Improving IEC 61850 interoperability and simplifying IED configuration through the standardisation of protection settings

Q. HONG[1*], V.M. CATTERSON[1], S.M. BLAIR[1], A. DYŚKO[1], C.D. BOOTH[1], T. RAHMAN[2]
[1] University of Strathclyde, [2] National Grid
UK

SUMMARY

One of the key benefits of IEC 61850 is that it can facilitate interoperability between Intelligent Electronic Devices (IEDs) from different vendors. However, at present, the scope of interoperability is constrained to communications data, such as Sampled Value (SV) and Generic Object Oriented Substation Events (GOOSE) messaging, and has not been extended to protection setting information. The protection functions are implemented using proprietary parameters and are typically stored in vendor-specific binary files, which make it very difficult to manipulate these data directly from external applications. Engineers must also understand the meaning and implications of modification of all proprietary setting parameters and often need to be trained in the use of vendor-specific tools, which is time consuming and potentially increases the risk of introducing protection setting errors. Furthermore, the existing IED configuration process is complex, involves many steps, and requires the use of various software tools.

To address these problems, this paper proposes the use of the IEC 61850 data model and System Configuration description Language (SCL) to represent protection settings. The proprietary protection settings data are mapped to the IEC 61850 standardised data and saved as SCL files. The common representation of protection settings in SCL files can also be interpreted and converted back to proprietary settings, thus achieving protection setting interoperability. A prototype tool that implements the process has been developed and demonstrated by the authors. In the paper, the entire process is described using examples.

The SCL files, based on an XML syntax that can be easily manipulated automatically by applications such as protection coordination tools, are used to streamline the existing IED configuration process. A simplified IED configuration process using the SCL based setting files is proposed in the paper. Compared with the existing process, the new process is significantly streamlined, and permits an IED-independent system configuration tool to carry out the entire configuration process. No proprietary software or communications are needed. It also allows the protection settings to be performed at a system level, rather than individually on a “per device” basis.

q.hong@strath.ac.uk

The key challenges that must be addressed in order for the proposed process to be widely adopted are: the IEC 61850 data model for protection settings is not complete; vendors may prefer to maintain proprietary formats; the data model should have the capability to be extended for future protection functions. This paper reports the progress towards addressing these challenges.

KEYWORDS

IEC 61850- Power system protection-Standardisation-Interoperability

1. INTRODUCTION

One of the key benefits that IEC 61850 provides is interoperability across IEDs from different vendors [1]. However, presently only interoperability for communications data, such as SV and GOOSE messaging, has been achieved. The protection setting information is still represented using proprietary parameters and is typically stored in vendor-specific file formats. Therefore, interoperability for protection settings has not been achieved.

The protection setting process is typically carried out using vendor-specific software, which brings significant inconvenience. The appropriate tool for each vendor must be available. Engineers must be trained to use the appropriate vendor’s software. When replacing one vendor’s device with another, all settings must be recalculated and re-applied, which is time consuming and could potentially introduce errors. The number of proprietary file formats makes it difficult for utility companies to develop a consistent data management system, which normally requires the file format to be uniform. Finally, the proprietary setting file formats can be difficult to manipulate directly with computer applications, which is not an efficient arrangement.

Further to these issues, the present IED configuration process, as defined in IEC 61850-6 [2], is complex. It involves many steps using system configuration software and vendor-specific IED configuration software. Some negative comments about the difficulties that can be experienced during the configuration process have been made [3] . There is also existing work trying to simplify the present configuration process [4, 5] .

To tackle these practical problems, the authors propose the use of the data model and SCL provided by IEC 61850 [2, 6-8] to represent protection settings. Proprietary protection setting data are mapped to the IEC 61850 data model and stored in SCL files. The SCL files, carrying standardised protection setting data, can be interpreted and mapped back to proprietary settings for other types of IEDs to achieve protection setting interoperability. A previous paper described this process at a high level [1]; this has now been implemented and a working prototype tool that can automatically perform the process has been developed. The authors also propose a new IED configuration process by using SCL-based setting files, which is significantly streamlined compared with the existing process. The SCL files, based on XML syntax, can thereby be easily manipulated by computer applications, such as protection testing and coordination tools [9].

