Scientific
Research

Development of IEC61850 Based Substation Engineering Tools with IEC61850 Schema Library

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ABSTRACT

IEC 61850 *allows the replacement of conventional wire based systems to communication based system with local area network. Since new engineering processes are introduced in substation, the specifications and tools are required combined with new skills across the substation engineering. In order to construct the IEC* 61850 *based substation automation system, the IED engineering tools as an engineering means are necessary to cope with the substation automation by full digital devices in the real power systems. Compared the configuration tools provided IEDs vendors which are able to support the operation and communication analysis between IEDs, the XML based IED integration engineering tools as substation engineering tools which are developed can build, edit and save the ICD, SCL and CID files. Particularly, the substation engineering tools are possible to apply the IEC* 61850 *based IEDs for the engineering process of systems and also provide the reliability and efficiency of system for the utilities and manufacturers. The developed tools are applied to test and create the SCL files for domestic-made IEDs, and then compared with the conventional tools. The reliability including accuracy of results was proved.*

1. Introduction

Power systems are considered the domain of conservative engineering in well established past practices. Expectations for reliability and security of the electricity supply chain remain of paramount importance which must be a fundamental part of all substation engineering. On the other hand, the power industry is facing significant challenges in the years ahead driven by increases in the number of industry and renewable energy projects as well as aged asset replacement and sprawling networks. At the same time, the proverbial skills shortage has impacted on the number of experienced professionals in all area of specification operation and maintenance of the power system [1].

The IEC 61850 standard was certainly a long time coming with its first work efforts to create it starting in the early 1990's. This was driven by the power industry essentially calling for a solution to the multitudes of protocols used to just monitor operation of the substation even within the two decades that communication technologies had been deployed to provision SCADA facilities. We just have to learn a new process and jargon to be able to define our requirements then configure a system

to deliver them over a different type of technology, which at present just happens to involve an Ethernet LAN instead of thousands of wires. The IEC 61850 specifies the substation configuration description language (SCL) based on extended markup language (XML) format for configuring and engineering the substation automation (SA). The SCL defines the station single line diagram, function allocations, mandatory/optional and extensible data, services, communications, and configuration parameters. The objective of SCL is to have a common description of SA exchanged between different vendors [1,2].

IEC 61850 is a new definition and requires a new engineering process that we have done previously in substation. Therefore, this paper proposed the IEC 61850 based IED integration engineering tools, which are substation engineering tools, with IEC 61850 schema library as a core technology in order to cope with the operational management and communication analysis between IEDs interoperation.

The final goal of proposed substation engineering tools accomplishes the dedicated SA system tools in KEPCO system. For the purpose of this goal, we are going to develop the configuration and maintenance functions as

well as the commissioning/testing functions. At first, we developed the IEC 61850 based schema library and enhanced the specification of general purpose of tools. Also the proposed tools are applied to five IEDs of different manufactures and then verify the validation of tools. Conclusively, the substation automation system in KEPCO including smart grids will cope with the demands of increased power system reliability and flexibility with greater access to information throughout the power networks in the future.

2. Review of IED Engineering Tools

IEC 61850 specifies the SCL based on XML format for configuring or engineering the SA system. According to CIGRE Technical Brochure 246 [1], the primary equipment has an average lifetime of approximately 40 years and secondary equipment such as protection, control or communication equipment approximately 20 years. Consequently, the secondary equipment has to be refurbished once during the lifetime of the substation. Nowadays there are already over a thousand implementations of IEC 61850 worldwide offering a significant experience. There is a learning of GOOSE (generic object oriented substation event) messages; the meaning of SSD, SCD, ICD and CID files; how to interpret and rely on conformance certification for interoperability; designing a LAN network for performance criteria; understanding XML language and tools that bind these together.

The conventional engineering tools [2] build a logical node (LN) as a standard interface to deliver the data in substation and can manage the underlying file system in order to data exchange between IEDs. In this study, the logical node could be interoperated to handle and analyze the used communication service and received data, also we focused on the development of system that the standard could be applied for the identification of data objects and data objects allocation in logical node. So we analyzed the overseas advanced engineering tools and referred the related structure of user interface in IEC 61850 international standard.

