SIEMENS energy

Noedra Atlas

Normative & regulatory compliance: IEC 61850 testing



Na

Noedra Atlas
Energy Advisory



Introduction

IEC 61850 is a globally recognized standard for communication in power systems and substation automation. It enables reliable, high-speed, and interoperable data exchange between Intelligent Electronic Devices (IEDs). In addition to communication protocols, it defines a structured data model and the Substation Configuration Language (SCL), ensuring consistent and efficient system engineering.

As power systems evolve toward digital substations and distributed energy resources, compliance with IEC 61850 is essential for achieving interoperability, performance, and long-term reliability. To support this, specialized testing and validation tools are used throughout the engineering and commissioning process.

The SCL Checker acts as a configuration validation tool, verifying SCL files against the IEC 61850 standard and engineering rules. It helps ensure that system configurations are correct and consistent, allowing issues to be identified early and reducing integration risks.

The Client Simulator enables functional testing by simulating IEC 61850 client services such as reporting, control, and data access. It allows engineers to verify device behavior without requiring a complete system setup, improving efficiency during factory and system testing.

The Performance Testing Device serves as a diagnostic and analysis tool for IEC 61850 networks. It simulates GOOSE and Sampled



Values traffic to perform load and stress testing, while also analyzing network performance parameters such as latency and jitter. In addition, it supports time synchronization analysis (NTP/PTP) and can operate as a PTP Grandmaster, ensuring accurate timing across the system.

Together, these tools provide a comprehensive solution for validating configuration, functionality, communication, and performance. They help ensure robust, standards-compliant systems and support the reliable operation of modern digital substations.



SCL Checker

The SCL Checker is a specialized tool for validating SCL files to ensure full compliance with the IEC 61850 standard, including both schema validation and logical consistency checks. It accurately identifies and highlights configuration errors, enabling fast and efficient troubleshooting.

For large and complex SCL files – often exceeding 10,000 lines – manual verification is time-consuming and error-prone. The SCL Checker automates this process with an extensive, up-to-date test suite aligned with IEC 61850 conformance requirements. It performs comprehensive validations within seconds, significantly improving accuracy, reducing engineering effort, and increasing overall productivity.

Key features

- Supports IEC 61850 Edition 1 and Edition 2
- Executes UCA International Users Group test procedures based on the IEC 61850-10 Standard
- Verifies that the SCL files are well-formed and compliant with the IEC 61850-6 schema
- Compares SCL contents with exposed IED data models and services
- Verifies the presence and order of data according to the IEC 61850-7-3 and 7-4
- Always up to date with the latest UCAIug test procedures
- Uses official namespace description (*.nsd) files to ensure robustness and eliminate tool-related inconsistencies
- Provides graphical visualization of SCL files and IED data models
- Logs test execution progress and results in a clear, human-readable format
- Supports automatic and repetitive validation of SCL files
- Enables fast localization and identification of SCL errors
- Supports remote testing of IEDs (cloud-ready)

Applications

- SCL verification during IEC 61850 device development, system design, integration, configuration, and FAT (Factory Acceptance Testing)
- IEC 61850 conformance and interoperability testing
- Support for IED product development processes
- Preparation for UCAIug IED certification

Benefits

- Fast and fully automated verification of SCL files, including IED data models and services
- Reduces IEC 61850 design and configuration issues during product development, system integration, commissioning, and FAT (Factory Acceptance Testing)
- Supports efficient IEC 61850 device certification, reducing preparation time and costs
- Easy-to-learn and user-friendly interface
- Simple and quick configuration



Client Simulator

The Client Simulator is a versatile and user-friendly tool that enables automated testing of IEC 61850 devices. It provides an extensive test suite with selectable IEC 61850 test cases, along with a comprehensive library of services for interacting with devices and analyzing their behavior.

In addition to standard and conformance testing, the tool allows users to create and customize test scenarios by combining existing building blocks. Its intuitive graphical interface ensures quick adoption, enabling users to efficiently perform testing, diagnostics, and interoperability analysis.