The paper is organised as follows: section 2 introduces the use of the IEC 61850 data model for storing protection settings; section 3 presents the methodology to represent proprietary settings using the IEC 61850 data model, saved as SCL files, and to convert this representation back to proprietary settings; section 4 describes the simplified IED configuration process using the SCL-based setting files; and section 5 presents challenges associated with the proposed work, possible solutions to these challenges, and future work.

2. IEC 61850 DATA MODEL FOR PROTECTION SETTINGS

IEC 61850 provides a standardised data model to facilitate interoperability across IEDs from various vendors. Application functions are decomposed into the smallest possible entities, termed logical nodes (e.g., a distance protection zone). Multiple logical nodes build a logical device (e.g. a virtual protection device in an IED) and multiple logical devices then compose a physical device (e.g., a physical IED) [1]. There are 30 logical node definitions for protection functions, e.g. logical node "PDIS" for the distance protection function [8]. Within the logical nodes, there are data objects representing the settings, e.g. "DirMod" represents the direction mode in logical node "PDIS". The data objects are instances of common data classes (CDCs) as defined in IEC 61850 7-3 [7], which contain a set of data attributes to describe more detailed information e.g. unit, maximum, and minimum values.

Currently, the logical nodes are widely used, e.g. in IED Capability Description (ICD) files, to indicate the IED's capability, but not used for storing protection settings. Vendors may use some of the standardised data objects, but these are typically not used for protection settings. The process of specifying protection settings is instead performed separately in vendor-specific software, using proprietary files to store the data.

One of the main reasons for the existing approach is that the data model for describing protection functions is not complete. In the existing protection logical nodes, the relevant setting data objects are defined as optional [10] and because different vendors have different algorithms and capabilities with different parameters, the data objects are often not sufficient to describe the existing protection characteristics.

There are on-going activities to suggest extensions to the IEC 61850 data model for protection settings [9, 11]. The IEEE Power System Relaying Committee Working Group H5 (PSRC WG H5) published a report [11] that proposes a data model for describing the distance protection function and suggests the use of IEC 61850 SCL files as a common format for IED configuration. The newly proposed logical node for distance protection provided by PSRC WG H5 allows description of the majority of features and characteristics. In this paper, it will be used to demonstrate the proposed approach.

3. REPRESENTING PROTECTION SETTINGS USING IEC 61850 FOR IMPROVED INTEROPERABILITY

Existing IEDs use proprietary parameters to describe protection functions. To represent these data in the IEC 61850 data model, a mapping relationship between the proprietary data and the IEC 61850 standardised data model must be constructed.

The overall process, illustrated in Fig. 1, was originally proposed in [1], and has now been implemented within a prototype tool. This paper refines the mapping process into two stages, and details an approach to the automatic generation of SCL files. The section concludes by introducing a method of converting the SCL files back into proprietary formats to achieve setting interoperability.

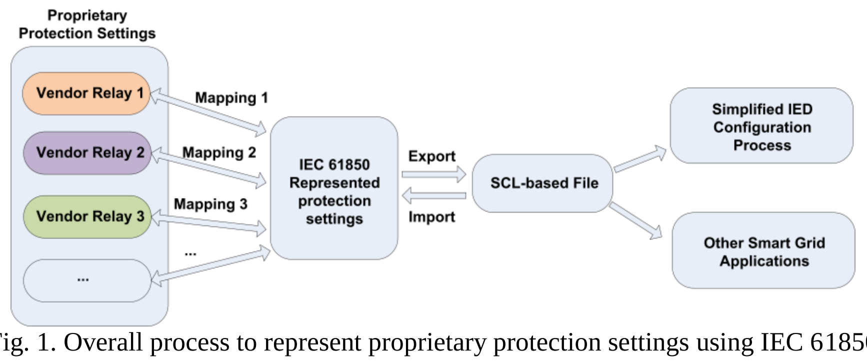

Fig. 1. Overall process to represent proprietary protection settings using IEC 61850

3.1 Mapping from proprietary settings to IEC 61850 data model

1) Initial modelling of IEDs to align with the IEC 61850 modelling approach

Most existing IEDs implement multiple protection functions. The ways of grouping the setting parameters vary between vendors, and typically do not directly match the IEC 61850 modelling approach. Therefore, the original IED's setting parameters must be regrouped to better match the IEC 61850 data model. The regrouping process will be referred to as initial modelling of the original IED to distinguish it from the later modelling process using IEC 61850. The initial modelling is illustrated in an example shown in Fig. 2.

