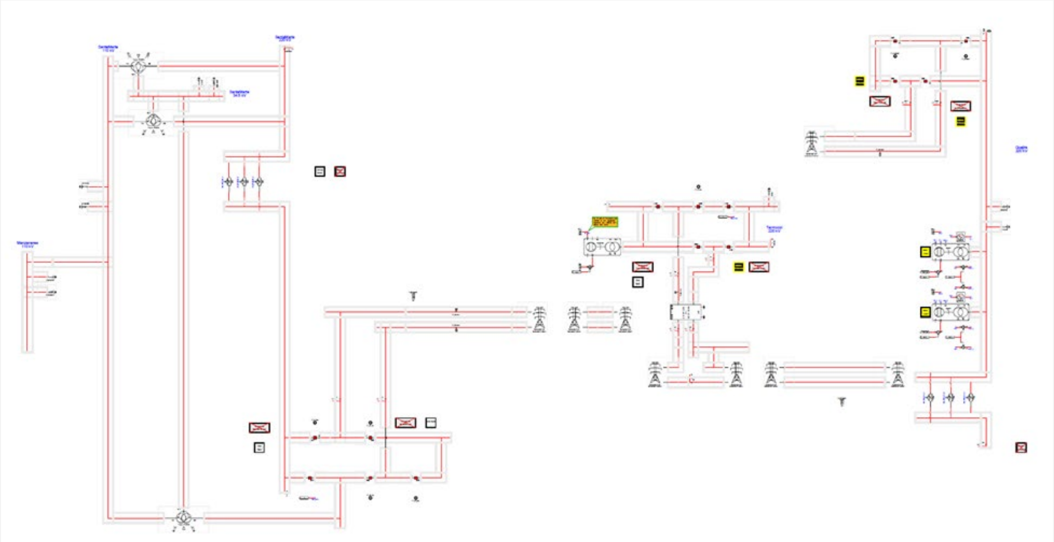
Analysis and discussion:

Transient cases in FPT marked the first firmware modifications to ensure an adequate response of the M-SSSC solution to different disturbances.

The FPT tests also helped to test the performance of the Human Machine Interface (HMI) while testing different online commands and exporting records in COMTRADE format directly from M-SSSC.

RTDS/HIL TESTS

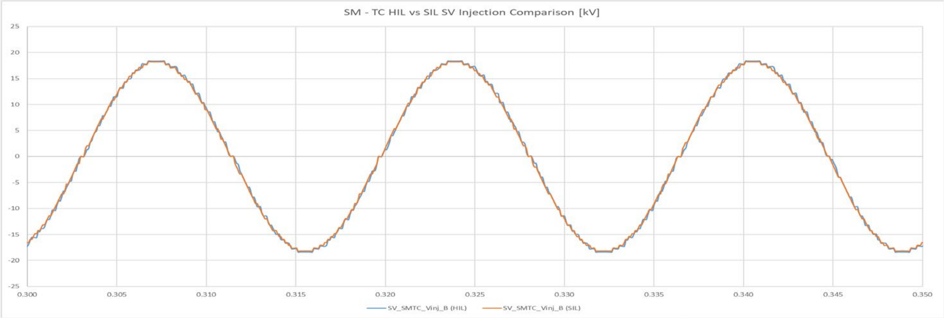
Harmonic Performance Tests (HPT)



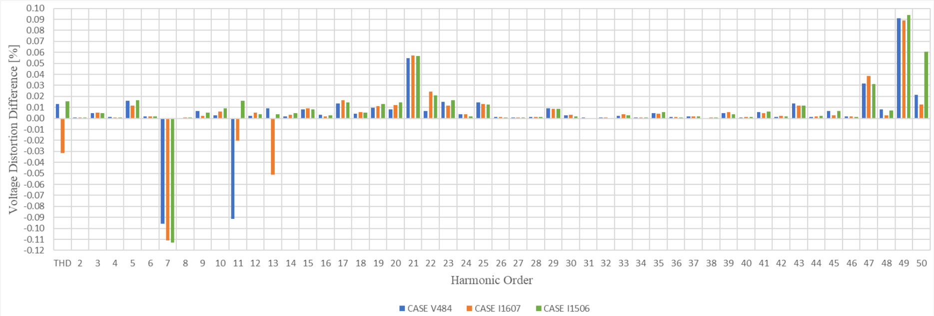
- **Configuration:** C-HIL + SIL
- **Description:** The HPT system includes a scaled-down representation of the customer network ring with frequency-dependent transmission line models and equivalent Foster-Cauer analog circuits from the surrounding network.
- **Goal:** HPT validates the harmonic emissions of the M-SSSC and its response to the background harmonics of the system. The tests use the C-HIL+SIL configuration and monitor the system behavior for a certain range of harmonics measured in the real system.