The SCL configuration file based XML to describe the entire system was represented and **Figure 1** shows the relationships between IEDs with various switches composed of the SA systems. The SA systems have the capability that are the monitoring, control, instrument and communication of the station, bay and process bus and also have the gateway, IEDs, etc. The SCD file defined by IEC 61850 creates a single source of all elements of the SA system operation. This single standard file removes all interpretation of the design with each application able to extract its specific data subset. IEC 61850 sets up a new process based on the SCL files. Therefore we need to know a new process to be able to define our requirements and then can configure a system to deliver them over a different type of technology which happens to involve an Ethernet LAN instead of thousands of
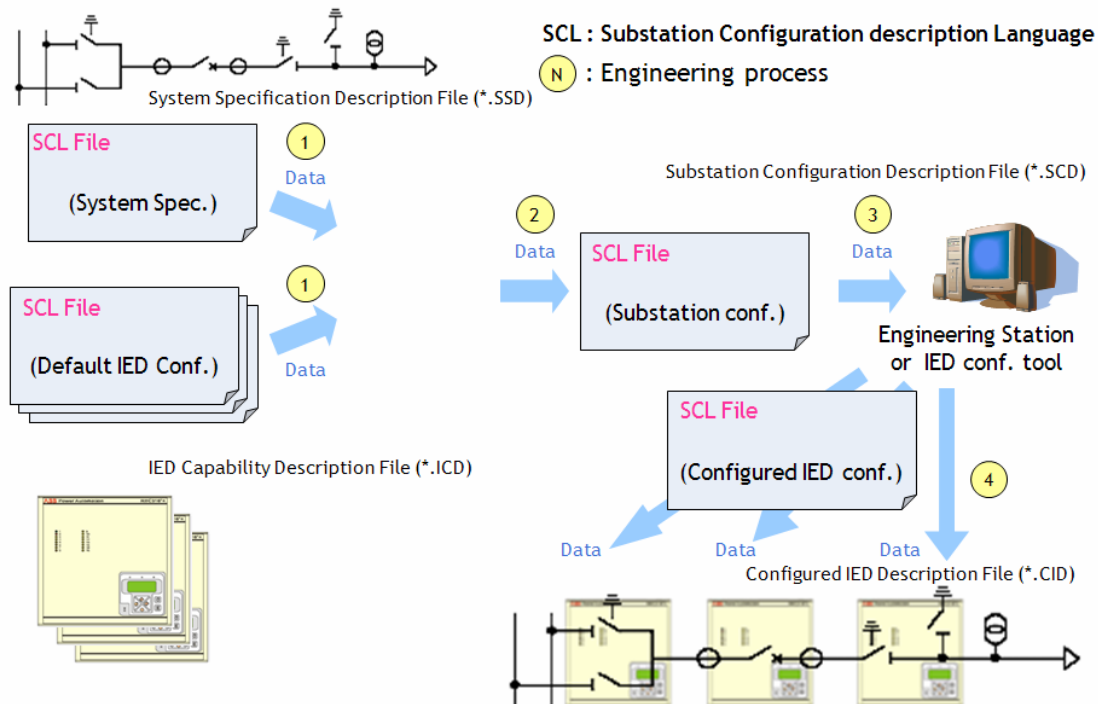

Figure 1. IED Engineering Procedures.

wires. The SCL defines the station single line diagram, function allocations, mandatory/optional and extensible data, services, communications, defaults and configuration parameters. The objective of SCL is to have a common description of SA exchanged between different vendors [3].

The SCL-manager for creating and editing the ICD and SSD files are interrelated and the element type in IEC 61850 schemas defined is compatible with UI prompt. In other words, the SCL-manager makes a setting the environment of IED in substation automation system. IED's all set to follow the IEC 61850 Schema and from organizations such as the official certification body, KEMA certified to run the validation should pass. At this point it is standard IEC 61850 is provided in the schema files. The engineering tools configured the SCD file with SSD contained an information of substation and ICD contained an information of configured IED. Such engineering process is the construction and setting the interface between IEDs or between IEDs and HMI in substation automation system. After the engineering process is finished on network, dataset, RCB, GOOSE, SMV, SGCB, etc., the CID files will be download to the all IEDs [4-6].