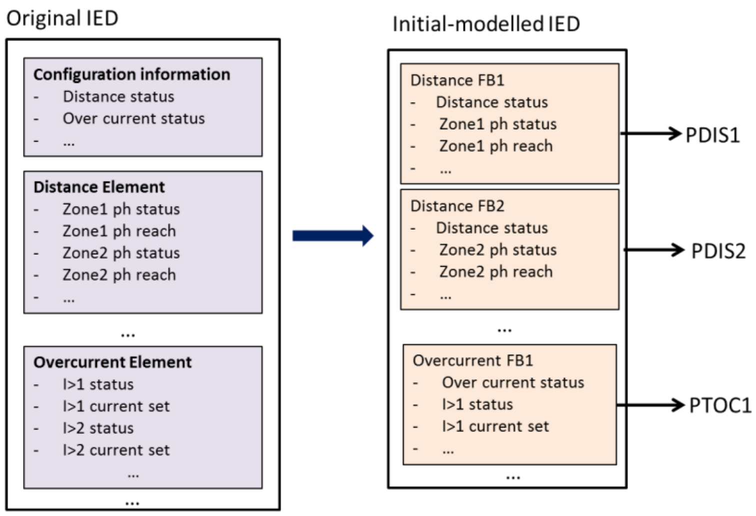

Fig. 2. Re-grouping of setting parameters to better match IEC 61850 data model

The original IED organises the settings into different sections, as shown with boxes in Fig. 2. Some of the settings in the configuration information section are shared by several protection elements. For example, the setting "Distance status" is shared by all distance protection zones to indicate whether the distance function is enabled or not. In the IEC 61850 data model, each distance protection zone is modelled as a PDIS logical node, which contains all of the settings including the zone-specific settings (e.g. zone reach) and the general settings for all zones (e.g. distance status). The initial modelling regroups the setting parameters into function blocks, which contain all settings that are relevant to the protection element to better match the IEC 61850 modelling approach. As shown on the right side of Fig. 2, "Distance FB1" means distance protection function block 1, which contains all settings of distance protection phase zone 1 that are needed to initialise the logical node PDIS. "Overcurrent FB1" means overcurrent function block 1 and it matches to the time overcurrent protection logical node "PTOC" [8].

The initial modelling process organises the settings in an object-oriented style, which lends itself well to implementation in an object-oriented programming language such as Java [12]. It also makes it more convenient to update the mapping relationship if there are extensions and changes to the data model in the future.

2) Mapping from proprietary settings to IEC 61850 data objects

The mapping relationships are built between the proprietary setting parameters grouped in function blocks and the data objects within the logical nodes. Fig. 3 shows an example of the mapping for one particular IED's [13] Zone 1 (Phase) positive impedance reach (Z1 Ph. Reach), which is represented by "PsImRch" data object in PDIS logical node. In this case, the mapping relationship is straightforward, i.e. the magnitude of PsImRch equals the primary value of Z1 Ph. Reach.

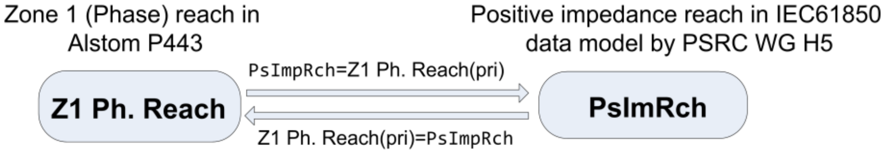

Fig. 3. Bi-directional mapping of positive impedance reach

In some cases, there are data objects defined in the logical node but no corresponding settings can be found on a particular vendor's IED. This is usually because the capability of the IED does not provide the settings. For example, the PDIS logical node describes the "Quad" characteristics with a data object "NgRisRch" to give the negative resistive reach [11]. However, in one specific IED [13] , the negative resistive reach is fixed at a value of 25% of the positive resistive reach. This type of information usually has to be obtained from the user manual or the technical support of the vendors. In such cases, the data objects will be set according to the information provided by manufacturers, and no mapping needs to be built.