RTDS/HIL TESTS

Harmonic Performance Tests (HPT) - Results



Comparison of C-HIL vs SIL voltage waveforms



Voltage Distortion Percent Change After M-SSSC

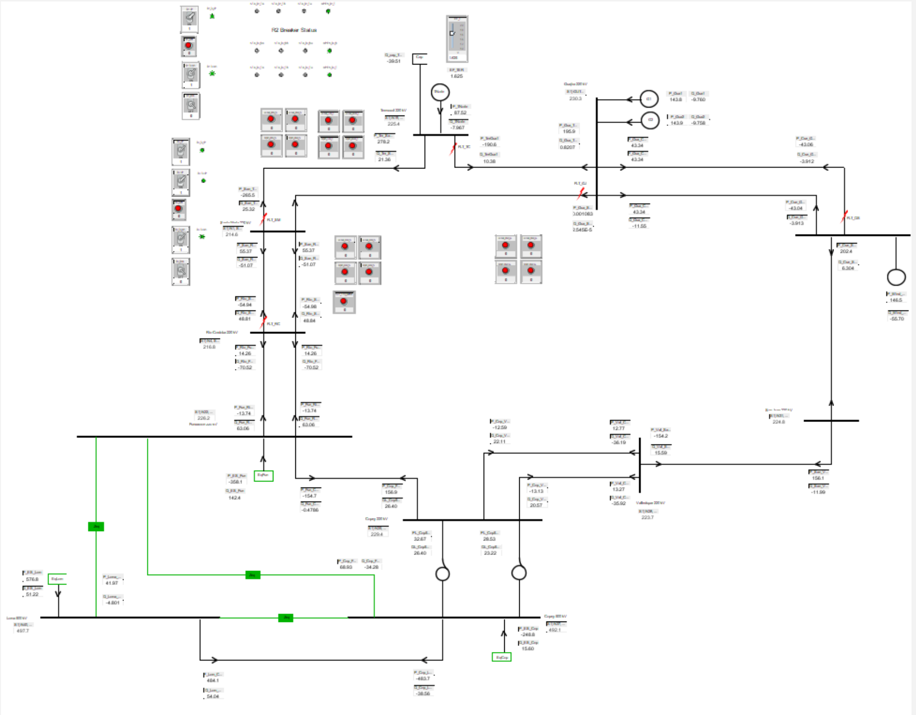
Analysis and discussion:

- The HPT tests confirmed that the algorithms implemented to optimize the converters' duty cycles helped keep the incremental harmonics within the limits allowed for the design.

- The results also showed a good performance of the M-SSSC control system facing real background harmonic conditions. The M-SSSC injects quadrature voltage to its fundamental component for all considered cases.

RTDS/HIL TESTS

Dynamic Performance Study (DPS)