3. Development of IEC 61850 Based Substation Engineering Tools

The SA system with IEDs consists of distribution and control system configuration of the substation, and the number of IEDs through communications performs the functions of monitoring, measurement, control, and protection. The IEC 61850 based IEDs are configured with the communication network and communication system means to configure the IEDs. In other words, the engineering process is the construction and setting the interfaces between IEDs or IEDs and HMI in substation. Using IEC 61850 schema files, the conventional configuration tools create, edit, and save the ICD, SCD and CID files. HMI data obtained from the parent to the user to perform monitoring and control. And it makes IEC 61850 based dataset to create and delete the data, and get the event messages, and also supports the engineering process allowed download, upload and search of files with a service of IEDs [2,3].

This paper provides the substation engineering tools based IEC 61850 with schema library of the core technology in order to cope with the operational management, communication analysis between IEDs. For this purpose, the eight schema files are developed with IEC 61850 standards and allow the communication between IEDs and HMI or IEDs. The engineering process results in SCL files, such as ICD, SCD and CID which are to be followed the syntax of IEC 61850. Also, the proposed

tools support the engineering process for the substation configuration data, IED, and communication setting in human machine interface device. Generally, by downloading the resulting files of engineering process, the engineering tools initialize the IEDs and acquire the H/W information, data specification of IEDs.

3.1. Procedures for Engineering

The engineering process with conventional tools is effective to the communication between IEDs for the same vendor but is not actually so good if the utility uses the third-party products. So far that has been an issue. In other words, if you use the engineering tools (DIGSI) which are provided by SIEMENS, the IEDs of SIEMENS are possible to perform the engineering process without a problem, but the third-party IEDs or other engineering tools are faced with a problem. Particularly, due to the absence of dedicated tools, the foreign-made engineering tools or text editors are used as configuration tools to modify the configuration files of domestic-made IEDs. Consequently, the system operators need to have a capability to facilitate a number of IED configuration tools in order to perform the engineering process of SA system according to the product's vendors.

The SSD file for information of system and ICD file for information of IEDs can be used to acquire the configuration information in substation and to possible the understanding of data flow or IEDs functions [3-4]. In particular, the interoperation is possible that the logical node interprets the received data and used communication services. The engineering tools used the data objects assigned to logical node and the identification of data objects for applying the standards.

3.2. Proposed Substation Engineering Tools

The proposed substation engineering tools are consisted of SCL-manager and SCL-engineering with IEC 61850 based schema library which is not the library of Sisco or Tamarack but the developed library. The eight schema libraries based IEC 61850 made of the standard XML schema defined in world wide web consortium with. Net

Table 1. System Model of IEC 61850.

	Contents	Module	File
Substation	Substation, Voltage Level, Bay, Equipment, Subequipment, Connectivity Node, Terminal	SCL-manager	.SSD
IED	IED, Server, LDevice, LNode, DO	SCL-manager	.ICD
Communication	Subnetwork, Access point, Router, Clock	SCL-engineering	.SCD

Framework 3.5 provided by Microsoft; SCL.xsd, SCL_BaseSimpleTypes.xsd, SCL_BaseTypes.xsd, SCL_Communication.xsd, SCL_DataTypeTemplates.xsd, SCL_Enums.xsd, SCL_IED.xsd, SCL_Substation.xsd and allowed to communicate between IEDs and HMI or IEDs. The engineering process results in SCL files, such as ICD, SCD and CID which are to be followed the syntax of IEC 61850 based schema files.

The SCL-manager as a text editor generates the ICD and the SSD file, and the generated ICD and SSD files are interrelated, the element and UI prompt followed IEC 61850 schema are mutually compatible. The SCL-engineering performs the engineering of power systems such as PT/CT connection, ratio etc., the protection systems such as setting of protective factors etc., the communication interfaces such as IP address configuration, SNTP servers interconnection, etc., and the functionality of IEC 61850 such as LN assignment, interlock logic, the report configuration and GOOSE configuration for dataset transferred to IEDs etc. And this generates the SCD and CID files for the function of engineering setting of Network, RCB, GOOSE, Dataset and IED attribution. The IEC 61850 based communication services make a setting for communications with SCD files user engineered between IEDs and this CID file can be downloaded to the IEDs. The HMI can receive the data information from the IEDs with data template configured and supports the monitoring, control of remote substation in real time.