There are also cases where no data object defined within the logical node is able to represent a setting on a particular vendor's IED. This is usually because the setting is related to a vendor-specific function, e.g. one particular manufacturer's dynamic "tilt top line" functions [13]. In such cases the information will be lost, but since the functionality itself is not interoperable, it therefore cannot be specified for another IED.

3.2 Saving protection setting data in SCL files

The mapping process as described in the previous section has been implemented using Java. IEC 61850-6 provides XML schema for its data model. By using the open source software Eclipse Modelling Framework (EMF) [14], the schema can be imported and a Java code representation of the data model can be automatically generated. During the mapping process, an instance of the model is created and assigned with details from mapping results, i.e. the IED is assembled with the relevant logical nodes and the values for data objects and their data attributes are assigned. EMF also performs the conversion between Java objects and SCL files automatically, as described in [15]. Therefore, the Java object form of SCL data can be easily exported using EMF as SCL files, which is based on XML syntax and is ready for other applications, such as protection coordination tool [9].

3.3 Converting IEC 61850 data to proprietary settings

To achieve interoperability of protection settings, the IEC 61850 setting data must be convertible back to proprietary settings. The destination format may be for a different vendor's device than the original source of the protection setting data. The overall process, as illustrated in Fig. 4, involves the following steps:

1) Import the ICD file to evaluate which logical nodes are available.
2) Match the logical nodes to the local functions. For example, PDIS logical nodes are matched to the local distance protection zones. If there are logical nodes in the ICD file but no local function is found, the logical nodes will not be processed. If there are local functions but no logical nodes specified in the ICD file, the local function settings will need to be set manually.
3) Map the data objects in the logical nodes to the local settings. Depending on the capability of the local IED, some information carried by the ICD file may be missing, e.g. one specific IED [16] uses a parameter to set its phase and ground reach; if there are different phase and ground reaches for a protection zone presented in ICD file, the user has to choose which one should be the local zone reach.

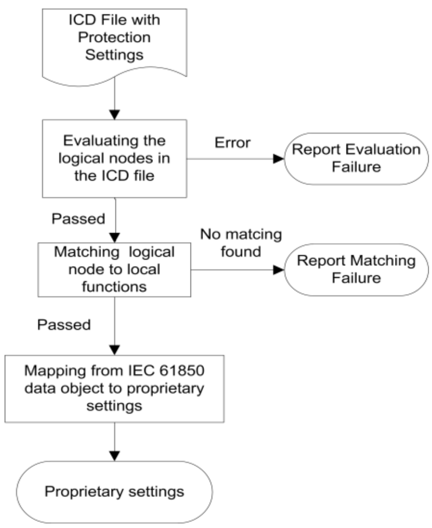

Fig. 4. Overall process to convert the setting data from SCL files to proprietary settings

4. SIMPLIFYING THE EXISTING IED CONFIGURATION PROCESS

An important benefit of SCL-based protection setting storage is the corresponding simplification of the system configuration process. The existing IED configuration process is complex. The configuration of communication functions and setting of protection functions requires various software tools, with the data stored in various formats. By representing the protection setting using IEC 61850, all configurations and setting data can be stored in a single SCL file. The IED configuration process can also be significantly streamlined.

4.1 Existing IED configuration process

Fig. 5 shows the existing IED configuration process. The ICD files are typically generated by the vendor-specific IED configuration tools. The system configuration tool, which is IED-independent, imports the ICD files and System Specification Description (SSD) file to perform system level configuration, e.g. adding information shared by all IEDs. A System Configuration Description (SCD) file is generated from the system configuration and feeds back to the IED configuration tool for IED specific configuration, e.g. communication parameters configuration [17]. The protection setting process is typically performed separately from the IED configuration in the vendor specific IED configuration tool, and the settings data are also stored separately in proprietary files.

There are several significant issues with this process: it involves using various vendor specific software tools; the system configuration, IED configuration, and protection settings are separate steps; configuration data are stored in different file formats; and many steps must be performed to fully configure an IED.

