

# 15 IEC 61850

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# 15.1 Introduction

IEC 61850 is an international standard defining communication protocols for intelligent electronic devices at electrical substations. It is a part of the International Electrotechnical Commission's (IEC) Technical Committee 57 reference architecture for electric power systems. The abstract data models defined in IEC 61850 can be mapped to a number of protocols. Possible mappings in the standard can be MMS (Manufacturing Message Specification), GOOSE (Generic Object Oriented Substation Event), SMV (Sampled Measured Values). These protocols can run over TCP/IP networks or substation LANs using high speed switched Ethernet to obtain the necessary response times below four milliseconds for protective relaying.



As of version v1.5.0, WCC Lite supports MMS type messaging. Logging and groups setting services are not supported.

# 15.2 IEC 61850 Server

WCC Lite can act as a IEC 61850 server to serve data to remote SCADA systems. For example, WCC Lite can be used to acquire data from various protocols (Modbus, IEC 60870-5-103, etc.), this data can be redirected and propagated further to a single or multiple IEC 61850 clients. IEC 61850 Server supports TCP and TLS connection types. TCP connection can be secured with password authentication.

## Commands

WCC Lite **IEC 61850 Server** implementation defines four command types which are described by their control model:

- **Case 1:** Direct control with normal security (direct-operate);
- **Case 2:** SBO control with normal security (operate-once or operate-many);
- **Case 3:** Direct control with enhanced security (direct-operate);
- **Case 4:** SBO control with enhanced security (operate-once or operate-many).

Normal security commands are considered for execution if the command signal is found in Excel configuration. There aren't any additional checks in command execution in any master protocol.

Enhanced security commands need feedback from master protocol to either to succeed or fail. If feedback is not received within **command\_ack\_timeout\_ms** timeframe, the command is considered as failed.

Command value attributes (e.g. stVal) must be updated separately (if they need to be updated).



When using SBO commands, select is not routed to master protocol and select logic is performed only in IEC 61850 Server protocol.

## Configuring datapoints

To use IEC 61850 Server in WCC Lite, it has to be configured via an Excel configuration and data model must be uploaded. This configuration contains two Excel sheets where parameters have to be filled in - Devices and Signals.

### IEC 61850 Server parameters for Devices tab

| Parameter             | Type                       | Description  | Required      | Default value<br>(when not specified) | Range            |     |
|-----------------------|----------------------------|--|---------------|---------------------------------------|------------------|-----|
|                       |                            |  |               |                                       | Min              | Max |
| name                  | string                     | User-friendly name for a device                        | Yes           |                                       |                  |     |
| description           | string                     | Description of a device                                | No            |                                       |                  |     |
| device_alias          | string                     | Alphanumeric string to identify a device               | Yes           |                                       |                  |     |
| enable                | boolean                    | Enabling/disabling of a device                         | No            | 1                                     | 0                | 1   |
| protocol              | string                     | Protocol to be used                                    | Yes           |                                       | IEC 61850 Server |     |
| tls                   | string                     | Selecting if TLS should be used                        | No            | 0                                     | 0                | 1   |
| bind_address          | string (IP address format) | IP address of and interface to use with server         | No            | 0.0.0.0                               |                  |     |
| host                  | string (IP address format) | IP address list of allowed IPs (separated with spaces) | Yes           |                                       |                  |     |
| port                  | integer                    | TCP communication port                                 | Yes           |                                       |                  |     |
| tls_local_certificate | string                     | Local certificate for TLS connection                   | Yes (for TLS) |                                       |                  |     |
| tls_peer_certificate  | string                     | Certificate authority file for TLS connection          | Yes (for TLS) |                                       |                  |     |