In particular, the SCL-engineering provides the HMI and communication services based MMS, defines the objects and service with IEC 61850, and also supports the setting for real time control, monitoring in HMI with DB server of acquired data from IEDs. The others, the SCL-engineering transfers the data for equipments, and is received the monitoring, measuring data from IEDs, provides the information to HMI and supports the SA operation devices for interconnection among Gateway, HMI, and SCADA which is actually not implemented yet. The SCL-engineering in SA system means the setting, building the interrelated system with IEC 61850 between IEDs, IEDs and HMI. In other words, the SA system using IEDs composed the distributed control system in substation, performed the functions of protection, measurement, control and monitoring with multiple IEDs which have communication services IEC 61850 defined such as communication networks and methods.

Therefore this paper provides the IEC 61850 based schema library requested for the communication analysis and operation management between IEDs in substation. The SCL-engineering performs the downloading functions to IEDs, and creates the SCD and CID files for the network, report control block, GOOSE, dataset, and IED attribution. Also, it provides the capability to generate the SCL configuration information with a more integrated of ICD files and shows in **Figures 3** and **4**.
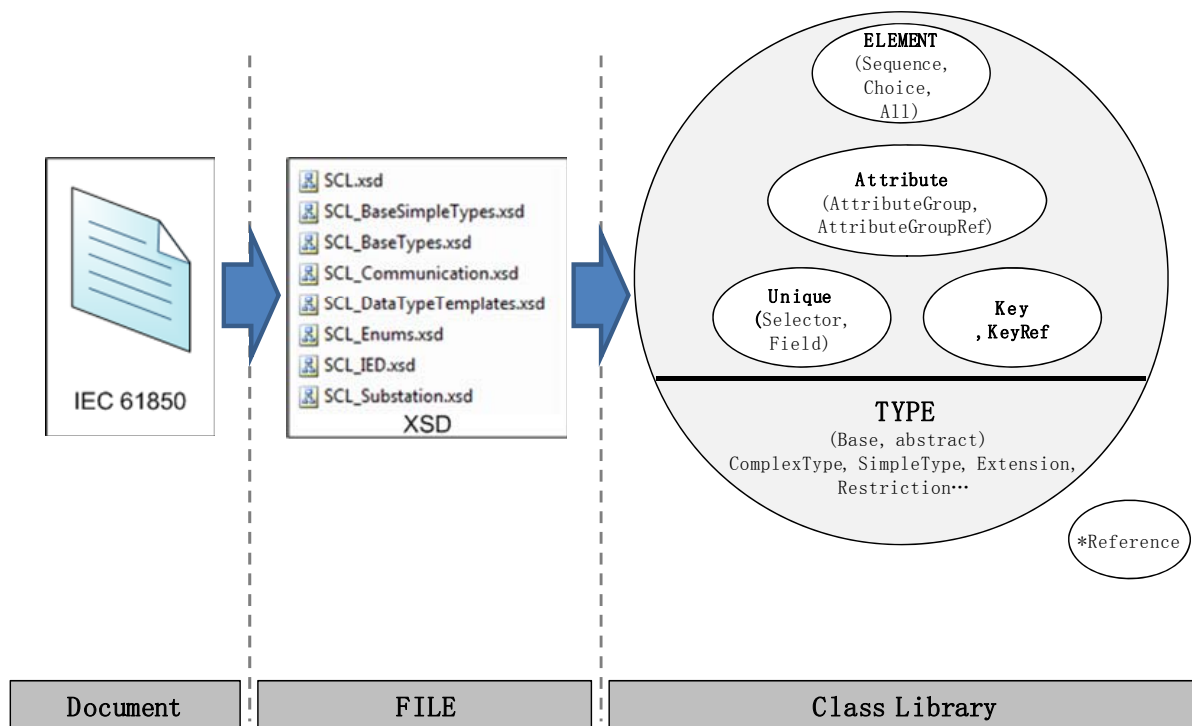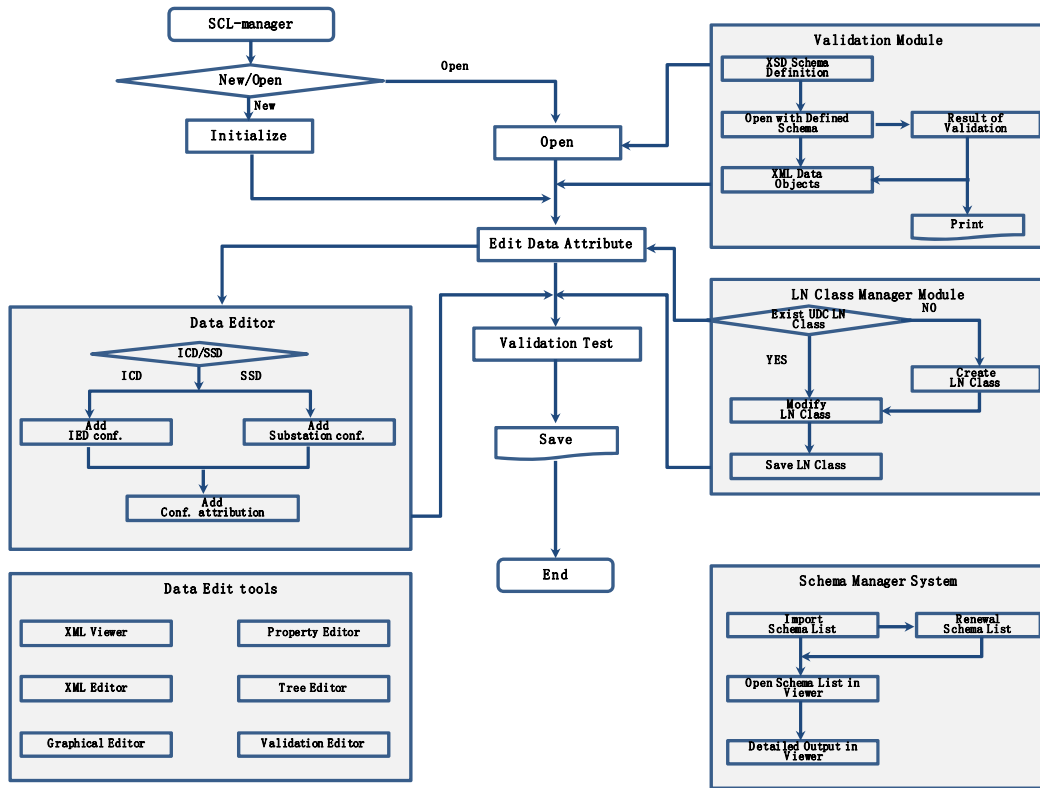