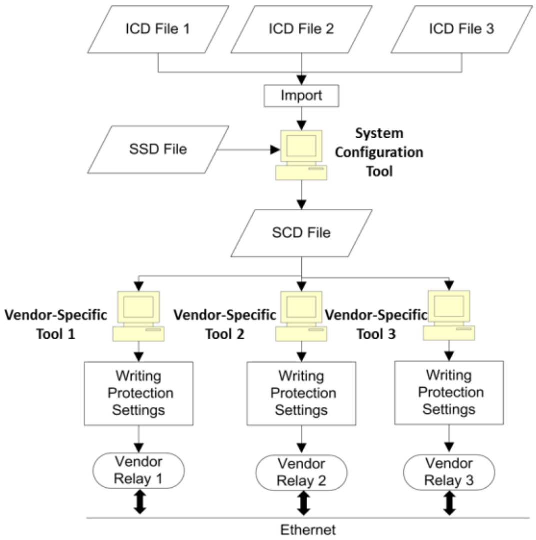

Fig. 5. Existing IED configuration process [1]

4.2 Simplified IED configuration process

By representing protection setting data using the process described in this paper, a simplified IED configuration process is illustrated in Fig. 6 [1]:

1) Legacy devices require the proprietary format to be converted to an SCL-based setting file, using the process described in Section 3. New IEDs with setting data stored as SCL format do not need this step.
2) The resulting SCL-based ICD file is read into the system configuration tool. Configuration at system planning level is performed, without vendor-specific details being considered.
3) The SCD (System Configuration Description) file is imported directly to each IED.
4) IEDs retrieve and apply protection settings automatically from the SCD file.

The proposed IED configuration process is significantly streamlined compared with the existing process. The system configuration, IED specific configuration, and protection settings can all be performed using an IED-independent system configuration tool. No proprietary software or communications protocols are required. All the configuration data including protection settings are stored in SCL files.

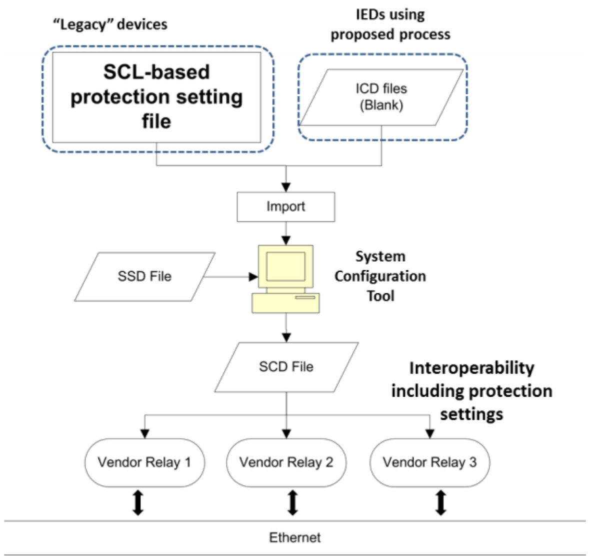

Fig. 6. Simplified IED configuration process

5. CHALLENGES AND POSSIBLE SOLUTIONS

To adopt the approach described in this paper, there are a number of challenges to address. Firstly, as identified in [1], the IEC 61850 protection functions data model is not complete. For example, for distance protection, the PDIS class does not provide a way of describing the shape of the characteristic used (Mho, Quadrilateral, etc.). This is now being partially addressed by the IEEE PSRC Working Group's extensions to the standard [11]. However, more work is needed to provide a comprehensive data model.

Second, manufacturers may prefer to use their own proprietary file formats and proprietary setting parameters, both for business strategy and to offer freedom to develop innovative functions without being constrained by the standard [1]. Given the compelling benefits of standards-conformant data representation, the authors believe it is the trend for future IEDs to use common format for protection setting representation and storage. The prototype tool developed by the authors provides an initial methodology for realising this future approach. In the meantime, the data model should allow extensions for future protection functions. One approach that may offer an acceptable compromise is for each vendor to provide its own IEC 61850 logical node description of any device's new functions. This allows vendors to develop and describe new functions, while interoperability is maintained for the standardised functions [1].

While the proposed approach includes support for legacy devices, it is believed the process is most practical for new substations with modern IEDs, rather than for retrofitting to existing substations.