|                        |         |   |                               |       |          |  |
|------------------------|---------|---|-------------------------------|-------|----------|--|
| tls_private_key        | string  | File consisting of private key for TLS connection                                       | Yes (for TLS)                 |       |          |  |
| event_history_size     | integer | Event log size  | No                            |       |          |  |
| ied_name               | string  | Name of an Intelligent Electronic Device  | Yes                           |       |          |  |
| authorization          | string  | Authorization type  | No                            |       | password |  |
| password               | string  | Authorization password for server device  | Yes (if authorization is yes) |       |          |  |
| model_filename         | string  | Filename of data model uploaded to WCC (with or without file extension)                 | Yes                           |       |          |  |
| edition                | string  | Which IEC61850 edition to use.  | No                            | 2     | 1,2, 2.1 |  |
| command_ack_timeout_ms | integer | Timeframe (ms) in which enhanced-security commands must be acknowledged (Default: 3000) | No                            | 3000  |          |  |
| report_buffered_size   | integer | Report control blocks buffer size in bytes (Default: 65536)                             | No                            | 65536 |          |  |
| report_unbuffered_size | integer | Unbuffered report control blocks buffer size in bytes (Default: 65513)                  | No                            | 65513 |          |  |

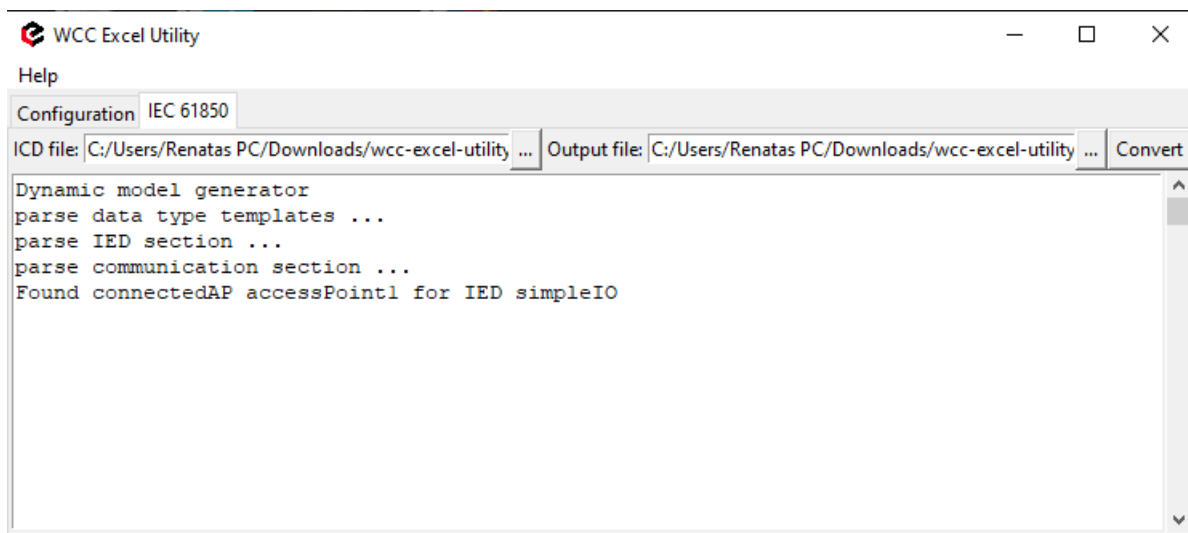
## IEC 61850 Server parameters for Signals tab

| Parameter    | Type    | Description   | Required | Default value<br>(when not specified) | Range |     |
|--------------|---------|---|----------|---------------------------------------|-------|-----|
|              |         |   |          |                                       | Min   | Max |
| signal_name  | string  | User-friendly signal name   | Yes      |                                       |       |     |
| device_alias | string  | Device alias from a Devices tab   | Yes      |                                       |       |     |
| signal_alias | string  | Unique alphanumeric name of the signal to be used   | Yes      |                                       |       |     |
| enable       | boolean | Enabling/disabling of an individual signal  | No       | 1                                     | 0     | 1   |
| log          | boolean | Allow signal to be logged. If <b>log is 0</b> signal will not be logged. If <b>log is more than 0</b> signal will be logged | No       | 0                                     |       |     |
| number_type  | string  | Number format type (BOOLEAN, FLOAT, INT16, etc.)  | Yes      |                                       |       |     |
| Id_instance  | string  | Instance of a logical device  | Yes      |                                       |       |     |
| In_class     | string  | Logical node class type   | Yes      |                                       |       |     |
| In_instance  | integer | Instance of a logical node  | No       |                                       |       |     |