Figure 2. IEC 61850 Schema Class Library.

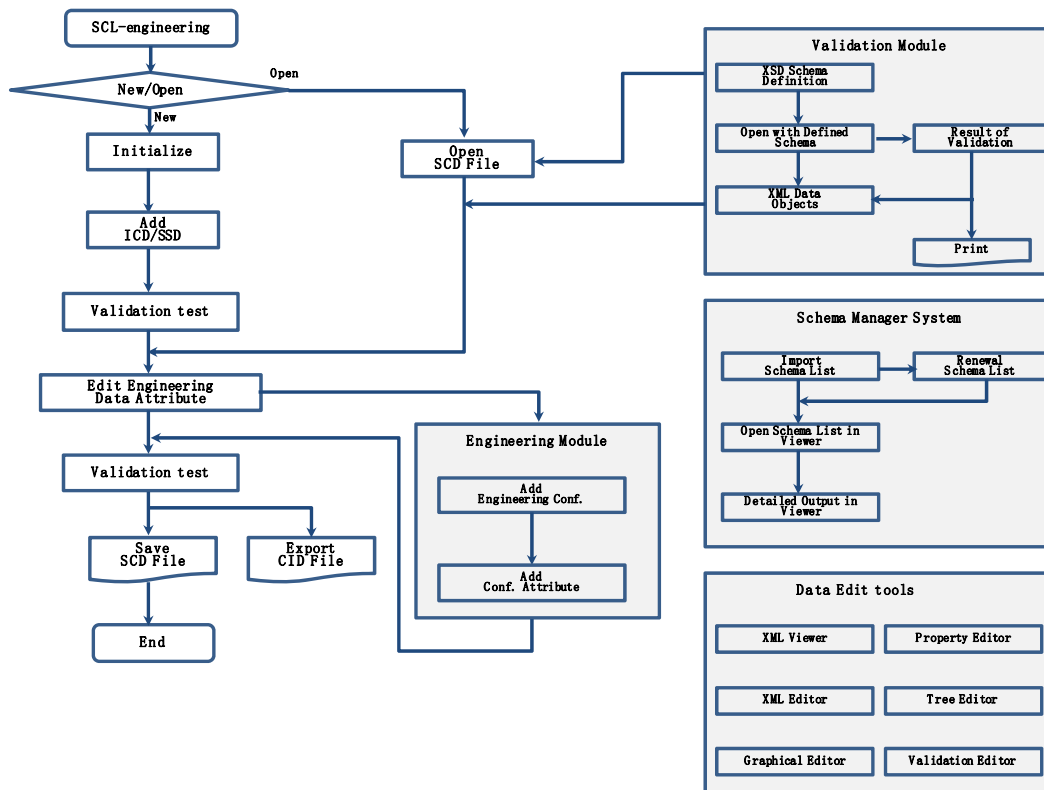
Figure 3. Flow Chart of SCL-manager.


Figure 4. Flow Chart of SCL-engineering.

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4. Field Test

The proposed substation engineering tools are show in **Figure 5**. In this paper, the schema validation and the accuracy of ICD, SCD, and CID files compared with UNICA or foreign-made engineering tools. Actually, according to the IEC 61850 schema version, the test results are different respectively. The proposed tools are applied to test and create the SCL files for domestic-made IEDs which the voltage levels are the 22.9 kV GIS, 170 kV main transformer and 154 kV transmission line.

