A Study on the Development of Model based SA Client Conformance Testing System

Nam Ho Lee*, Byung Tae Jang†, Yong Ho An* and Eung Bo Shim*

Abstract – Substation Automation System is basically operating throughout communicative services among IEC 61850 based devices. So, minimum requirement in order to install the system in the substation is to verify server and client conformance. This study aims to develop IEC 61850 SA client conformance testing system for verifying the full communication conformance of the substation automation system and this paper describes the design and implementation of the testing system.

Keywords: IEC 61850, Conformance, Substation Automation, Client

1. Introduction

IEC (International Electrotechnical Commission) has published the international standard for the substation automation system and communication interfaces which results in construction of the SAS(Substation Automation System) all over the world with system integration and IT technologies. Substation of power system in the center of environmental change must be able to provide the information such as data for maintenance and diagnosis of power facilities, and for monitoring, protection and control related to system operation. According to the reason, the conventional analog type substation is replaced to digital SAS(Substation Automation System) using computer based operation system and IED(Intelligent Electronic Device).

Substation Automation System is basically operating throughout communicative services among IEC 61850 based devices. So, minimum requirement in order to install the system in the substation is to verify server and client conformance of IED(Intelligent Electronic Device)s and HMI(Human Machine Interface)s according to the IEC 61850 standard. Even though UCA IUG (Utility Communication Architecture International Users Group) issued IEC 61850 conformance test procedures for both the server and the client, Much of the test is limited to IEDs as server and there is no client-only testing tool except KEMA server test tools [1-5]. This study aims to develop IEC 61850 SA client conformance testing system for verifying the full communication conformance of the substation automation system and this paper describes the design and implementation of the testing system. It is hard for test engineer to make testing procedures with the computer language based testing script such as C++ and Visual basic. Accordingly, the testing system includes the model based testing procedure editor and this means that it is easy for them to implement testing procedures by only choosing testing model. Currently, this testing system is being in utilization for Korean domestic IEC 61850 client products.

2. SA Client Conformance Testing System

2.1 Objectives of the Study

IEC 61850 SAS consists of a number of IEDs and HMI and can share all information through the digital network. Basically, because all of the IEDs and clients should support IEC 61850 communicative services for the SAS operation, Most of users require IEC 61850 conformance test as a minimized condition, which is the test to verify their communication function and data models according to the IEC 61850 international standard. In case of the server test, the standard has described how to test and procedures at the part-10, and a server testing system was already developed by KEMA and many IED manufactures and utilities are running the system. Otherwise, there is no client-only conformance testing system even though UCA IUG has already published IEC 61850 client testing procedures. So now, the certification testing on the client might be performed by manual verification of a test engineer using a IEC 61850 traffic analyzer. A big amount of the communication packets for client conformance test results in some human mistakes and long time consumption
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for the test. Accordingly, this study aims to develop the IEC 61850 client testing system in order to solve these problems similar to the server testing tools. In addition, we designed this new testing system based on not a computer language based script like visual basic but some test models. That is why test engineers are not familiar with computer languages and feel difficulty to make the test procedure with the script language. The testing system provides testing models and an editor for creating a client conformance testing procedures as user friendly environment.

2.2 IEC 61850 Client Conformance Test

In order to assure interoperability of IEC 61850 based SAS, IEC 61850-10 describes how to perform communication conformance test with a point of server view. This conformance test aims to reduce expense and time occurred in system integration by previously checking any problem of individual server from the test. So most of the utilities and system integrators may well require the certificate of IEC 61850 conformance to IED vendors. IEC 61850 conformance test consists of version management of documents, verification of SCL (Substation Configuration Description Language) file and test of IEC 61850 communication service and IED data model, as shown in Fig. 1.

Anyhow, only server conformance test may not guarantee full interoperability of the SAS. Because all communicative performance of the SAS must be done by the relation of server and client. Accordingly, UCA IUG published IEC 61850 client conformance test procedures (Revision 1.1) like table 1, which is similar to the server test in order to assure interoperability of the HMI as a client for IEC 61850 based SAS performance.