|               |        |                                       |     |             |   |  |
|---------------|--------|---------------------------------------|-----|-------------|---|--|
| In_prefix     | string | Prefix of logical node string         | No  |             |   |  |
| cdc           | string | Common Data Class (CDC) name          | Yes |             | SPS, DPS, INS, ENS, ACT, ACD, MV, CMV, SAV, SPC, DPC, INC, ENC, BSC, ISC, APC, BAC  |  |
| data_object   | string | Name of data object in dataset        | Yes |             |   |  |
| da_value      | string | Name of a data attribute value node   | Yes |             |   |  |
| da_time       | string | Name of a data attribute time node    | No  |             |   |  |
| da_quality    | string | Name of a data attribute quality node | No  |             |   |  |
| da_fc         | string | Functional constrain for data object  | Yes |             | ST,MX, CO, SP   |  |
| control_model | string | Model of output control               | No  | status-only | status-only, direct-with-normal-security, sbo-with-normal-security, direct-with-enhanced-security, sbo-with-enhanced-security |  |

## Converting and uploading data model

To use IEC61850 Server protocol in WCC Lite, user must upload a data model in specific format (file extension .cfg). These data models can be converted from SCL files (.icd or .cid files). To convert a data model, the user must use WCC Excel Utility. There's a separate tab for this operation as shown in picture below.



Converted file can be uploaded in WCC Lite web interface, Protocol Hub section. Current model can be also downloaded in the same page as shown in picture below.

|               |                  |           |          |         |       |               |  |
|---------------|------------------|-----------|----------|---------|-------|---------------|--|
| PROTOCOL HUB  | STATUS           | SYSTEM    | SERVICES | NETWORK | USERS | LOGOUT (ROOT) |  |
| CONFIGURATION | IMPORTED SIGNALS | EVENT LOG |          |         |       |               |  |

### Protocol configuration

#### IMPORT PROTOCOL CONFIGURATION

Here you can import Excel configuration file. Up to 1000 signals are allowed. All previous signals will be replaced.

|                             |   |   |
|-----------------------------|---|---|
| Configuration file:         | <input type="button" value="Choose File"/> No file chosen | <input type="button" value="Import configuration"/>     |
| PLC (IEC-61499) Boot file:  | <input type="button" value="Choose File"/> No file chosen | <input type="button" value="Import FBOOT file"/>        |
| IEC61850 Server model file: | <input type="button" value="Choose File"/> No file chosen | <input type="button" value="Import server model file"/> |

#### DOWNLOAD CONFIGURATION

Current configuration (IEC61850-server-test (1).xlsx):

Template configuration:

Current IEC 61850 Server model file (Elseta\_SimpleIO.cfg):

## Debugging an IEC 61850 server application

If the configuration for IEC 61850 Server is set up, a handler for the protocol will start automatically. If the configuration is missing or contains errors, the protocol will not start. It is done intentionally to decrease unnecessary memory usage.

⚠ If IEC 61850 Server does not work properly (e.g. no communication between devices, data is corrupted, etc.), a user can launch a debug session from command line interface and find out why the link is not functioning properly.

 To launch a debugging session, a user should stop `iec61850-server` process and run `iec61850-server` command with respective flags as you can see below:

```
iec61850-server
```

```
-h [--help] Show help message
-c [--config] arg Configuration file location
-V [--version] Show version
-d [--debug] arg Set Debug level
-r [--redis] Show Redis messages
-C [--commands] Show command messages
-R [--readyfile] arg Ready notification file
```

# 15.3 IEC 61850 Client

WCC Lite can be used as a master station to collect data from IEC 61850 compatible server devices such as protection relays. As relays require fast, secure and responsive interfaces, WCC Lite can be considered as a valid option. For additional security a user can use encrypted transmission (TLS) or set up a password.

As TCP (TLS) connection can encounter issues and break, automatic reconnection is implemented. After every failed reconnection attempt the fallback delay is doubled starting from 1 second up until 32 seconds. After that connection reestablishment will be attempted every 32 seconds until a successful connection.