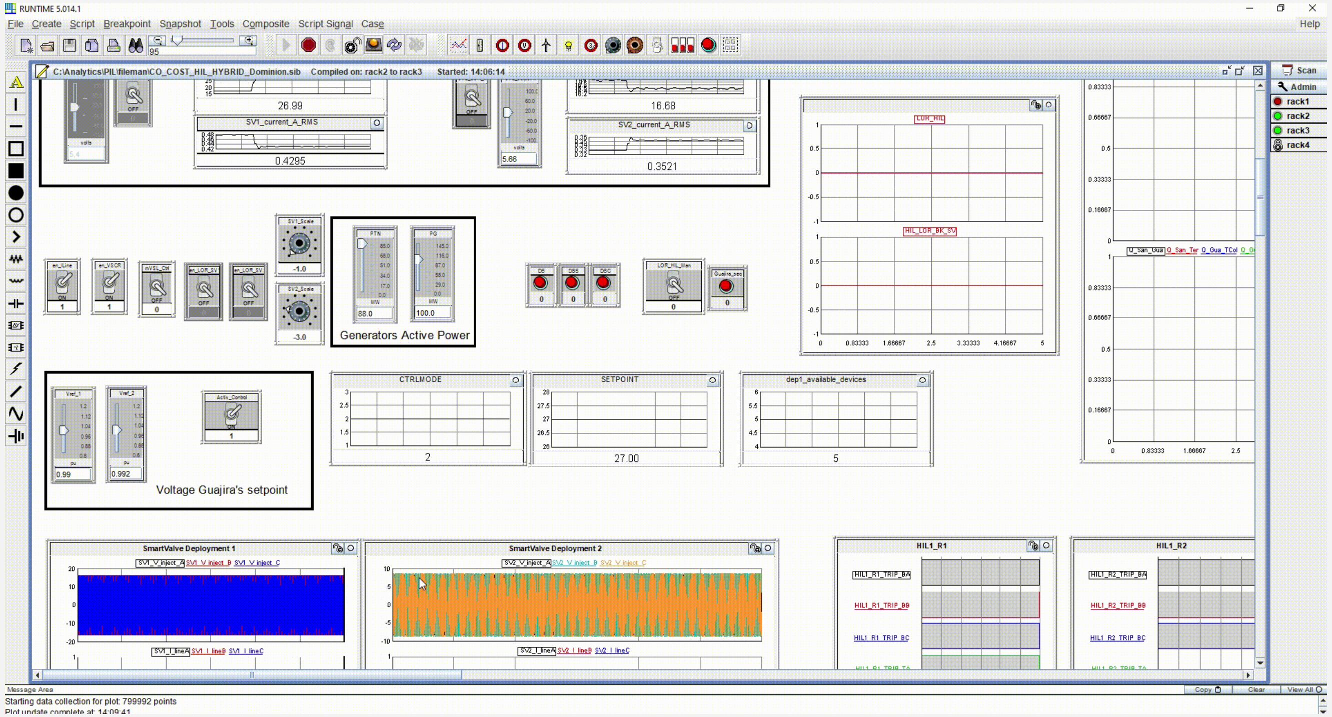
- **Configuration: C-HIL + SIL + PIL**

- **Description:** The project's area of influence is modeled within the RTDS. The accuracy of the network model was tested against load flow results and dynamic simulations using the National Interconnected System database.

- **Goal:** DPT tests use the C-HIL+SIL+PIL configuration to validate the M-SSSC and protection scheme response to realistic and critical system failures.

RTDS/HIL TESTS

Dynamic Performance Study (DPT) - Results



Analysis and discussion:

- The DPT cases were fundamental to finalizing the configurable adjustments of the M-SSSC solutions at the Santa Marta substation.

- The tests captured ISA best practices in protection coordination. They focused on ensuring proper coordination between the M-SSSC bypass actions and components' protection schemes near the M-SSSC installations.

CONCLUSION

- This work summarizes the analysis, design, implementation, and validation of performance tests on the RTDS for a real energy flow control solution based on the M-SSSC in the Colombian electrical grid.

- The tests were fundamental to guarantee a proper integration of the M-SSSC solutions with the existing network, establishing a series of good practices built from the experience of real transmission systems in the ISA group.