Table 1. UCA testing procedures for IEC 61850 client

<table>
<thead>
<tr>
<th>Conformance Block</th>
<th>Mandatory</th>
<th>Conditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Basic Exchange</td>
<td>cAss1, cAss2, cAss3, cAss4, cAssN1, cAssN4, cAssN5, cAssN6, cServ5, cServN3</td>
<td>Automatic startup: cAssN7, GetXxxDirectory: cServ1, cServ2, cServ3, cServ4, cServN1, SetDataValues: cServ6, cServ4, GetDataValues: cServ7, cServ2, Quality: cServN6, TimeQuality: cServN6</td>
</tr>
<tr>
<td>2: Data Sets</td>
<td>cDsl, cDsl2, cDsl5, cDslN1</td>
<td>GetDataValues: cDsl3, cDslN2, SetDataValues: cDsl4, cDslN3</td>
</tr>
<tr>
<td>2+: Data Set Definition</td>
<td>cDsl6, cDslN4</td>
<td>DeleteDataSet: cDsl7, cDslN5</td>
</tr>
<tr>
<td>3: Substitution</td>
<td>cSub1, cSub2, cSub3</td>
<td>cSub1, cSub2, cSub3</td>
</tr>
<tr>
<td>4: Setting Group Selection</td>
<td>cSgl2, cSglN1</td>
<td>GetLogicalNodeDirectory (SGCB): cSgl1, GetSettingGroupValues: cSgl2</td>
</tr>
<tr>
<td>4+: Setting Group Definition</td>
<td>cSgl3, cSgl4</td>
<td>cSgl3, cSgl4</td>
</tr>
<tr>
<td>6: Buffered Reporting</td>
<td>cBr2, cBr3, cBr4, cBr5, cBr6, cBr7, cBr8, cBr9, cBr10, cBr11, cBr12, cBrN2, cBrN3, cBrN7, cBrN8, cBrN9</td>
<td>cBr2, cBr3, cBr4, cBr5, cBr6, cBr7, cBr8, cBr9, cBr10, cBr11, cBr12, cBrN2, cBrN3, cBrN7, cBrN8, cBrN9</td>
</tr>
<tr>
<td>12a: Direct control</td>
<td>cCtl4, cCtlN1, cDOes1, cDOes2</td>
<td>Test: cCtl1, Check: cCtl2, Change control model: cCtl3</td>
</tr>
<tr>
<td>12b: SBO control</td>
<td>cCtl4, cCtlN1, cSBOns1, cSBOns2, cSBOns3, cSBOns4</td>
<td>Test: cCtl1, Check: cCtl2, Change control model: cCtl3, Cancel: cSBOns4</td>
</tr>
<tr>
<td>12c: Enhanced Direct control</td>
<td>cCtl4, cCtlN1, cDOes1, cDOes2</td>
<td>Test: cCtl1, Check: cCtl2, Change control model: cCtl3, Cancel: cSBOns4</td>
</tr>
<tr>
<td>12d: Enhanced SBO control</td>
<td>cCtl4, cCtlN1, cSBOns1, cSBOns2, cSBOns3</td>
<td>Test: cCtl1, Check: cCtl2, Change control model: cCtl3, Cancel: cSBOns4</td>
</tr>
<tr>
<td>13: Time sync</td>
<td>cTm1</td>
<td>Optional: cTm2, cTm3, TimeQuality: cTm2, cTm3, cTmN2, clockNotSynchronized: cTmN1</td>
</tr>
<tr>
<td>14: File transfer</td>
<td>cFt1, cFt2, cFt3, cFtN1, cFtN2</td>
<td>SelfFile: cFt4, cFtN3, DeleteFile: cFt5</td>
</tr>
</tbody>
</table>

Fig. 1. IEC 61850 server conformance test.
Documents for the client conformance test such as PICS, PIXIT and TICS are also used as not only reference of IEC 61850 communication service test of the client but also selection of test items. In case of a server test, a SCL file of IED should be required to check if data model of IED such as logical node is implemented according to IEC 61850 7-2 and 7-4. But the client test only needs a SCL file of the SAS for verifying its own communicative request function and constructing a database of the client testing system.