## Acquiring data via report control blocks

As per IEC 61850 standard, the report control block controls the procedures that are required for reporting values of data objects from one or more logical nodes to one client. Automatic reporting enables data servers (slave devices) to only send data on its (or its quality) change, thus saving network bandwidth. Instances of report control blocks are configured in the server at configuration time.

Report control blocks send information that is defined in their respective datasets. Dataset is a set of data elements grouped to represent some data group. For example, it is a common practice to group measurements and events into different groups.

A server restricts access to an instance of a report control block to one client at a time. That client exclusively shall own that instance and shall receive reports from that instance of report control blocks. There are two classes of report control blocks defined, each with a slightly different behaviour:

- buffered-report-control-block (BRCB) - internal events (caused by trigger options data-change, quality-change, and data-update) issue immediate sending of reports or buffer the events (to some practical limit) for transmission, such that values of data object are not lost due to transport flow control constraints or loss of connection. BRCB provides the sequence-of-events (SOE) functionality;
- unbuffered-report-control-block (URCB) - internal events (caused by trigger options data-change, quality-change, and data-update) issue immediate sending of reports on a best efforts basis. If no association exists, or if the transport data flow is not fast enough to support it, events may be lost.

Buffered report control blocks are therefore useful to keep event data, for example, keeping the last known state of a relay switch where a loss of information might lead to a confusion and even financial losses. Unbuffered report control blocks are particularly useful for data which is useful only momentarily, e.g. measurements of voltages, current or power. This information can change frequently and old measurements might not reflect the real state of a substation.

To allow multiple clients to receive the same values of data object, multiple instances of the report control classes shall be made available.

Buffered report control blocks are usually configured to be used by a specific client implementing a well-defined functionality, for example, a SCADA master. The client may know the ObjectReference of the BRCB by configuration or by the use of a naming convention.

Parsing of report control blocks is based on types of Common Data Class (CDC). Some of these types can have more than one data point of interest. Table below shows what data attributes are supported from various Common Data Classes. To select which data attribute should be used a `da_value` column should be filled with a data attribute name. Common Data Classes consist of data attributes with different Functional Constraints therefore to get the status points of interest correctly the user must fill in a correct value in `da_fc` column.

IEC 61850 Client supported data attributes:

| Common Data Class        | Function Constraint | Data attributes   |
|--------------------------|---------------------|---|
| SPS<br>DPS<br>INS<br>ENS | ST                  | stVal   |
| ACT                      | ST                  | general<br>phsA<br>phsB<br>phsC<br>neut   |
| ACD                      | ST                  | general<br>dirGeneral<br>phsA<br>dirPhsA<br>phsB<br>dirPhsB<br>phsC<br>dirPhsC<br>neut<br>dirNeut |

|                          |    |                  |
|--------------------------|----|------------------|
| MV                       | MX | instMag<br>mag   |
| CMV                      | MX | instCVal<br>cVal |
| SAV                      | MX | instMag          |
| SPC<br>DPC<br>INC<br>ENC | ST | stVal            |
| BSC<br>ISC               | ST | valWTr           |
| APC<br>BAC               | MX | mxVal            |

Some of data attributes are structures themselves, for example, `mag` attribute is a struct that can hold integer or float values. To select a fitting attribute the user should extend `da_value` parameter with additional attributes, for example, if float magnitude value is to be selected from MV Common Data Class, `da_value` column should be filled with `mag.f` value; if the user intends `cVal` magnitude value in float format from CMV Common Data Class, `da_value` should be filled with `cVal.mag.f` value. See IEC 61850-7-3 for more information about Common Data Classes.

To ensure the integrity of configuration, WCC Lite has additional checks implemented at configuration time. If report control block (or its dataset) with a predefined ObjectReference doesn't exist, it is considered that IEC 61850 Client has not been configured properly or configuration has been changed in either of IEC 61850 devices and cannot be matched, therefore should be considered invalid.