Key features

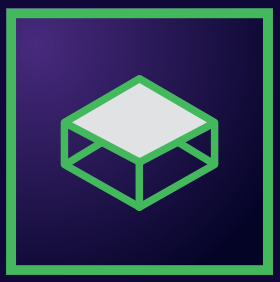
- Supports IEC 61850 Edition 1 and Edition 2
- Supports services including Basic Exchange, DataSet, Reporting, GOOSE, SV, Logging, Substitution, Control Settings, Time Synchronization, File Transfer, and Tracking
- Executes UCA International Users Group (UCAIug) detailed test procedures based on the IEC 61850-10 standard
- Can be integrated into complex testing environments (via console/command-line interface)
- Provides easy control of the testing environment, including Ethernet switches, time servers, power supplies, and secondary injection test sets

Applications

- IEC 61850 conformance testing
- Functional testing of IEC 61850 IEDs and systems
- Support for IED product development

Benefits

- Fast and flexible automated testing of IEC 61850 systems and IED behavior
- Detailed verification of IEC 61850 implementations
- Enables the design and execution of custom test cases through a flexible interface
- Logs test execution progress and results in a clear, human-readable format
- Captures network traffic simultaneously on two network interfaces (recorded in PCAP format for analysis with tools such as Wireshark)
- Advanced GOOSE engine supports publishing of GOOSE messages, including malformed or faulty messages for negative testing
- Enhanced test case editor with syntax highlighting
- Visual representation and interactive access to server data models
- GOOSE message publishing and subscribing
- Network traffic generation for testing and analysis
- Preparation for UCA International Users Group (UCAIug) IED certification
- Simplifies the setup of a conformance testing laboratory
- Enables generation and capture of IEC 61850-specific network traffic, which can be stored for detailed offline analysis



Performance Testing Device

The Performance Testing Device (PTD) enables precise capture and analysis of time-critical behavior in IEC 61850 process bus systems. It validates both Sampled Values (SV) and GOOSE communication, including message structure, timing, and functional performance of publishers and subscribers.

The platform verifies SV synchronization, stream integrity, and responses to disturbances such as delays or packet loss. For GOOSE, it performs accurate timing measurements, including latency analysis using “GOOSE ping-pong” methods.

With high-precision hardware supporting nanosecond timestamping and time synchronization protocols (NTP, PPS, PTP), the PTD also provides detailed network traffic capture for advanced diagnostics. It enables reliable testing under realistic and high-load conditions, ensuring performance, interoperability, and IEC 61850 compliance.

An integrated web-based user interface further enhances usability, allowing simple configuration, execution, and analysis of tests directly via a browser. It enables efficient generation, monitoring, and validation of SV and GOOSE traffic, supports time synchronization configuration, and provides real-time insights along with downloadable data for offline analysis.

Key features

Capture and analysis:

- Supports multiple parallel Sampled Values (SV) streams in accordance with IEC 61850-9-2 LE and IEC 61869-9
- Guarantees up to 106 parallel GOOSE streams (with or without fixed-length encoding)
- Publishing mechanisms are configured using integrated Python scripting within the Client Simulator

Time Synchronization Options:

- Internal clock – uses its internal clock
- NTP (Network Time Protocol) – Synchronization over the Ethernet network interface
- NTP + PPS (Pulse Per Second) – Combination of NTP over Ethernet with an additional PPS signal, PPS (5V TTL) is connected via the RJ45 “COM” port on the device
- PTP (Precision Time Protocol) – High-accuracy time synchronization using IEEE 1588 PTP; can also operate as a PTP Grandmaster clock, providing time synchronization to other devices in the network

Publishing:

- Capture and analysis of multiple simultaneous GOOSE streams
- Includes detailed UCA International Users Group (UCAIug) test procedures
- Test procedures for Sampled Values publishers in accordance with the Implementation Guideline for Digital Interface to Instrument Transformers using IEC 61850-9-2 (9-2LE)
- Ready-to-use testing for IEC 61869-9 Sampled Values publishers and subscribers

Extending Client Simulator Testing:

- GOOSE performance testing based on IEC 61850-5 and IEC 61850-10
- Capture and analysis of Sampled Values streams according to IEC 61850-9-2 LE and IEC 61869-9
- Capture and analysis of multiple simultaneous GOOSE streams