Test of IEC 61850 ACSI (Abstract Communication Service Interface) verifies a client to send a number of communication requests correctly as setting values and receive positive and negative responds including IEC 61850 report and command termination from IEDs. Through this test, the client will be assured to be able to communicate freely under IEC 61850 SAS environment. A client passed by IEC 61850 conformance test means that it has communication ability with interoperability for SAS.

2.3 Model based System Design

Model based test process that this study applied for IEC 61850 client conformance test, can create conceptual models of a device under test and make a test case from these test models instead of writing down hundreds of test case documents by the manual works. This system design has advantages to be able to implement various test cases by a little change with the same test models and reduce design time of the test procedures. And also, this design concept orients to construct test automation system based on the test design and cut down on human mistakes. Fig. 2 shows the flow diagram of the model based test process and this process is described as followed 5 steps.

- Create a model with test environment and description of IEC 61850 client conformance test.
- Design a test case by using a few test models
- Convert an executable test format from the conceptual test case
- Perform client conformance test by executing the client testing system based on the test case
- Analyze a test result

An IEC 61850 based client is using a lot of communication services such as ACSI and Report to communicate with IEDs of SAS and manual test will take too much time. Accordingly, it is required to develop a conformance testing system based on test models to solve complexity of the conformance test and reduce test time and human mistakes.

2.4 Implementation of the Testing System

Model based SA client testing system consists of a testing procedures execution part, a packet analyzer part and a test verifier part including the model based test case editor.

Fig. 3. Configuration of the client conformance testing system.

A model based test case editor was designed to create a test case by Drag & Drop of test models and provide user friendly user interface for test environment setting. Test models that the testing system has, are classified as test guide, ACSI verification, test initiation, test repeat and so on. The system supports ICD (IED Configuration Description Language) parser to select IEC 61850 data of SAS for verifying ACSI request of the client. And this feature results in minimizing user input. The test model of ACSI verification can choose which ACSI the client request to an IED and select error type and a related error message once
the IED sends a negative response. Fig. 4 shows GUI (Graphical User Interface) of the model based test case editor.

Fig. 4. GUI of the model based test case editor.

A test verifier part can show the traffic packets between the client and the IED as OSI-7 layers format and convert MMS packets into IEC 61850 ACSI format while the testing system is executing the conformance test. ACSI services that the test verifier part can analyze, are as follows.

- **IEC 61850 communication association:**
  - Associate, Abort, Release
- **Data read and write:**
  - GetServerDirectory, GetLogicalDeviceDirectory, GetDataValues, GetDataDirectory, GetDataSetDefinition, SetDataValues
- **Dataset:**
  - GetDataSetValues, SetDataSetValues
- **Report service:**
  - GetRCBValues, SetRCBValues
- **Control:**
  - Operate, Select, Cancel, SelectWithValue
- **File transfer:**
  - GetFile, GetFileAttributeValues, DeleteFile

A test verifier part verdicts whether both the communication function of the client and the server response comply with IEC 61850 standard or not according to the model based test procedures. Additionally, the testing procedures execution part shows contents of an ICD file of the server and all test flow through the log viewer. One of the special features of the testing system is to mark verified messages with index number connected with communication packets and a test engineer can confirm the test result of the testing system very conveniently.

Fig. 5. GUI of testing procedures execution part.

After selecting a test case from database of model based testing procedures, model based SA client testing system starts the client test in sequence of test guide, client and server running, client request, server response, packet capture and analysis, client reaction evaluation and final evaluation like Fig. 6.

Fig. 6. Action flow of the client conformance testing system.
3. Conclusion

As the smart grid becomes a new paradigm of a power system, IEC 61850-based SAS is expected to play a key role in the smart grid and KEPCO has planned to construct IEC 61850 based substation automation system for all domestic substations since 2012. Accordingly, KEPCO is considering to adopt IEC 61850 conformance test in order to verify IEC 61850 communication of IEDs and clients. So we expect that the result of the study will be one of the useful testing tools for SAS real application.

References


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