6. CONCLUSIONS

This paper proposes the use of the IEC 61850 data model and its SCL file format to represent protection settings. A process that maps the proprietary settings to a common representation of data, saves the data as SCL files, and can convert the data back to proprietary settings, has been developed and implemented. The key benefits are that full interoperability and interchangeability among different vendors' IEDs is achieved; the IED configuration process becomes significantly simpler without the need for proprietary software; and comprehensive protection setting information, exported in SCL-based files, becomes available for multiple software applications.

To achieve the proposed approach, there are also attendant challenges. The existing IEC 61850 data model does not provide a full description of all protection settings presently used by each vendor, and IED vendors may prefer to persist with proprietary file formats. Furthermore, the data model has to be extended to cover future protection functions. However, a prototype tool has been implemented which demonstrates that the methodology is feasible. More work is needed to develop a comprehensive data model to realise the compelling benefits of adopting this process.

BIBLIOGRAPHY

[1] Q. Hong, S. M. Blair, V. M. Catterson, A. Dysko, C. D. Booth, and T. Rahman, "Standardization of power system protection settings using IEC 61850 for improved interoperability," in *Power and Energy Society General Meeting (PES), IEEE*, 2013, pp. 1-5.

[2] IEC, " IEC 61850-6: Configuration description language for communication in electrical substations related to IEDs," 2 ed, 2010.

[3] N. R. Burnham, "Network Rail and IEC 61850, A User's Perspective of the Standard," presented at the 11th IET International Conference on Developments in Power System Protection(DPSP), Birmingham, UK, 2012.

[4] A. Apostolov, "Simplifying the configuration of multifunctional distribution protection and control IEDs," in *Electricity Distribution, 2005. CIRED 2005. 18th International Conference and Exhibition on*, 2005, pp. 1-4.

[5] E3 - Spanish Electricity Companies for Studies on IEC 61850, "Minimum common specification for substation protection and control equipment in accordance with the IEC 61850 standard," Jun 09, 2010.

[6] IEC, "IEC 61850-1: Introduction and overview," 1 ed, 2003.

[7] IEC, "IEC 61850-7-3: Basic communication structure –Common data classes," 2 ed, 2011.

[8] IEC, "IEC 61850 7-4: Basic communication structure —Compatible logical node classes and data object classes," 2 ed, 2010.

[9] A. Apostolov and B. Vandiver, "On the standardization of distance characteristics," in *Power Systems Conference: Advanced Metering, Protection, Control, Communication, and Distributed Resources, 2007. PSC 2007*, 2007, pp. 209-212.

[10] ENTSOE. (Jan 04, 2014). *IEC61850 TaskForce - Punch List*. Available: http://www.entsoe.eu/fileadmin/user_upload/_library/news/IEC61850_standard/121018_PunchListTF61850_15102012V4.pdf

[11] Wroking Group H5, "Common Format for IED Configuration Data " IEEE Power System Relaying Committee, 2013.

[12] Java. (Jan 06, 2014). Available: http://java.com/en/

[13] AlstomGrid. (Dec 19, 2013). *Alstom MiCOMho P443 Technical Manual*.

[14] EMF. (Eclipse Modeling Framework Project, Oct 26,2013). Available: http://www.eclipse.org/modeling/emf/

[15] S. M. Blair, F. Coffele, C. D. Booth, and G. M. Burt, "An Open Platform for Rapid-Prototyping Protection and Control Schemes With IEC 61850," *Power Delivery, IEEE Transactions on*, vol. 28, pp. 1103-1110, 2013.

[16] ABB. (Dec 19, 2013). *Line distance protection REL670 technical reference manual*. Available: http://search-ext.abb.com/LibraryDownloadManager/Default.aspx?resource=http://www05.abb.com/global/scot/scot387.nsf/veritydisplay/0fd403f4c81c5a9cc1257b0c0044665b/$file/1MRK506312-UEN_C_en_Technical_reference_manual__REL670_1.2.pdf

[17] GE Energy. (Jan 06, 2014). *D60 Line Distance Protection System Instruction Manual*. Available: http://www.gedigitalenergy.com/products/manuals/d60/d60man-x2.pdf