Applications

- Time-domain analysis of GOOSE and Sampled Values behavior
- Validation of GOOSE and Sampled Values publishers and subscribers
- Verification of Sampled Values mechanisms and data formats
- Simulation of multiple GOOSE and Sampled Values communication streams
- Support for IED (Intelligent Electronic Device) product development
- Preparation for UCA International Users Group (UCAIug) IED certification
- IEC 61850 conformance testing

Benefits

- Single-platform solution for validation of MMS, GOOSE, and Sampled Values, including message format, content, functionality, and time-sensitive behavior
- Seamless integration into existing test environments with capabilities for generating, capturing, and storing IEC 61850 network traffic for detailed analysis



Use cases

1. GOOSE Performance Testing

Validating GOOSE message exchange alone does not ensure correct application performance. Testing should include repeated sequences across devices, network topologies, and redundancy scenarios. Timing is critical, especially for trip signals. IEC 61850 defines methods such as the “ping-pong” test to verify timing requirements under both normal and stressed conditions. Testing should be performed in both laboratory and real network environments to account for delays caused by failures and reconfigurations.

2. SV Performance Testing: Publisher (MU) and Subscriber (IED)

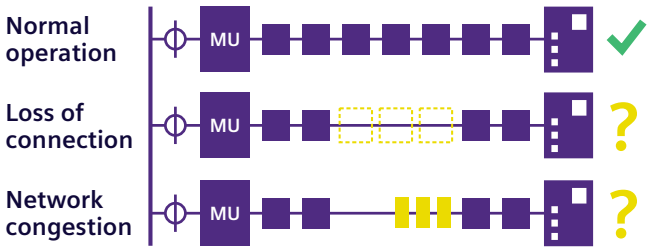
Validation covers three key areas:

- Message content conformity – correct structure of identifiers, values, and quality attributes
- Digital-to-analog consistency – accurate representation of analog signals, including conversion, quality tagging, and synchronization
- Time performance compliance – precise alignment of sampling and publishing with absolute time

SV streams are captured and analyzed to verify packet structure, transmission behavior, and timing, with automated testing improving efficiency and accuracy. An SV subscriber must perform reliably under both normal and unstable conditions. Using configurable simulated SV streams, scenarios such as synchronization loss, delays, or packet loss can be tested. Ensuring stable and predictable behavior under all conditions is essential, and such scenarios can be effectively validated using the performance testing platform.

For example:

- If it loses time synchronization and begins to drift
- If it arrives later than expected
- If packet loss occurs or bursts of packets are received