## Number Types

IEC 61580 has a distinct `number_type` field when compared to other protocols.

| <b>number_type</b> |
|--------------------|
| BOOLEAN            |
| INT8               |
| INT16              |
| INT32              |
| INT64              |
| INT128             |
| INT8U              |
| INT24U             |
| INT32U             |
| FLOAT32            |
| FLOAT64            |
| ENUMERATED         |
| OCTET STRING 6     |
| OCTET STRING 8     |
| OCTET STRING 64    |
| VISIBLE STRING 32  |
| VISIBLE STRING 64  |



|                    |
|--------------------|
| VISIBLE STRING 65  |
| VISIBLE STRING 129 |
| UNICODE STRING 255 |
| TIMESTAMP          |
| QUALITY            |
| CHECK              |
| CODEDENUM          |
| GENERIC BITSTRING  |
| CONSTRUCTED        |
| ENTRY TIME         |
| PHYCOMADDR         |
| CURRENCY           |
| OPTFLDS            |
| TRGOPS             |

## Controlling remote equipment via commands

The control model provides a specific way to change the state of internal and external processes by a client. The control model can only be applied to data object instances of a controllable Common Data Class (CDC) and whose ctlModel DataAttribute is not set to status - only. Such data objects can be referred to as control objects. If controls are enabled in a IEC 61850 Server device the user can configure controls by filling control\_model column in Excel configuration with a control model (*direct-with-normal-security*, *sbo-with-normal-security*, *direct-with-enhanced-security*, *sbo-with-enhanced-security*) as well as setting functional constraint in da\_fc column to CO.

Depending on the application, different behaviours of a control object shall be used. Therefore, different state machines are defined. Four cases are defined:

- **Case 1:** Direct control with normal security (direct-operate);
- **Case 2:** SBO control with normal security (operate-once or operate-many);
- **Case 3:** Direct control with enhanced security (direct-operate);
- **Case 4:** SBO control with enhanced security (operate-once or operate-many).

IEC 61850 standard enables the user to plan command transmission in advance - set the timer when the command should be issued. However, as this possibility is rarely used in practice, it is not implemented as of version v1.5.0. All issued commands are executed immediately.

For more information on control class model, please consult IEC 61850-7-2 standard.

If ctlModel is read-only, messages from internal database will be ignored for this point, otherwise a subscribe callback will be launched to handle commands as soon as they are sent. If CDC of a signal does not have means of control, ctlModel parameter is ignored.

Originator identification can be attached to a station so that replies to command requests could be forwarded to only one device. To use this functionality a user should select an origin identifier by filling value in Excel configuration, originator column. Originator category is always enforced to tell that remote control command is issued.

## Configuring datapoints

To use IEC 61850 Client in WCC Lite, it has to be configured via an Excel configuration. This configuration contains two Excel sheets where parameters have to be filled in - Devices and Signals tables.

Table IEC 61850 Client parameters for *Devices* tab

| Parameter | Type | Description | Required | Default value<br>(when not<br>specified) | Range |
|-----------|------|-------------|----------|--|-------|
|-----------|------|-------------|----------|--|-------|

|                       |                            |   |               | specified) | Min              | Max |
|-----------------------|----------------------------|---|---------------|------------|------------------|-----|
| name                  | string                     | User-friendly name for a device                   | Yes           |            |                  |     |
| description           | string                     | Description of a device                           | No            |            |                  |     |
| device_alias          | string                     | Alphanumeric string to identify a device          | Yes           |            |                  |     |
| enable                | boolean                    | Enabling/disabling of a device                    | No            | 1          | 0                | 1   |
| protocol              | string                     | Protocol to be used                               | Yes           |            | IEC 61850 Client |     |
| tls                   | string                     | Selecting if TLS should be used                   | No            | 0          | 0                | 1   |
| ip                    | string (IP address format) | IP address of server device                       | Yes           | 0.0.0.0    |                  |     |
| port                  | integer                    | TCP communication port                            | Yes           | 102        |                  |     |
| tls_local_certificate | string                     | Local certificate for TLS connection              | Yes (for TLS) |            |                  |     |
| tls_peer_certificate  | string                     | Certificate authority file for TLS connection     | Yes (for TLS) |            |                  |     |
| tls_private_key       | string                     | File consisting of private key for TLS connection | Yes (for TLS) |            |                  |     |
| event_history_size    | integer                    | Event log size                                    | No            |            |                  |     |
| ied_name              | string                     | Name of an Intelligent Electronic Device          | Yes           |            |                  |     |
| authorization         | string                     | Authorization type                                | No            |            | password         |     |
| password              | string                     | Authorization password for server device          | No            |            |                  |     |
| originator            | string                     | Origin identifier for device                      | No            |            |                  |     |

