

Consistency and Completeness Checking of 61850 SCL Files for Compliance and Interoperability

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System Configuration Language (SCL) files are the basis for defining how IEC 61850 devices, interfaces, and systems operate. The usage of SCL files presents an opportunity to create more interoperable devices by following the IEC 61850 standard. However, many compatibility and interoperability issues can be caused by a variety of syntax, formatting, naming, and other issues within SCL files.

For compatibility across IEC 61850 devices, SCL files describe many different aspects of the entire system, including Server Object Models, device settings, connectivity, addresses, reporting, and other configuration settings according to the IEC 61850 standard. Errors in these files can be detected either automatically with a software parsing tool or manually during interoperability testing with equipment. There are several benefits to automating the checking process with a software tool including having more consistent results and reducing the time and effort to test large, complex files. It is nearly impossible to catch all potential issues with a parsing tool, but test coverage can be significantly increased if SCL files are verified in tandem with interoperability testing.

There are many necessary checks to ensure that SCL files describe all of the information needed, in a consistent way, for an IEC 61850 system to interoperate correctly. As a simple example, IEC 61850 Clients read control block definitions to discover and subscribe to available data in the Server Object Model. The ICD File, which defines the Server control blocks, should be checked to ensure that the control block and DataSet definitions follow the conventions set in the IEC 61850 standard and fully resolve in the Object Model. This checking will streamline the publishing and subscription process and improve the interoperability of the Server device with other devices.

Benefits at Different Stages

Checking SCL files at different stages of the engineering process can produce many benefits:

- **IED development:** during the development of IED's, engineers can verify that capabilities of their device are completely defined in the ICD template file. This will benefit users of the device during configuration and help ensure that the development process covers all necessary aspects of the Object Model and services defined by the IEC 61850 standard.
- **IED Configuration:** during the configuration of IED's, control blocks and DataSets can be verified to ensure that interfacing devices can subscribe to messages without interoperability issues. This can greatly reduce the time and effort spent during system debugging.
- **System Configuration:** during lab and field testing, system level configuration can be verified to ensure that, across the whole system, several different instances of IED's are using consistent definitions for control blocks, DataSets, Object Models, and other system level configuration information. Checking IEC 61850 system level configuration in this manner can help avoid unforeseen problems in the field and allow field testing to proceed to other aspects of the system with fewer delays.

SCL Checking Categories

SCL files contain many different configuration aspects for both IEDs and entire systems. All of these configurations could conceivably be verified for consistency and completeness against the IEC 61850 standard. It is therefore helpful to categorize the different types of checks at a very high level. Five major categories are presented below and illustrated in Figure 1 to provide an overall view of what could be checked and what level of difficulty each presents.

Level 5 – Vendor Specific
Level 4 – Substation Level
Level 3 – Communication and Services
Level 2 – Object Model Resolution
Level 1 – Schema Validation

Figure 1: SCL Checking Categories

Level 1 - Schema Validation: this category involves validating the basic syntax rules of XML plus the specific XML Schema defined by IEC 61850-6. These syntax checks can be performed by a variety of XML parsing tools. Validation of the XML Schema is a straightforward check that should be performed, but falls short of validating an SCL file because it is limited to verifying the syntax and structure of the XML language. Above and beyond XML validation, there are several IEC 61850 specific checks that must be validated.

Level 2 - Object Model Resolution: this category includes verification of the Object Model definitions according to IEC 61850 and related standards that are supported by SCL files. Verifying the Object Model can be challenging because it must verify that both a complete definition exists for the Object Model and the minimum set of definitions exists for each Logical Node as specified in the standard. All tokens must resolve throughout the entire hierarchy of the Object Model in order to verify that a complete definition exists for Logical Nodes, Data Objects, and Data Attributes. In addition to the structure of the Object Model, the naming, order, and type of Logical Nodes, Data Objects, Data Attributes, and Enumerations must be verified against applicable standards.

Level 3 - Communication and Services Configuration: this category involves checking the Communication and IED sections of the SCL file, including addressing, control block, and DataSet definitions. Control block verification can include GOOSE, Sampled Values (61850-9-2), reports, and logs.

Level 4 - Substation Level: this category verifies system related configuration in the Substation section of SCL files. These types of checks would be done on System Configuration Definition (SCD) Files or Configured IED Description (CID) Files, where there are higher level system configuration parameters. This category of checking would typically be performed by System Configuration Tools which have an overall view of the entire system and access to the information required to check at this level.