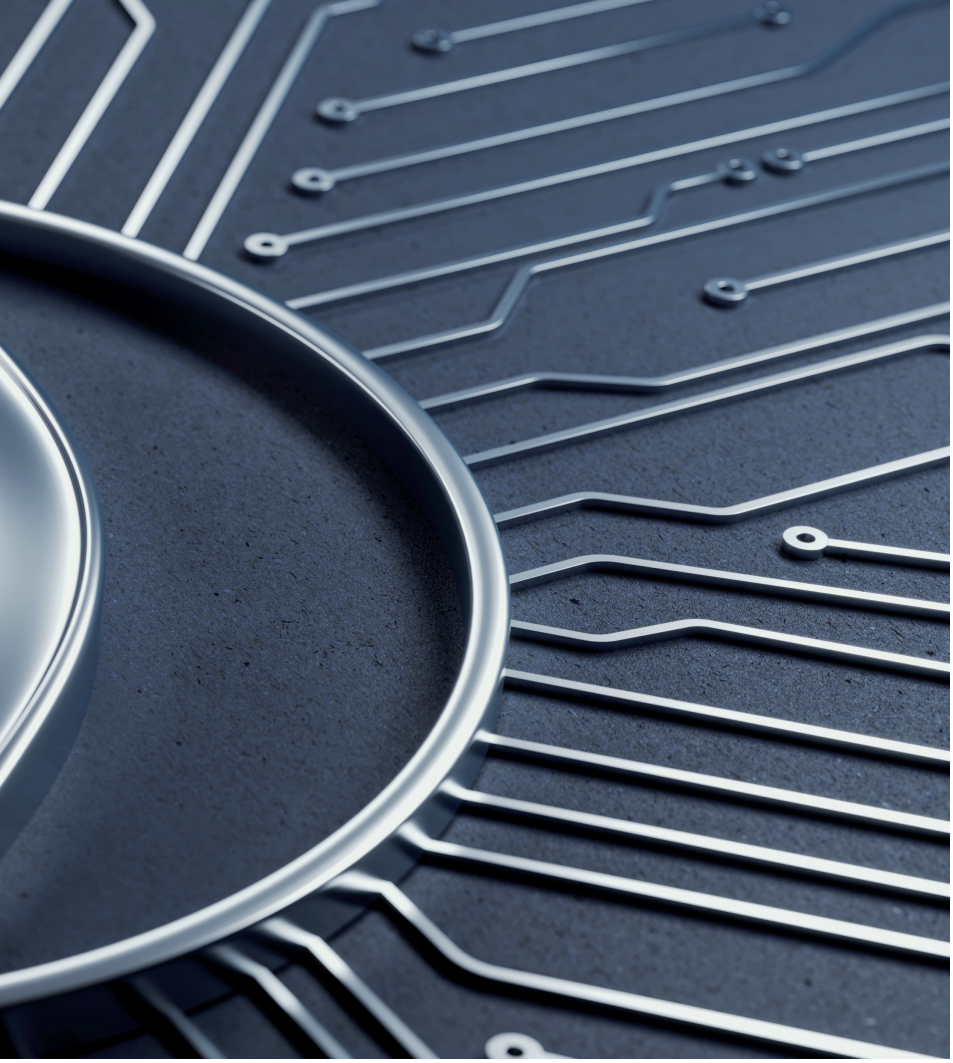


Integration of IEC 62351 Cybersecurity

Our IEC 61850 testing platform also supports testing if cybersecurity requirements in accordance with the IEC 62351 standard series. By incorporating IEC 62351-3 (TLS) and IEC 62351-4 (secure MMS) testing capabilities, the solution enables validation of secure communication channels and compliance with modern substation security requirements. It supports testing of:

- IEC 62351-3 MMS over TLS, focusing on TLS connection establishment and validation, based on the methodologies outlined in IEC 62351-100-3
- IEC 62351-4 End to end secured MMS based on UCAIug comprehensive test procedure, derived from IEC 62351-100-4 requirements

This approach provides users with a structured method to verify both functional and security aspects of IEC 61850 communication.



Key features

- MMS over TLS connection testing in accordance with IEC 62351-3
- Secure MMS communication testing based on IEC 62351-4
- Implementation of UCAIug conformance test procedures (IEC 62351-100-4)
- Automated execution of standardized security test cases
- Validation of certificate handling and authentication mechanisms

Applications

- Cybersecurity validation of IEC 61850-based systems
- Conformance testing for IEC 62351 compliance
- Substation automation system security assessment
- Factory Acceptance Testing (FAT) and Site Acceptance Testing (SAT)
- Interoperability testing of secure IED communications

Benefits

- Ensures compliance with evolving IEC 62351 cybersecurity standards
- Reduces risk of misconfiguration in secure communication setups
- Provides standardized and repeatable security testing procedures
- Enhances confidence in system resilience against cyber threats
- Consolidates functional and security testing within a single platform
- Improves efficiency in validation and certification processes



Published by

Siemens Energy Global GmbH & Co. KG
Grid Technologies
Siemens Promenade 9
91058 Erlangen, Germany

For more information, please visit our website:
siemens-energy.com
or contact us
E-Mail: support@siemens-energy.com
Phone: +49 911 6505 6505
© 2026 Siemens Energy

Subject to changes and errors. The information given in this document only contains general descriptions and/ or performance feature which may not always specifically reflect those described,or which may under go modification in the course of further development of the products. The requested performance features are binding only when they are expressly agreed upon in the concluded contract. All product designations may be trademarks or product names of Siemens Energy Global GmbH & Co. KG or other companies whose use by third parties for their own purposes could violate the rights of the owners.

Siemens Energy is a trademark licensed by Siemens AG.