Tables 2 and **3** show the results of validation of SCL files which are generated by proposed tools using the same IEC 61850 schema version as the UNICA. Compared with foreign-made conventional tools, the proposed tools are proved to the reliability including accuracy of results. Particularly, the additional functions promoted the practical application of proposed tools by domestic manufacturers and engineers of utility. But the substation engineering tools need to develop the additional functions for the user's convenience in the future.
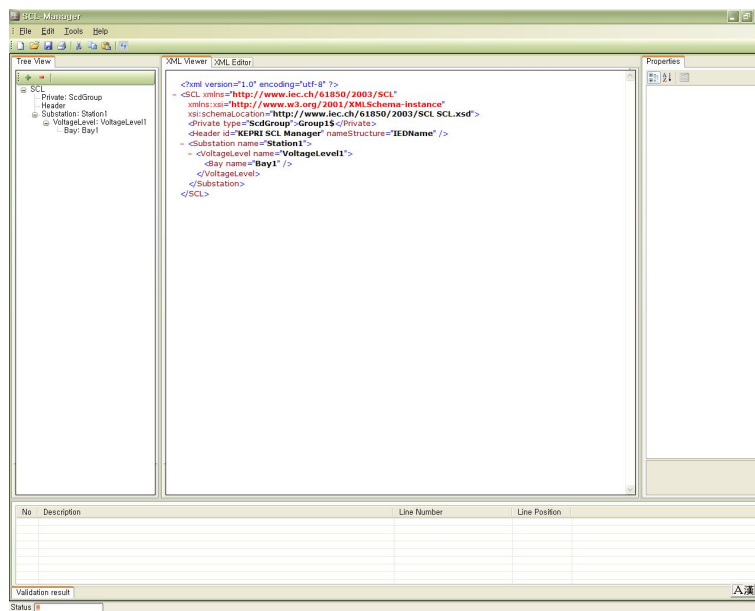
(a)
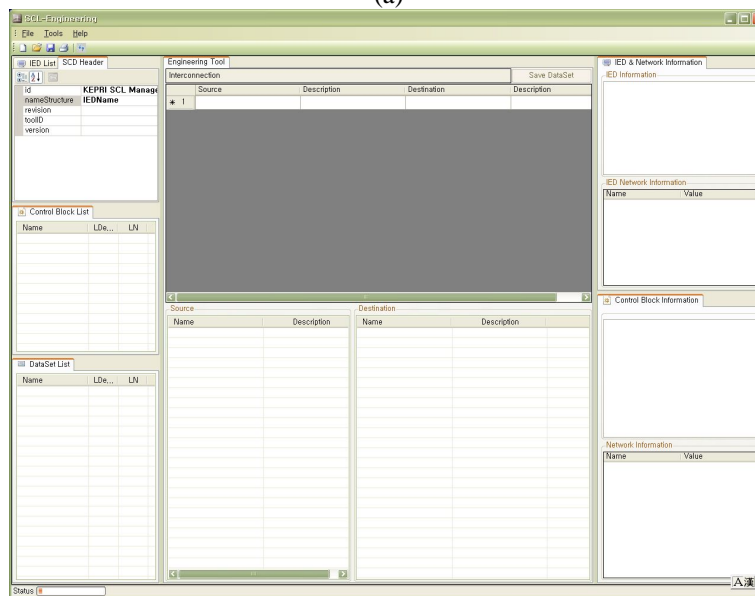
(b)