Level 5 - Vendor Specific: this category includes the private fields as well as the use of Generic Process I/O (GGIO) that are allowed by the IEC 61850 standard for further extensibility of the standard. Verification of these sections in SCL files would need to be performed by vendor specific configuration tools which have access to the definitions of vendor specific parameters.

This paper discusses how to address the Level 2 and Level 3 categories listed above. This level of checking is recommended as a first step in publishing an ICD file or using an ICD file from an external source. Substation Level checking (Level 4), as well as other Vendor Specific (Level 5) configurations, are out of the scope of this paper. An explanation of a few key checks are described below to illustrate how to effectively implement some of the Level 2 and Level 3 category checks listed above. Many more checks would be necessary to thoroughly check an SCL file and the examples below are not intended to be exhaustive.

Object Model Resolution

In order to check the Object Model contained in an SCL file, the file must be parsed to verify that both a complete model exists and that the minimum set of definitions for each particular LNodeType exist according to the relevant standard. Standards used for Object Model definitions can include IEC 61850 7-3, 7-4, IEC 61400-25 (Wind Turbines), IEC 61850-7-410 (Hydroelectric Power Plants), and IEC 61850-7-420 (Distributed Energy Resources).

In order to verify that a complete and consistent model exists, the following steps should be followed:

- Verify that the object model can fully be resolved:
 - Check that all tokens resolve to build a completely defined Object Model
 - Verify all instance data in IED section
 - Path is correct and found in object model
 - Initial value is valid based on given type in the object model
 - Initial value is within a valid range based on type
 - If instance data has multiple values (i.e. it is part of a Setting Group) verify:
 - A setting group exists
 - The number of values is less than or equal to the number of setting groups defined
 - Verify that DataSet definitions are resolved by Object Model
 - Verify that all Control Blocks with DataSets defined refer to an existing accessible DataSet in the model
 - Note the existence of a Log and LogControl element. Either both or none should exist.
- Verify DataTypeTemplates section across LNodeType, DOType, DAType, and EnumType:
 - Check for empty or not found attributes for example: id, cdc, InClass, name, bType
 - Verify bType is valid
 - Verify if bType is a struct or enum then the type attribute exists
 - Verify there are no duplicate templates present in the object model
 - Flag any unused types
 - Note any custom cdc or InType items
- Verify the Object Model definition against the standard:
 - Check that mandatory elements are present (IEC 61850-7-3, -7-4, -7-4XX)
 - Check type and functional constraints (IEC 61850-6, -7-3)
 - Find any name, order, and type inconsistencies for LogicalNodeType, DOType, DAType, and EnumType (IEC 61850-6, -7-2, -7-3, -7-4, -7-4XX)

Communication and Services Configuration

In order to check the Communication and Services sections of the SCL file, the following naming and consistency checks should be performed:

- Match access points and their Logical Device in the IED to their corresponding communication section

- Verify that any GOOSE or Sampled Values control blocks have corresponding definitions in the communication section with valid addressing
- Verify Services section and flag mismatches between the IED control blocks and the services sections description, including:
 - IED has a Report Control block but no reporting services defined
 - IED has more report control blocks than its defined maximum
 - Services do not allow dynamic DataSet to be defined at runtime but does not define any DataSets in the IED
 - Report Settings do not allow dynamic configuration of the DataSet, however no DataSet is set in the IED report control

SCL Checking Resources

Many vendors provide some form of SCL checking built into their IEC 61850 related tools which provide a wide variety of checks to ensure that SCL files can be loaded into devices without causing configuration issues. There are a few SCL checking tools that were designed to operate independent of vendor specific configuration tools. Examples of tools which provide this functionality are available from vendors GridClone, DNV GL, Siemens, and Triangle MicroWorks.

Triangle MicroWorks offers a free, on-line tool which implements all of the Level 1, 2, and 3 checks outlined in this paper. The free tool, SCL Consistency and Completeness Check (C&C Check), performs Object Model checking against the following standards: IEC 61850 7-3, 7-4, IEC 61400-25 (Wind Turbines), IEC 61850-7-410 (Hydroelectric Power Plants), and IEC 61850-7-420 (Distributed Energy Resources). The tool also checks Control Blocks, DataSets, Services, and Access Point definitions. SCL C&C Check is provided as a free, on-line service at <http://www.TriangleMicroWorks.com/SCLWebCheck> to help promote interoperability of IEC 61850 devices and systems.