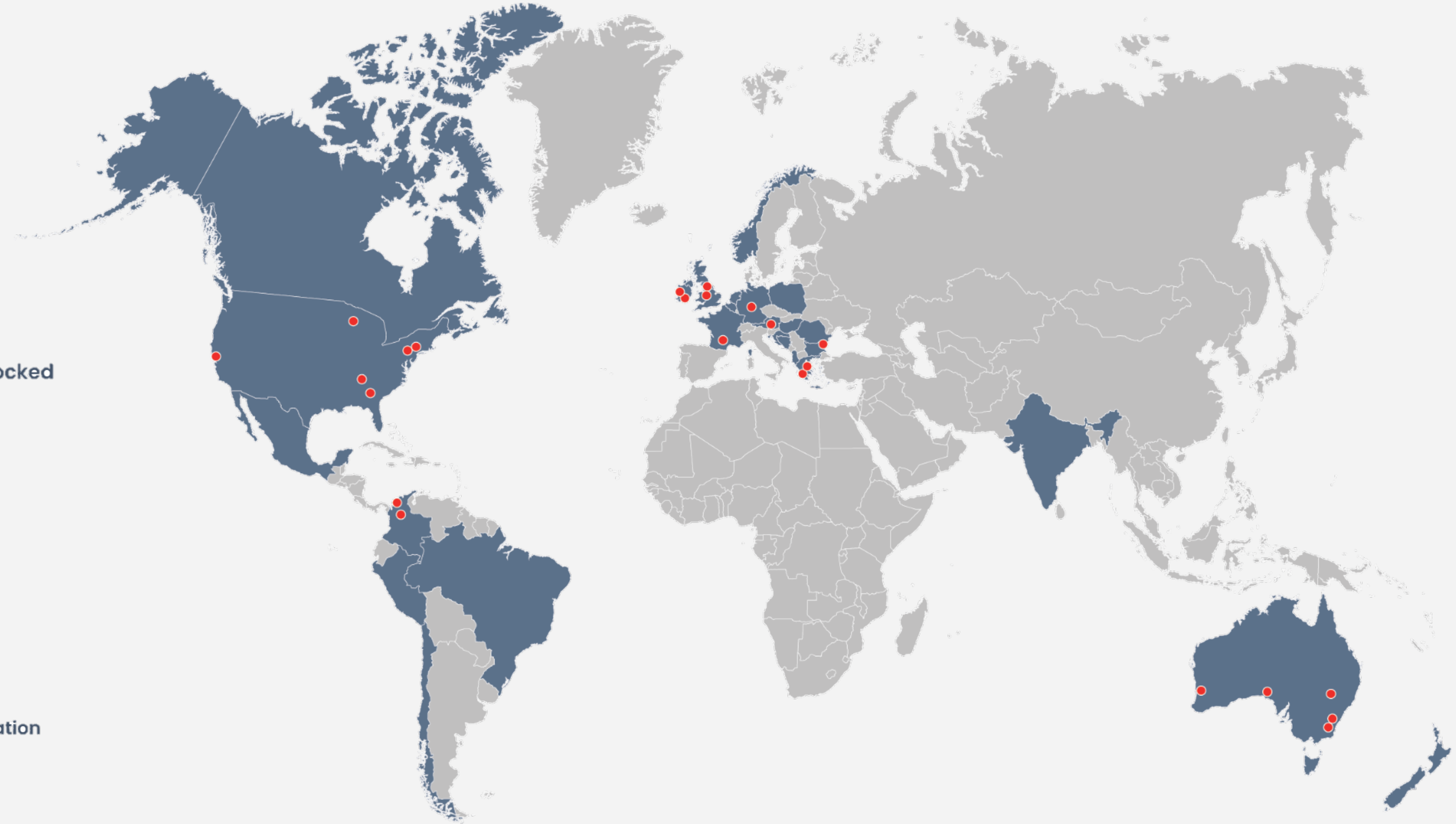
- Relevant aspects identified and resolved during the testing process in the RTDS provided a technical guarantee to consider the M-SSSC as an effective solution with great potential to achieve an optimal and sustainable network that responds to the challenges imposed by the modern paradigm in expanding the transmission network.

3.5 GW

of network capacity unlocked

3,200

device-years of operation



Active markets

Projects in service or in execution

Customers

amprion

People. Power. Possibilities. Central Hudson A FORTIS COMPANY

Grupo Energía Bogotá

PG&E

UK Power Networks

isa

nationalgrid

epm

minnesota power AN ALLETE COMPANY

ipto

ElectraNet

LA DWP Los Angeles Department of Water & Power

AusNet services

EIRGRID

ESO

Rte

ELES

*Logos shown here are for projects with signed contracts, most of which are already installed. Smart Wires is working with an additional 40+ utilities on multi-million dollar projects that are in the late stages of development.