Figure 5. Proposed Substation Engineering Tools. (a) SCL-manager; (b) SCL-engineering.

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Table 2. Results of Validation of SCL files.

Contents	Proposed Tools	KALKI, SCL -Manager	ASE, Visual SCL	TMW, ICD Editor	UNICA
Schema version*	1.0	2.0**	1.4	1.4	1.0
Validation test	No error	No error	No error	No error	No error
ICD file test	No error	No error	No error	No error	No error
SCD file test	No error	No error	No error	No error	No error
CID file test	No error	No error	No error	No error	No error

*The schema version represents the SCL version of IEC 61850 version 1.0;
**The schema version in KALKI, SCL-Manager does not represent the SCL version of IEC 61850 second edition.

Table 3. Results of Engineering process with Proposed Tools.

Test contents	Details	Results
SCL-manager	IED creation	Pass
	Logical Node creation	Pass
	LN Class creation	Pass
	GOOSE Control Block creation	Pass
	Report Control Block creation	Pass
	SMV Control Block creation	Pass
	SG Control Block creation	Pass
	IEC 61850 validation test	Pass
	ICD file creation	Pass
	SSD file creation	Pass
SCL-engineering	ICD file import	Pass
	GOOSE CB communication setting and DataSet creation	Pass
	Report CB communication setting and DataSet creation	Pass
	SMV CB communication setting and DataSet creation	Pass
	SG CB communication setting and DataSet creation	Pass
	IEC 61850 validation test	Pass
	SCD file creation	Pass
	CID file creation	Pass

5. Conclusions

The substation automation system consists of the Ethernet communication networks with IEC 61850 based, and provides the interface applicable functions. The proposed substation engineering tools consist of the SCL-manager, SCL-engineering, and IEC 61850 schema library as a core technology and enhance the user's convenience.

The proposed tools can manage the SCL files such as ICD, SCD and CID files for the digital substation with IEC 61850 based SA system and also provide the dedicated SA system tools which are applied for all domestic-made IEDs in engineering process, communication service and HMI system in KEPCO. Therefore, the KEPCO can expect to the economical effects through rational and integrated SA system. Also, the reliability of IEDs and software design/development using UML make an enhancement with efficiency and convenience of user interface.

Nowadays, the utility's concerning focus on the benefit of the SSD file as a first step in creating the SA system design since the SSD file establishes the relationship between the primary plants and the secondary systems or elements. If new bays are added to the system, it gives a simple method to complete the sections of SA system by elimination the need for extensive reengineering or/and retest of schemes which have already been proven in system operation. Clearly, this kind of aspect of standardization gives benefits throughout the whole substation life cycle not just the initial construction of substation.

Particularly, we are going to expect the tools in a few years that proposed tools have to provide the function like as; system specification tools, system configuration tools and IED configuration tools, and commissioning /testing function like as; communication network design and management, system testing tools (network analyzer, simulation), function testing tools, installation check and finally maintenance tools.

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