Table IEC 61850 Client parameters for *Signals* tab

| Parameter    | Type    | Description   | Required | Default value<br>(when not specified) | Range |     |
|--------------|---------|---|----------|---------------------------------------|-------|-----|
|              |         |   |          |                                       | Min   | Max |
| signal_name  | string  | User-friendly signal name   | Yes      |                                       |       |     |
| device_alias | string  | Device alias from a Devices tab   | Yes      |                                       |       |     |
| signal_alias | string  | Unique alphanumeric name of the signal to be used   | Yes      |                                       |       |     |
| enable       | boolean | Enabling/disabling of an individual signal  | No       | 1                                     | 0     | 1   |
| log          | boolean | Allow signal to be logged. If <b>log is 0</b> signal will not be logged. If <b>log is more than 0</b> signal will be logged | No       | 0                                     |       |     |

|                      |         |   |     |             |   |  |
|----------------------|---------|---|-----|-------------|---|--|
| number_type          | string  | Number format type                              | Yes |             |   |  |
| ld_instance          | string  | Instance of a logical device                    | Yes |             |   |  |
| ln_class             | string  | Logical node class type                         | Yes |             |   |  |
| ln_instance          | integer | Instance of a logical node                      | No  |             |   |  |
| ln_prefix            | string  | Prefix of logical node string                   | No  |             |   |  |
| cdc                  | string  | Common Data Class (CDC) name                    | Yes |             | SPS, DPS, INS, ENS, ACT, ACD, MV, CMV, SAV, SPC, DPC, INC, ENC, BSC, ISC, APC, BAC  |  |
| data_object          | string  | Name of data object in dataset                  | Yes |             |   |  |
| da_value             | string  | Name of a data attribute value node             | Yes |             |   |  |
| da_fc                | string  | Functional constrain for data object            | Yes |             | ST,MX, CO, SP   |  |
| control_model        | string  | Model of output control                         | No  | status-only | status-only, direct-with-normal-security, sbo-with-normal-security, direct-with-enhanced-security, sbo-with-enhanced-security |  |
| dataset              | string  | Full object reference of a dataset              | Yes |             |   |  |
| report_control_block | string  | Full object reference of a report control block | Yes |             |   |  |
| intgPd               | integer | Integrity period in milliseconds                | No  | 0           |   |  |



It should be noted that ACT and ACD messages can only be parsed from report if either only 'general' attribute or all attributes attached to all three phases and neutral can be found in report

IEC 61850 Client has an additional signal which can be configured to show communication status. It is used to indicate if the server device has disconnected from client (WCC Lite). To configure such signal, two columns should be filled with particular values. To a newly created additional signal one should make `job_todo` equal to `device_status` and `tag_job_todo` equal to `communication_status`. Communication error status is set after a disconnection of a server device.

## Debugging a IEC 61850 Client application

If configuration for IEC 61850 Client is set up, handler for protocol will start automatically. If configuration is missing or contains errors, protocol will not start. It is done intentionally to decrease unnecessary memory usage.

IEC 61850 Client command line debugging options

```
iec61850-client
```

```
-h [ -help ] Show help message
-c [--config] arg Configuration file location
-V [--version] Show version
-d [--debug] arg Set debugging level
-r [--redis] Show Redis messages
-C [--commands] Show command messages
-D [--datasets] Show dataset messages
--report Show report messages
-R [--readyfile] arg Ready notification file
```



If IEC 61850 Client does not work properly (e.g. no communication between devices, data is corrupted, etc.), a user can launch a debug session from command line interface and find out why link is not functioning properly.



To launch a debugging session, a user should stop `iec61850-client` process and run `iec61850-client` command with respective flags as was shown above.